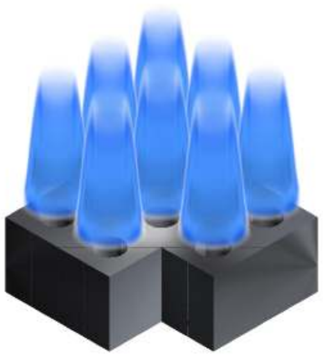
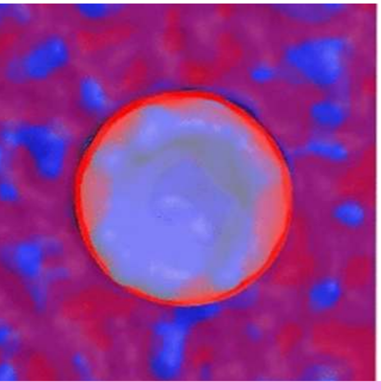
Annual Report & Research Programme





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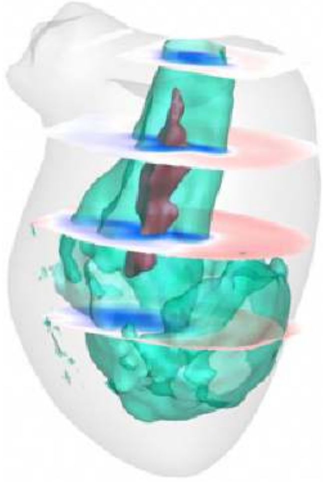

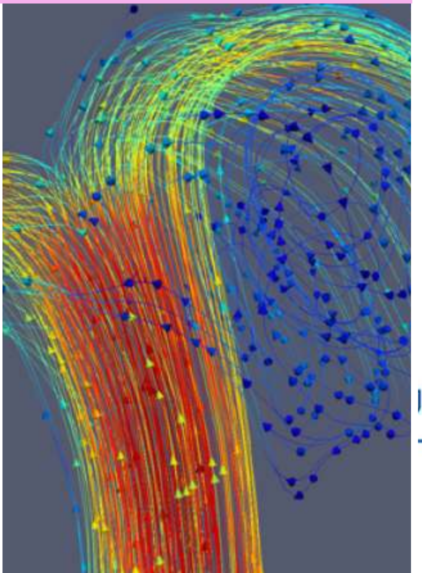

J.M.Burgerscentrum

Research School for Fluid Mechanics

TUD, TUE, UT, RUG, WUR, UU

ANNUAL REPORT & RESEARCH PROGRAMME 2019

JM Burgerscentrum
Research School for Fluid Mechanics

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Preface

Prof.dr.ir. CJ van Duijn
Chairman of the JMBC Board

Prof.dr.ir. GJF van Heijst
Scientific Director

This annual report of the J.M. Burgerscentrum provides an overview of the activities of our research school during the year 2019. The core of the report consists of the description of the research projects, carried out by the JMBC groups. In each project report the relevant information (title, theme, staff involved, project aim, achievements, publications, funding source, application, etc.) is given. As usual, a number of research highlights are presented.
The Annual Report also provides general information about the research school, such as its goals, its organization, and its relation with industries and technological institutes.

The number of PhD projects carried out by the JMBC groups is still quite large (approximately 350 at the end of 2019). In addition, about 60 Postdocs are registered at the school. Although the sponsoring of such projects directly via the universities has become almost non-existing, the financing of projects via NWO (formerly mostly via FOM and STW) and via industries and technological institutes remains at a high level. Also, the sponsoring of projects via the European Research Council is quite substantial. Finding funds for our PhD projects remains an important task for all JMBC groups.

In the academic year 2018 – 2019 the following JMBC courses were organised: ‘Particle-based Modeling Techniques’, ‘Fundamental Fluid Dynamics Challenges in Inkjet Printing’ (in close collaboration with Océ), ‘CFD 2’, ‘Combustion’, ‘Experimental Techniques in Fluid Mechanics’, ‘Particle Technology’, ‘Complex Flows and Complex Fluids’ (CISM-JMBC), ‘Capillarity-driven Flows in Microfluidics’.

The JMBC course programme for the academic year 2019 – 2020 contains the following courses:

‘Solution Methods in Computational Mechanics’ (EM-JMBC), ‘CFD 1’, ‘Turbulence’, ‘Shallow Flows’ (VKI-JMBC), ‘Computational Multiphase flows’, and ‘Micro- and Nanofluidics’, and ‘PIV’. The lecture course ‘Solution Methods in Computational Mechanics’ will be organized as a joint course of the research schools Engineering Mechanics and JMBC, while the course ‘Shallow Flows’ is organised jointly with the Von Karman Institute, and will given in Brussels (B). All these courses are organised in order to give the JMBC PhD students the opportunity to deepen their knowledge in various aspects of fluid dynamics, but also to widen their perspective and give them an overview of the wide field of fluid dynamics. It is therefore recommended for our PhD students to take the opportunity and to participate in these courses.

The activities of the JMBC continue to ensure that the Dutch fluid mechanics field is a lively and well-connected community, with numerous mutual appointments at collaborating groups and collaborative research projects in which multiple JMBC groups participate. The JMBC contact groups continue to be an important instrument for cohesion. These contact groups stimulate interaction and collaboration between researchers, developers, and users. This is done through organizing regular meetings aimed at getting to know each other’s activities and learn about developments and applications.

Another important instrument to maintain the coherence throughout the research school is the annual JMBC meeting: the two-day Burgers Symposium. In 2019 this Symposium was held on 21-22 May 2019 in Conference Centre ‘De Werelt’ in Lunteren. The programme included two plenary keynote lectures: the Burgers Lecture by Prof. Emmanuel Villermaux (Institute IRPHE & Aix-Marseille Université, Fr) and the Evening Lecture by Dr. Claudia Cenedese, Woods Hole Oceanographic Institution, Woods Hole, USA).

The two-day framework of the Symposium allowed to accommodate a substantial number of presentations by junior researchers: in parallel sessions a total of about 70 presentations by PhD students and postdocs were given. The programme also contained a plenary session in which four newly appointed junior staff members gave a presentation about their research. The Symposium was concluded by an Award session for various prizes: the Charles Hoogendoorn Fluid Dynamics Award 2018 (KIVI) was presented to the recipient, Dr. Yasin Toparlar (former PhD student at TU/e), two Young Scientist Awards were presented for the best two junior presentations at the Symposium, and finally the Gallery Award for the best entry in the JMBC Gallery of Fluid Motion exhibition of the Symposium.

As remarked before, the year 2018 was a special year for the Dutch fluid dynamics community, as it was exactly 100 years ago (in September 1918) when Jan Burgers was appointed in Delft as the first professor in fluid mechanics in The Netherlands. To commemorate this historical mark, it was decided to publish a book about the development of fluid mechanics – both in academic and industrial settings – in The Netherlands during the subsequent 100 years after Burgers' appointment. This book "A Century of Fluid Mechanics in The Netherlands" is authored by Dr Fons Alkemade and published by Springer. After some delay, this book was published in 2019, and copies were sent to all permanent staff members of the JMBC and a number of close relations of the research school. The book can be purchased directly from Springer.

Once a while, we are approached by groups that are potentially interested in becoming a member of our research school. For admission of a new group, we follow a standard procedure. The group leader of the group that wishes to participate needs to submit a written motivation, a research plan and CVs of the staff members involved. Based on this application the scientific director consults a number of professors in the JMBC about the candidate group. The application and the advice are then sent to the board of the JMBC, which takes the final decision.

We are very pleased that in 2019 a new group joined the JMBC: the group Aeroacoustics of the Aerodynamics, Wind-Energy and Propulsion (AWEP) department of the Faculty of Aerospace Engineering at TUD, consisting of Prof. Damiano Casalino, Dr. Daniele Ragni, Dr. Francesco Avallone and a number of PhD students and postdocs.

In 2019, some prestigious awards Vici and ERC grants) were obtained by a number of senior staff members of the JMBC. At the end of 2019, also the recipients of two other awards were announced: Dr Cees Voesenek (former PhD student at WUR) was announced to be the winner of the KIVI Hoogendoorn Fluid Mechanics Award 2019, while the Leen van Wijngaarden Prize 2019 was awarded to Dr Florian Muijres (WUR) for his excellent work on the biomechanics and aerodynamics of animal flight. The recipients will receive their awards at the Burgers Symposium 2020.

Jointly with the research school Engineering Mechanics, the JMBC forms the Centre of Excellence 'Fluid and Solid Mechanics'. This centre also forms the basis of the 4TU Research Centre Fluid & Solid Mechanics (FSM), which used to receive some financial support from the 4TU Federation. This support was generally used to enhance the profile and visibility of the 4TU Research Centre FSM, to promote collaboration with industrial partners, to expose the relevance of research in fluid and solid mechanics to society, to support young scientific talent, and to attract international top-quality visiting scientists. Unfortunately, because of changes in the 4TU policy, the 4TU funding of the Research Centre FSM was discontinued per 1 January 2018.

Due to the enthusiasm and the combined knowledge, skills and facilities of the participating research groups, the JMBC continues to be a very stimulating, multidisciplinary environment for advanced research in fluid mechanics and for the education of talented graduate and postgraduate students. The board and the management team of the JMBC highly value the large effort of the staff of the JMBC in reaching the goals of the research school.

Prof.dr.ir. CJ van Duijn	Prof.dr.ir. GJF van Heijst
Chairman of the JMBC Board	Scientific Director JMBC

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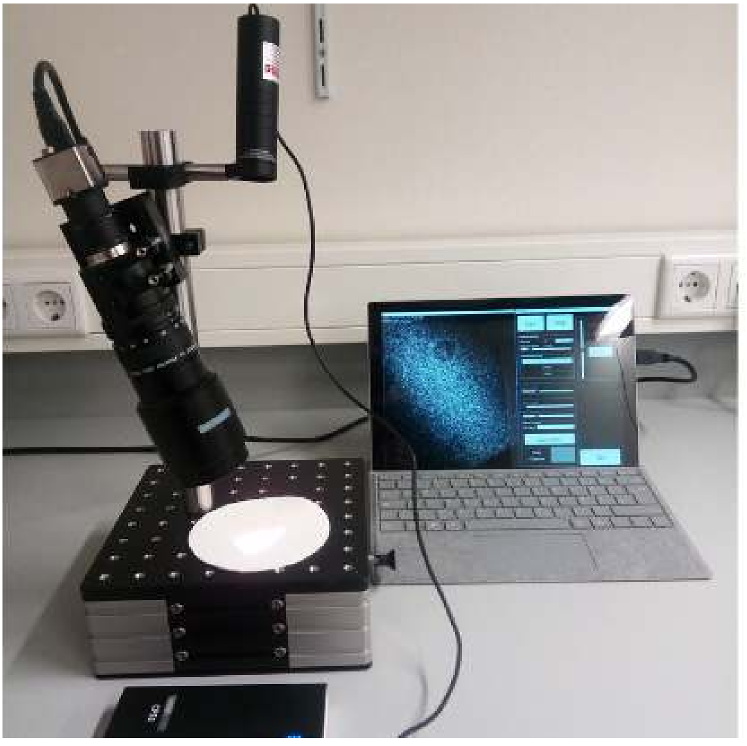
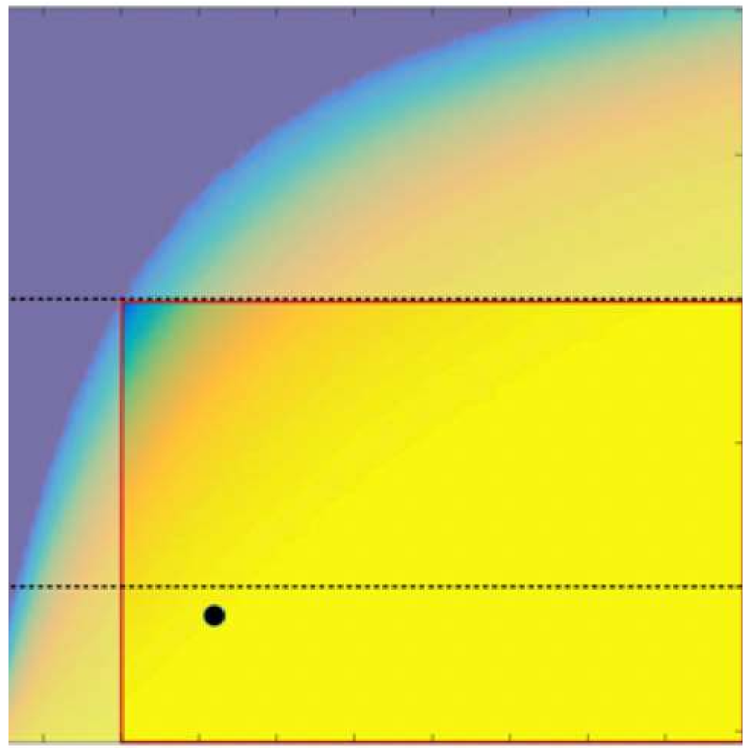


ORGANISATION



Organisation

The JM Burgerscentrum (JMBC) is the national research school for fluid mechanics in The Netherlands. Its main goals are:

- Stimulation of collaboration of the participating groups with respect to their research efforts. The JMBC aims at being one of the leading institutes for fluid mechanics in the world.
- Organization of advanced courses for PhD-students. These courses are also attended by postdocs and by researchers from industries and technological institutes.
- Co-operation with industries and technological institutes. The aim is to promote the use of up-to-date knowledge on fluid mechanics for solving practical problems.
- Strengthen the contacts between fluid mechanics research groups at Dutch universities and the international fluid mechanics community.

About 60 professors with their groups, in total about 200 senior scientific staff members, participate in the JMBC. These groups are located at the universities in Delft, Eindhoven, Twente, Groningen, Wageningen, and Utrecht. The various fluid-dynamics groups are based in different departments, and in different disciplines: in Civil Engineering; Mechanical Engineering, Maritime Technology, (Applied) Physics, Aerospace Engineering, Applied Mathematics, Chemical Technology, Biology, and in Physical Oceanography. The professors with their senior staff form the Council of Project Leaders, which meets regularly. At the end of 2019, approximately 350 PhD-students and 60 postdocs were registered as participants of the JMBC.

The scientific director of the JMBC is assisted by the Management Team, consisting of the local directors in Delft, Eindhoven and Twente (who are also representing the groups in Groningen, Wageningen and Utrecht). The running of the JMBC takes place under final responsibility of the Board of the JMBC.

The research projects carried out by the JMBC groups can be arranged in three main research themes:

- Complex dynamics of fluids
- Complex structures of fluids
- Mathematical and computational methods for fluid flow analysis.

A number of contact groups in different topical areas are active, in the sense that they strengthen the network between researchers at different groups, promoting the exchange of expertise and experience between the participating groups.

The various JMBC groups have intensive, active contacts and close links with industries and technological institutes in The Netherlands. This connection is formally facilitated by the Industrial Advisory Board, with members representing a large number of companies and technological institutes.

The JMBC research groups have various scientific contacts with research groups in other countries, often in the form of individual collaboration projects, but also in the form of organised networks. This international setting implies joint publications with other researchers from all over the world, and also exchange of staff: external visitors to the JMBC groups and JMBC staff visiting foreign fluid-mechanics groups.

As common practice in the scientific community, the research groups present their work at international conferences and in the form of journal publications. The number of publications from JMBC staff in well-known scientific journals is considerable.

Together with Engineering Mechanics (the Dutch research school on solid mechanics) the JMBC forms the 4TU Research Centre for Fluid & Solid Mechanics (FSM). This Research Centre has been recognized as a “centre of excellence” in The Netherlands and has in the past received significant funding by the Dutch Government for stimulating new research areas in fluid and solid mechanics. Unfortunately, because of changes in the 4TU policy, the 4TU funding of the Research Centre FSM was discontinued per 1 January 2018.

An important activity of the JMBC is the organisation of the Burgers Symposium, which is the annual two-day meeting of the research school. This annual meeting is usually attended by more than 250 participants (both staff, PhD students, and postdocs). In addition to the plenary Burgers Lecture and the Evening Lecture the Symposium programme includes oral and poster presentations by the JMBC PhD students. At the Symposium in 2019 approximately 70 presentations were given by junior speakers in a number of parallel sessions. Besides, a few newly appointed junior staff members presented their research in a plenary session.

Each academic year the JMBC organises a number of special courses, meant primarily as advanced fluid-dynamical education of the PhD students and postdocs of the JMBC. The topics of these courses varies from one year to another, although some courses are given every other year. These courses are also open to participants from other research schools and from industry.

Overview of the university groups participating in the JMBC per 1 January 2020

The fte figures for Scientific staff are *effective fte*, based on the following weight factors: Professor 0.3 fte | Part-time professor 0.1 fte | Associate professor 0.4 fte | Assistant professor 0.4 fte. The figures for PhD students and Postdoctoral fellows represent *numbers*.

University and (sub)faculty	Scientific staff (fte)	PhD students	Postdocs
TUD			
Energy Technology (3ME-ET)			
BJ Boersma	2.3	6	-
Fluid Mechanics (3ME-FM)			
J Westerweel, DJEM Roekaerts, RAWM Henkes *(p)*, G Ooms *(em)*	1.9	5	1
Multiphase Systems (3ME-MS)			
C Poelma	0.7	11	-
Maritime and Transport Technology (3ME-MTT)			
J Westerweel, C van Rhee, TJC van Terwisga *(p)*	2.7	8	-
Complex Fluid Processing (3ME-CFP)			
J Padding	0.7	7	-
Transport Phenomena (CE-TP)			
CR Kleijn, A de Haan, HEA van den Akker *(p)*	2.3	16	1
Product and Process Engineering (CE-PPE)			
JR van Ommen	1.1	5	-
Numerical Analysis (AM-NA)			
C Vuik, C Oosterlee *(p)*	1.6	9	1
Mathematical Physics (AM-MP)			
AWH Heemink, M Verlaan *(p)*	4.4	10	-
Aerospace Engineering (AWEP-AERO)			
F Scarano, S Hickel	4.6	27	2
Acoustics (AWEP-ACOUSTICS)			
D Casalino	1.1	8	-
Fluid Mechanics (CEG-FM)			
AJHM Reniers, JD Pietrzak, WSJ Uijttewaal	1.3	13	-
Geoscience and Remote Sensing (CEG-GRS)			
HJJ Jonker, AP Siebesma, BJH van de Wiel	2.1	7	-
TUE			
Fluids and Flows (AP-F&F)			
HJH Clercx, GJF van Heijst, F Toschi, AA Darhuber	2.8	22	4
Transport in Porous Media (AP-TPM)			
OCG Adan *(p)*	0.1	2	-
Elementary Processes in Gas Discharges (AP-EPG)			
GWM Kroesen, U Ebert *(p)*	1.2	3	-
Energy Technology (ME-ET)			
DMJ Smeulders, EH van Brummelen, HA Zondag *(p),* H Wijshoff *(p),* H van Duijn *(em),* AA van Steenhoven *(em)*	3.2	7	2
Power and Flow (ME-PF)			
NG Deen, LPH de Goey, JGM Kuerten, M Golombok *(p)*, B Vreman *(p)*	5.1	26	2
Microsystems (ME-MS)			
JMJ den Toonder	1.5	9	4
Multi-scale Modelling of Multiphase Flows (CET-MMM)			
JAM Kuipers	1.5	26	2

University and (sub)faculty	Scientific staff (fte)	PhD students	Postdocs
Chemical Process Intensification (CET-CPI)			
M van Sint Annaland	0.7	6	-
Interfaces with Mass Transfer (CET-SIM)			
CWM van der Geld	0.3	1	-
Centre for Analysis, Scientific Computing and Applications (MCS-CASA)			
B Koren, MA Peletier, JJM Slot *(p)*	2.3	4	1
Urban Physics and Wind Engineering (CEBE-UPWE)			
B Blocken	1.1	12	4
UT			
Physics of Fluids (TNW-PoF)			
D Lohse, D van der Meer, J Snoeijer, M Versluis, X Zhang, A Prosperetti *(p)*, R Verzicco *(p),* L van Wijngaarden *(em)*	3.9	47	21
Physics of Complex Fluids (TNW-PCF)			
F Mugele	0.7	5	2
Soft Matter, Fluidics and Interfaces (CT-SFI)			
RGH Lammertink	0.7	11	-
Engineering Fluid Dynamics (ET-EFD)			
CH Venner	1.1	6	-
Thermal Engineering (ET-TE)			
G Brem, J Kok, Th. van der Meer *(em)*	2.2	5	-
Multiscale Mechanics (ET-TFE-MSM)			
S Luding	1.9	3	2
Water Engineering Management (ET-WEM)			
SJMH Hulscher, K Wijnberg	4.2	14	1
Applied Analysis (EEMCS-AA)			
EWC van Groesen	0.3	-	-
Mathematics of Computational Science (EEMCS-MACS)			
JJW van der Vegt	0.3	-	-
Multiscale Modelling and Simulation (EEMCS-MMS)			
BJ Geurts	0.3	1	2
RUG			
Computational Mechanics and Numerical Mathematics (CMNM)			
RWCP Verstappen, AEP Veldman *(em)*	1.5	3	3
WUR			
Experimental Zoology (EZO)			
JL van Leeuwen	0.7	3	-
Food Process Engineering (FPE)			
CGPH Schroen	0.7	1	1
Physical Chemistry and Soft Matter (PCC)			
J van der Gucht	1.1	4	-
UU			
Institute for Meteorology and Oceanography (IMAU)			
H Dijkstra, LRM Maas	1.0	2	-

Overview of university participants

	TUD	TUE	UT	RUG	WUR	UU	Total
Scientific staff *(effective fte)*	26.8	20.6	15.6	1.5	2.5	1.0	68
PhD-students	132	118	89	3	8	2	352
Postdocs	5	19	28	3	1	0	56

Industrial Board

It is a privilege to contribute to the Annual Report of the J.M. Burgers Centre (JMBC), the research school for fluid dynamics in The Netherlands, as the chair of the Industrial Board.

As indicated, in 2018 we took the initiative to develop several NWO proposals in the area of bubbly flow in electrolysers and industrial granular flow. The very good news is that both projects are approved. In both projects 3 different universities and different industries are collaborating in the area of developing new models hand-in-hand with experimental validation. Also worth mentioning is a project proposal in the area of electro-chemical reactors via ISPT. This project is aiming at creating new functionalities via a combination of traditional and additive manufacturing methods. A close collaboration in the areas of membrane materials, catalysis and manufacturing methods. In the modeling area we anticipate close collaboration between expertise in chemistry, flow phenomena (mass and heat) and construction materials. The Dutch part of project is mirrored in Germany with a similar budget, and institutes and industries from Germany. As can be seen from these examples, we are seeking interaction between industries, universities, and institutes, and push for projects in both existing and new business areas and on top of that interactions between disciplines like process engineering, materials, mechanical engineering, etc. We expect all these projects to kick-off late 2019 or in 2020. Looking forward to a fruitful 2020, and also looking at new initiatives.

As in 2018, also in 2019 the fast development of computational and data science and digitalisation is on the agenda. Sensors become cheaper and faster, while models can be operated ‘real time’. These developments have significant effects on workflows and interactions between fundamental sciences and process engineering tools. Open source and open access are also now recognized at EU level as important vehicles to validate, disseminate and maintain knowledge developments.

An important aspect in creating easier access to models is the availability of the models and enough and affordable hardware to run the models on. In 2020 we will explore these aspects further, in combination with earlier mentioned open source and open access developments.

Ir. P Veenstra
Shell
Chairman of the Industrial Advisory Board

Contact group "Multiphase Flow"

The objective of the contact group Multiphase Flow is to stimulate interaction and collaboration between researchers, developers, and users in the area of multiphase flow from universities, institutes and industries. This is done through organizing regular meetings (once or twice per year) aimed at getting to know each other's activities and to learn about developments and applications of multiphase flow technology. This will provide a good forum to identify the needs of the users and to bring to the attention new possibilities for applying multiphase flow research results. Industry, a research institute or a university in turn act as host of the meetings. The program consists of a series of lectures on a specific theme and a visit of some of the local multiphase flow facilities. Examples of themes covered are: dynamic multiphase flows, multiphase flows with surface-active agents, and innovation with multiphase flow. In September 2019 a successful one-day meeting was held at Marin in Wageningen, including a number of presentations and a visit of the new multiphase wave lab facility at Marin.

Contact : Dr. Y Tang (TUE), Dr.ir. SG Huisman (UT), Prof.dr.ir. C Poelma (TUD)

Contact group "Computational Fluid Dynamics (CFD)"

Computational Fluid Dynamics (CFD) has established itself as an indispensable scientific discipline at the intersection of physics, engineering, mathematics and computer science. Society relies more and more on numerical simulations, while at the same time the field becomes more and more specialized. In a series of JMBC courses the state of the art in computational fluid dynamics is presented from an introductory level to state-of-the-art methods. The aim of the contact group CFD is to bring together developers, scientific staff, PhD students and users to share new developments and experiences. To that end the CFD contact group organizes an annual meeting, which provides a platform for discussing the latest development. This event also aims to promote the interaction between CFD users from academia, industry and research institutes. Young researchers are encouraged to present their latest work during this one day event. In 2019, the annual CFD contact group meeting took place on Tuesday 29 March 2019 in Delft.

Contact : Dr.ir. MI Gerritsma (TUD), Prof.dr.ir. RWCP Verstappen (RUG)

Contact group "Combustion"

The contact group combustion is an informal network between the groups active in combustion in Delft, Eindhoven, and Twente, bringing together the researchers in the Netherlands in an international context. The combustion topic is interpreted in a broad sense and covers solid, liquid and gaseous (fossil and renewable) fuels. About every three years the contact group Combustion organizes the JMBC course on Combustion, bringing PhD students and other academic and industrial researchers to the forefront of experimental, theoretical and numerical research on fundamental and applied combustion. The latest edition took place in January 2019, and was organized in association with ERCOFTAC.

Since many years the JMBC groups also play an important role in the organization of the annual COMBURA symposium. This symposium is the major annual event in the Netherlands for exchange of information on combustion research and its applications. Its goal is to enhance the mutual collaboration between the different academic and industrial researchers and to interest more industrial parties for the fundamental research on combustion. In 2019, COMBURA took place in Soesterberg on 9 – 10 October. The theme of Combura 2019 was 'Sustainable fuels for energy and transportation'. Keynote lectures were given by dr. Jaap Kiel, (ECN-TNO), Prof. Sebastian Verhelst (Ghent University and Lund University), and Dr. Ruud Eggels (Rolls-Royce Deutschland), embedded in an interesting program of oral and poster presentations on the research by the participants..

Contact : Dr.ir. RJM Bastiaans (TUE), Dr.ir. JBW Kok (UT), Dr.ir. JA van Oijen (TUE), Prof.dr. DJEM Roekaerts (TUD)

Contact group "Lattice-Boltzmann techniques"

The Lattice-Boltzmann schemes can be seen both as flexible and efficient solvers for macroscopic fluid equations or as particle-based simulation techniques which make close contact with the kinetic theory of gases. It is this last feature that allowed, in recent years, the partial disclosing of the huge potential of the method. The Lattice Boltzmann method has demonstrated great accuracy and performance in dealing with multiphase and multicomponent flows, from laminar to turbulent, in presence of simple or complex boundary conditions. Additionally the method allows the study of colloidal systems, of complex fluids and of thermal flow problems. The contact group promotes the organisation of educational and research events, also in synergy with other national and international organizations.

Contact: Prof.dr. F Toschi (TUE)

Contact group "Turbulence"

Turbulent flows are omnipresent in industrial applications and the environment. Owing to the non-linear character of the governing Navier-Stokes equations, the structure and dynamics of turbulence is complex. It is for these reasons that turbulence has been studied for already more than a century, in particular after the pioneering work of Osborne Reynolds on transition and turbulence in pipe flow. While early research focused on understanding of turbulence in single-phase flow, research on turbulence nowadays addresses a much broader class of turbulent flows such as e.g. turbulent multiphase flows, turbulent reacting flows, turbulence in supercritical fluids, etc.

The contact group "Turbulence" organizes annual meetings between researchers of the JM Burgerscentrum active in the field of turbulence with the aim to strengthen contact between them and to exchange results and experience. PhD students and other researchers are given the opportunity to present their results in an informal setting that promotes discussion. The meetings take about a day with a program consisting of typically 7-8 talks from different researchers/ groups, usually followed by a tour through the laboratory of the hosting institute and a "drinks session" at the end of the day. The program of a meeting typically covers both fundamental and applied research topics as well as the development of experimental techniques and numerical simulation methods for turbulent flows.

The 2019 meeting of the contact group Turbulence was held on 5 April 2019 in Eindhoven, hosted by Dr.ir. RPJ Kunnen (TUE) and attended by approx. 30 participants.

Contact: Dr. R Pecnik (TUD), Dr.ir. WP Breugem (TUD), Dr.ir. RJAM Steven (UT), Dr. M Duran Matute (TUE)

Contact group "Experimental Techniques"

The contact group Experimental Techniques forms a platform where experiments and experimental techniques can be shared and discussed. The main function of the contact group is to organize meetings with experimental fluid dynamics research groups, including research on turbulence, multiphase flows, granular flows and microfluidics. An important contribution of the contact group is the organization of the JMBC course on Experimental Techniques in Fluid Mechanics. The course is very popular among the JMBC members as it gives a broad overview of advanced experimental techniques commonly used in fluid mechanics laboratories. The last course was organised in the University of Twente in June 2019 and counted with 40 participants and 13 lecturers from all over the country. The next course will be held in 2021 again at the University of Twente..

Contact : Prof.dr.ir. M Versluis (UT), Prof.dr.ir. C Poelma (TUD), Dr.ir. RPJ Kunnen (TUE), Dr. A Marin (UT)

Contact group "Biological Fluid Mechanics"

More and more research is conducted at the interface between biology and fluid mechanics. This happens within many disciplines, from physiology (e.g. the interaction between blood flow and vessel walls) to aerodynamics (e.g. flapping animal flight). All these topics deal with the interaction between fluids and complex, changing geometry, and thus require similar experimental, numerical and analytical approached. One of the main challenges in this highly interdisciplinary research field is to bridge the gap between physics (fluid mechanics) and medical/biological sciences. To stimulate this, we aim to bring together researchers that work on Bio-Fluid Mechanics, by organizing seminars, workshops and courses on this topic. Although the contact group is affiliated with the JM Burgerscentrum, the participation from researchers from outside the JM Burgerscentrum is highly encouraged.

The contact group has led a rather dormant life during the last few years, but in 2019 a new start was made with a fresh coordinating team. The first kick-off meeting was held on 17 May 2019 at Delft University and Technology. The focus of a full-day meeting was on biomedical and biological applications and attracted 65 participants from the university medical centres (EMC Rotterdam, LUMC), industry (Philips) and academia (UT, TUE, TUD, WUR, UvA, UG). In 2020, Bas Borsje (UT) will be added as an additional contact person. It is aimed to organize the next Bio-Fluid Mechanics meeting in May 2021.

Contact: Prof.dr. S Kenjeres, Dipl.-Ing. (TUD), Dr.ir. F Muijres (WUR), Dr.ir. B Borsje (UT)

Contact group "Microfluidics"

The contact group "Microfluidics" was established in 2005. The purpose of the contact group is to bring together students and postdocs interested in fluid dynamic aspects of microfluidics and give them a forum for presenting their results and exchanging ideas. Also, the contact group serves as a platform to exchange information about relevant conferences, workshops, courses, and research grant opportunities. Topics of interest include wetting and capillarity-driven flows, two-phase flow, micro-mixing, drop generation and control, emulsification, contact line dynamics, flow visualization, and measurement techniques. Attention is also given to also related applications such as microfluidic devices for medical diagnostics, water quality monitoring, and advanced cell culture systems.

Members of the contact group organize the JMBC course "Capillarity-driven flows in microfluidics" that has successfully taken place in May 2017 at the University of Twente, and will be organised again in June 2019. In 2018, a brandnew course will be organized: "Micro- and Nanofluidics". In this course, the participant will learn about micro- and nanofluidic principles, technology, and applications, but also get extensive hands-on experience with designing, making, and testing microfluidic devices. The course was successfully held 28-31 May 2018 at Eindhoven University of Technology. 27 participants, all PhD students or postdocs from JMBC groups, joined the course. The Micro- and Nanofluidics course will be organized every two years.

Students and researchers, who are interested in the activities of the group and want to attend our symposia, are invited to contact the organizers of the contact group and have their name added to the mailing list..

Contact : Prof.dr. F Mugele (UT), Prof.dr.ir. JMJ den Toonder (TUE)

Burgers Program for Fluid Dynamics at the University of Maryland (USA)

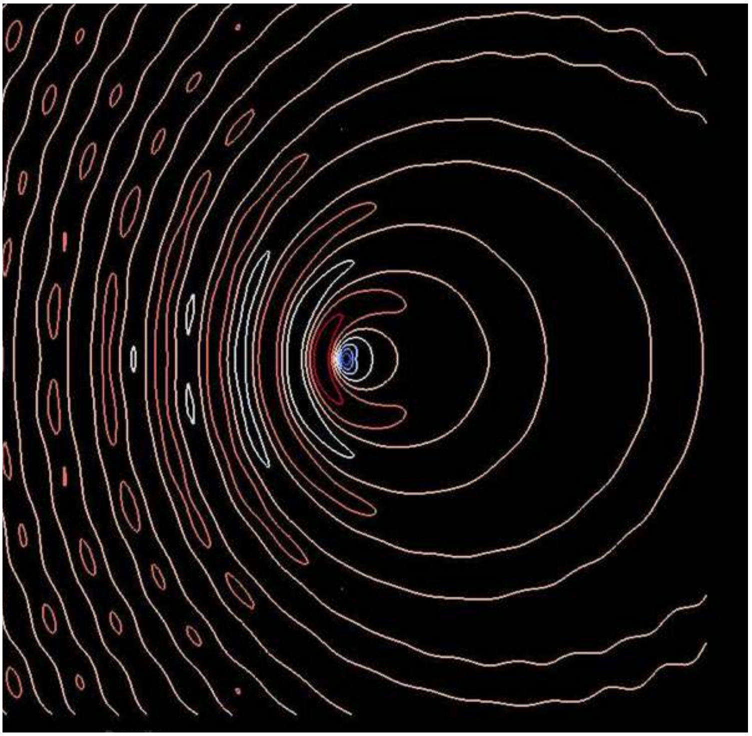
Inspired by the intellectual heritage of Johannes M. Burgers, who had a second career (1955 - 1981) at the University of Maryland after his retirement at the Technical University of Delft , the mission of the Burgers Program for Fluid Dynamics is to enhance the quality and international visibility of the research and educational programs in fluid dynamics and related areas at the University of Maryland, in partnership with the J.M. Burgerscentrum (JMBC). Fluid dynamics in this context is viewed to include a broad range of dynamics, from nanoscales to geophysical scales, in simple and complex fluids. The establishment of the Burgers Program was celebrated with an inaugural symposium at the University of Maryland in November 2004. Gijs Ooms, then Scientific Director of the JMBC, gave a lecture on the life and legacy of Burgers on that occasion. The interdisciplinary Burgers Program encompasses almost 80 faculty members spread over 22 different units in the College of Computer, Mathematical and Natural Sciences and the A. James Clark School of Engineering. For detailed information, go to http://www.burgers.umd.edu/.

There have been numerous faculty and student exchanges between groups of the JMBC and the Burgers Program. Visitors to Maryland have come from the Technical Universities of Delft and Eindhoven, Leiden University, Twente University, and Utrecht University. Over thirty journal articles have resulted from these exchanges. At the annual Burgers Symposium in November of each year, the Burgers Lecture has been given by JMBC faculty: Frans Nieuwstadt, Bruno Eckhardt, Gijs Ooms, Detlef Lohse, Wim van Saarloos, Kees Vuik, Wim Briels and Henk Dijkstra as well as by several others from France, Germany and the United States. The Burgers Lecture was to be given by Jim Kok of University of Twente in the Fall of 2019 but was postponed until the Fall of 2020 at the request of the speaker. Each spring semester the Burgers Program holds a PhD student/Post-doctoral Fellow showcase Symposium, together with fluid dynamics groups from Johns Hopkins University and George Washington University. Five or six seminars are offered each academic semester in the Fluid Dynamics Reviews series. Beginning in 2010, the Burgers Program also began offering advanced level, week-long Research Summer Schools. The subjects have been Topics in Turbulence (twice), Granular Flows - from Simulations to Astrophysical Applications and Data Assimilation in the Geosciences. Students from the JMBC have participated in each of these. In 2019 a Research Summer School on ‘Topics in Multiphase Flow and Thermal Transport’ was organized, while one on ‘Fire Safety Science’ was planned for 2020 (although it had to be postponed until 2021 due to the coronavirus pandemic).

After serving as director of the Burgers Program for a number of years, Prof. James Wallace retired in 2019, and he was succeeded by Prof. James Duncan, who is Keystone Professor at the Department of Mechanical Engineering, specialized in experimental and numerical studies of various fluid flows, with focus on wave phenomena.

Prof. James Duncan
University of Maryland

HIGHLIGHTS



Elastohydrodynamic solid-liquid-solid dewetting

Maciej Chudak[1] and Anton A. Darhuber[1]

[1] Fluids & Flows Group, Department of Applied Physics, Eindhoven University of Technology

The presence and stability of thin liquid films between two solid surfaces is of great scientific and technological relevance for many systems and applications. For minimizing wear in bearings, a stable liquid film is desirable. To prevent aquaplaning on wet roads, the liquid film should be removed as efficiently as possible to maximize traction. Similarly, for residue-free nanoimprint lithography, a swift and complete removal of intervening liquid is required. The strength of adhesion between organic or polymeric surfaces is considerably reduced by the presence of a water film, as the Hamaker constant for the interaction of e.g. two polystyrene or poly-tetra-fluoro-ethylene halfspaces across vacuum is 7 to 10 times higher than across an ultrathin water layer.

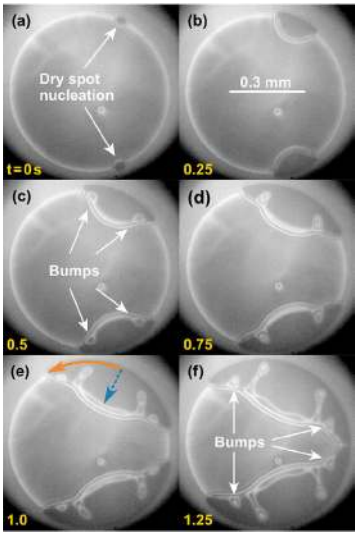


Fig. 1: (a) Simultaneous dry-spot nucleation in two locations on the perimeter of the contact spot. (b)–(f) The expansion rate of the dry spots is highly anisotropic and significantly faster along the edge of the contact spot [4].

Roberts and Tabor reported the spontaneous collapse of thin liquid films confined between a rubber surface and an SiO_2 lens for film thicknesses below 40 nm in 1968. Brochard-Wyart and de Gennes were the first to present an analytical model for the dewetting of water films between a rigid solid and a rubber [1]. By balancing the surface energy change with the viscous dissipation in the liquid they derived the scaling law for the growth rate of an axisymmetric dry spot. Martin and Brochard-Wyart presented experiments that confirmed the predicted scaling laws [2]. Persson et al. additionally considered the non-uniformity of the pressure distribution inside the contact area [3].

Brochard et al. and Persson et al. focused on axisymmetric dewetting, which is a rather rare occurrence and needed to be induced intentionally by artificial defects or protrusions on one of the confining solids. In contrast, we conducted systematic experiments of non-axisymmetric dewetting. An elastomeric half-sphere is pressed onto a flat layer of the same material with liquid confined between them.

Due to the applied pressure, the liquid film thickness h decreases in time. After h has become sufficiently low, dry-spot nucleation occurs at regions of minimum film thickness, usually at the rim of the contact spot. Figure 1 illustrates a fortuitous example, where two dry-spots nucleated almost simultaneously at different locations around the rim. It can be seen that the shape evolution proceeds in an essentially mirror-symmetric fashion, which proves that the dewetting process is governed by hydrodynamic effects and is not obscured by random surface defects and heterogeneities. The arrows in Fig. 1(e) indicate that the dewetting speed is highly anisotropic and is higher along the perimeter than radially inwards. Moreover, the receding liquid rim does not remain flat and smooth but develops bumps that will eventually break-up into droplets. This instability is more pronounced for thinner films as seen in Fig. 2, where only a single dry spot nucleation took place. After their formation, these droplets are subsequently propelled towards the edge of the contact spot by the contact pressure gradient. The contact pressure is highest in the centre of the contact spot and decays towards its edge.

Fascinatingly, the coalescence process of a radially moving droplets with the bulk liquid outside of the contact spot can proceed in a continuous or discontinuous fashion. Fig. 3(a-i) shows an example of a partial, discontinuous coalescence. The liquid bridge connecting the droplet and outer liquid displays a non-monotonic behaviour. It initially grows [Fig. 3(b) and (c)] then shrinks [Fig. 3(d)] and eventually disintegrates [Fig. 3(e)]. This cascading behaviour can occur multiple times during the lifetime of a droplet. Up to nine consecutive cascades were observed for a single droplet. Figure 3(j) compares the time history of the droplet footprint area of a non-cascading droplet and one that cascades five times. The latter shows a pronounced staircase-like morphology with a relatively uniform area reduction ratio A_n / A_{n-1}.

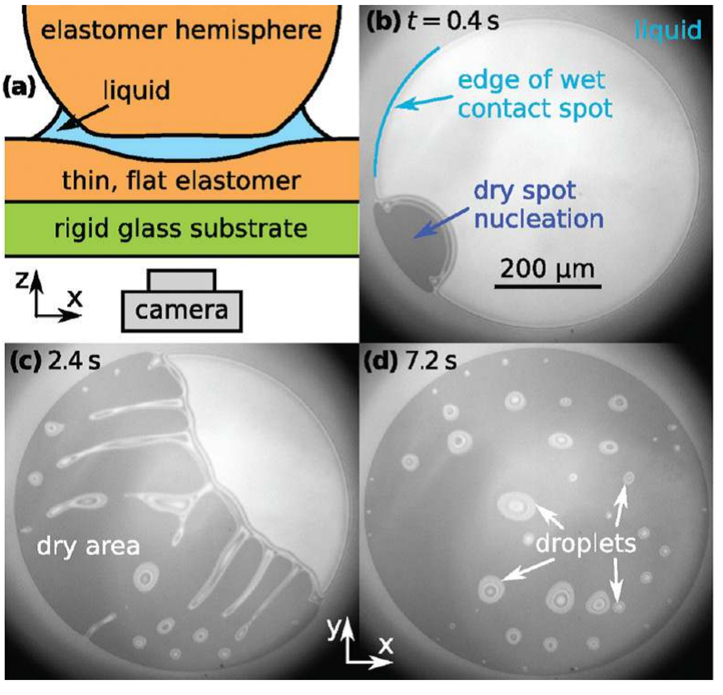


Fig. 2: (a) Side-view sketch of the experimental geometry. (b–d) Microscope images of dry spot nucleation and dewetting in the wet contact zone between an elastic half-sphere and a flat elastic layer. Frequently droplets are created due to an instability of the dewetting rim. (e) Microscope images of a droplet moving towards the edge of the contact spot [5].

The physical mechanism that causes the partial coalescence in this system is currently unclear, as is the reason why some droplets coalesce in a continuous fashion and others do not. Partial coalescence of spherical droplets at air-water interfaces is related to the cushioning effect of the gas interlayer and capillary-inertial effects, all of which play no role in our system.

We developed a theoretical model to simulate soft elastohydrodynamic lubrication phenomena and the dewetting of thin films between soft elastic surfaces numerically. The model combines the Reynolds equation for thin liquid film flow and linear elasticity accounting for the stresses and deformations of the soft elastomeric components. The three-dimensional implementation allows us to study non-axisymmetric geometries. The elastic deformation in the limit of slow deformation and small strain is governed by the Cauchy momentum equation for a stationary system, assuming the elastic material properties to be linear, non-dissipative, isotropic and homogeneous. The partial wettability is implemented in the elastohydrodynamic framework by means of the concept of disjoining pressure Π, for which an empirical relation based on two power-law terms was used.

We successfully validated our model using the available analytical models for axisymmetric dewetting. The model successfully predicts the effect of periodic surface topography on the shape of the dry spot [6]. Moreover, the model reproduces the morphology of the dewetting spots as well as their anisotropic growth dynamics shown in Fig. 1 very well [4]. The numerical simulations can also reproduce the shape and escape dynamics of non-cascading droplets in Fig. 2 qualitatively well [5].

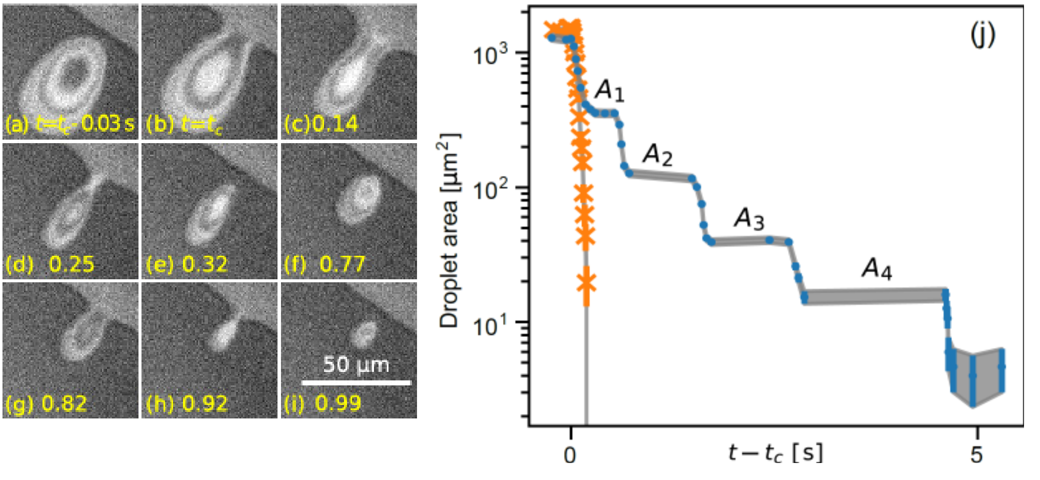


Fig. 3: (a-i) A droplet undergoing a discontinuous coalescence with the bulk liquid outside of the contact spot. The indicated time increments are given relative to frame (b) where coalescence started. The scale bar in (i) applies to all images. (j) Droplet footprint area as a function of time. The blue circles correspond to the data shown (a–i). The orange crosses refer to a droplet undergoing a continuous, non-cascading coalescence [5].

Droplets that undergo a coalescence cascade tend to move much slower than droplets that merge in a single coalescence event. Furthermore, the speed of motion of the cascading droplets is not proportional to the local pressure gradient. Using numerical simulations, we have investigated surface roughness and spatial modulations of Young's modulus and the spreading parameter as potential mechanisms that could slow the droplets down. As for the latter two, we generally found that for experimentally conceivable parameter variations, the reduction in contact line speed was far less than two orders of magnitude. In contrast, surface roughness induced a speed reduction comparable with the experimental observations and is thus a viable candidate for the responsible mechanism.

Additional details about the results that were briefly introduced above can be found in references [4-6].

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Modelling highly turbulent wave overtopping flows over flood defences

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Yearly, tens of billions of dollars are spent worldwide on the construction and reinforcement of flood defences to protect low-lying coastal areas against flooding. Without a strong cover, any flood defence will wash away by the waves attacking the structure during storm events [1]. Waves approach the dike in relatively deep water and change their shape when they reach the dike. On the seaward dike slope, the wave breaks and the broken wave runs up the dike, overtops the crest and then runs down the landward slope (Figure 1). These highly turbulent overtopping waves may cause an intolerable amount of water overtopping at the dike and also exert high forces on the dike cover, which threaten the stability of the dike. Therefore, accurate estimates of the amount and the characteristics of the overtopping flow are essential for the design and safety assessment of flood defences [2].

Nowadays, wave overtopping flow is described using bulk flow properties such as depth-averaged velocities, shear stresses or other flow-averaged estimates. However, spatially and temporally varying processes, such as turbulence and flow accelerations have shown to be important flow characteristics that determine the forces on dikes. Wave overtopping flow is highly complex, with high velocities (up to 10 m/s), very high degrees of turbulence while the flow is intermittent, which complicates accurate measurements and numerical modelling.

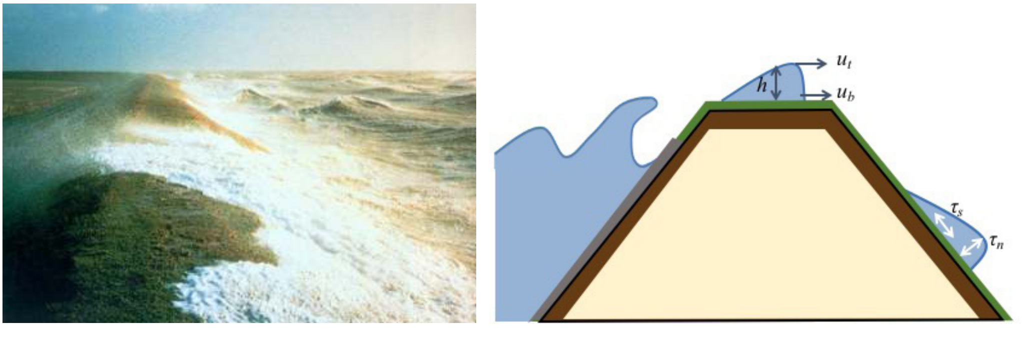

Figure 1: Waves approach the dike and break on the seaward dike slope. The broken waves run up the dike, overtop the crest and then run down along the landward slope. Left: photograph of grass covered dike during wave overtopping [5] (Picture courtesy: HR Wallingford). Right: Schematization of wave overtopping on a grass-covered dike. The overtopping flow has a layer thickness h, the flow velocity near the bed u_b and the flow velocity in the top layer u_t. Typical layer thickness and velocities range between 1-50 cm and 1-10 m/s respective. The waves pull on the grass cover with a shear stress τ_s parallel to the dike surface and a normal stress τ_n perpendicular to the dike surface (figure adapter after [4]).

With our research, we aim to increase the fundamental understanding of the flow processes and the forces that these complex flows exert on the dike covers. The characteristics of the wave overtopping flow depend on the wave characteristics, the geometry of the dike cover, local changes in the surface roughness and small-scale irregularities in the dike cover. Berms and roughness elements are often applied on dikes to effectively reduce the amount of overtopping. Detailed physical model tests are very expensive and time-consuming, and there are many variables that are hard to measure. Therefore, a numerical model has been developed to study these flow processes in detail for a wide range of wave characteristics and dike geometries.

The numerical wave overtopping model is developed in the open-source software OpenFOAM®, which solves the two-phase Reynolds-averaged Navier–Stokes equations using the Finite Volume method. For the turbulence, the k-ω SST model has been selected which accurately solves the turbulence in both the free-stream region and the boundary layer. The mesh consists of quadrilateral grid cells oriented parallel with the slope surface with a resolution of 10 mm in horizontal and vertical directions on the seaside slope and 20 mm on the crest and landward slope, both coarsening upwards. The model has been calibrated and validated on flume experiments [3] and field tests [4] and subsequently has successfully been applied to predict the amount of wave overtopping for highly complex dike configurations and to estimate the time and location dependent forces on the dike cover during wave overtopping [4].

Numerical modelling of wave run-up and overtopping at the seaward slope

Flume experiments were carried out in the Pacific Basin at Deltares (Figure 2a). Data from these experiments are used to improve existing empirical overtopping equations [3] and as validation data for the numerical model for wave overtopping discharge. These experiments showed that the effect of roughness is not constant, but varies with respect to the wave characteristics and dike configuration. New equations for berm and roughness influence factors have been developed that show a significantly better performance on estimates of the overtopping discharge within the tested range compared to existing formulae [3,6].

The range of dike configurations and wave conditions in these experiments was limited. Therefore, the numerical OpenFOAM model was developed and applied to these experiments to extend this range. The model was successfully calibrated on the experimental data and was capable of accurately predicting the average overtopping discharges at dikes with the accuracy within a factor of 2 of the experimental overtopping discharges. This validated model is now used to study the effects of different sizes of the seaward berm, the effect of the still water level and varying roughness and angles of the seaward slopes. This research also shows that placing revetments (each with a different roughness) at different elevations on the seaward slope can contribute differently to the overall roughness factor. Roughness elements on the upper slope are the most effective in reducing wave overtopping compared to the roughness elements on a berm or on the down slope. This research enables optimizing the dike design while maintaining the flood protection function of the dikes.

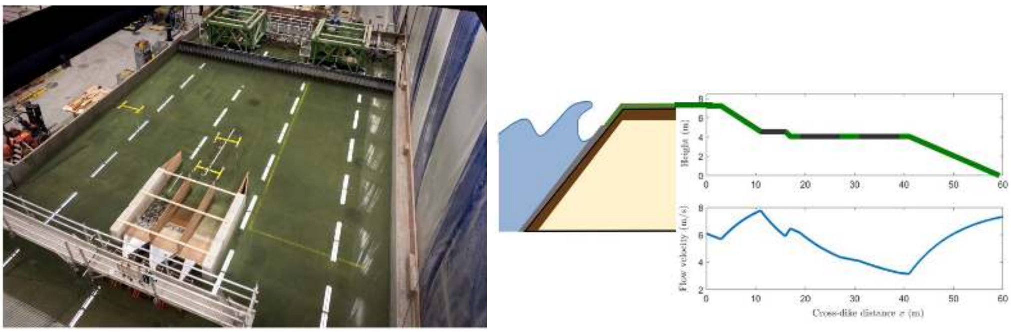

Figure 2: Left: Flume experiments in the Pacific Basin at Deltares to quantify the effect of a berm and revetments on overtopping discharge [3] (Picture courtesy W. Chen). Right: Results of the analytical model [7] to simulate flow velocity and layer thickness along a complex landward slope [1] .

Numerical modelling of wave overtopping at the landward slope

An analytical model has been developed to predict the maximum flow velocities along the landward slope [7] (Figure 2, right). This model gives accurately predicted flow velocities for a range of wave characteristics and dike geometries. The flow velocity is often used as input for dike erosion estimates [5]. However, turbulence in the wave overtopping flow caused by sudden changes in surface roughness, the slope angle and irregularities of the dike cover also affects dike cover erosion. It is still extremely challenging to measure turbulence in these high velocity, intermittent flows. Therefore, the numerical OpenFOAM model was developed and applied on the crest and landward slope of dikes (Figure 3, right), to more accurately quantify the characteristics of the overtopping flow. The OpenFOAM model was able to reliably predict shear stresses, normal stresses and pressures in the overtopping flow [4]. Application of the model to complex landward slopes (Figure 2, right) showed that the pressure increases up to a factor of 6 at transitions in the slope. The pressure increase from the crest to the landward slope can be related to the separation and reattachment with the slope of the overtopping flow leading to a high impact. High pressure at the inner toe, where the slope changes to a horizontal plane, are caused by jet formation related to the slope change. This new numerical model is a useful tool to quantify the erosion inducing stresses along the dike surface to locate the weak spots for cover failure and improve the design of grass-covered flood defences [4].

Figure 3: Numerical simulation of waves running up the dike with a berm and cause wave overtopping (Left). Overtopping waves run over the crest and cause high shear and normal forces due to the high velocities and turbulence (Right).

The future of numerical wave overtopping modelling

The numerical OpenFOAM model has been developed to better understand the impressive power of overtopping waves and their effect on the strength of our flood defences. The numerical modelling tool enables to identify the most important flow processes, which will contribute to the further development of design rules and guidelines for climate-proof flood management. In addition, uncertainties need to be quantified and included in new probabilistic risk frameworks to be able to probabilistically predict the strength of dike covers. In collaboration with Rijkswaterstaat, and Deltares, the developed knowledge and tools will be implemented into practical design tools.

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On recent progress in combined computational- and experimental-physical transport phenomena in biomedical applications

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We present some recent research highlights dealing with our current progress in combined computational and experimental physical transport phenomena, with a primary focus on the biomedical applications. The transport of mass, momentum, species, and energy - within biological systems - plays a fundamental role in the functioning of cells, tissues, and organs. It is recognized that some variations in biological transport processes can trigger a complex chain of biochemical reactions leading to various diseases (e.g., allergies, asthma, diabetes, atherosclerosis, cancer, etc.). The mathematical modeling and advanced computer simulations of the underlying mechanisms responsible for physical transport phenomena in living systems, can be powerful tools for potential predictions of the onset location and progression of various diseases. Detailed testing, validation, and verification of such mathematical models and computer simulations is crucial for potential clinical medical applications, Refs.[1-4]. Here we will address two clinically interesting cases: (i) a patient-specific saccular aneurysm detected in the brain vascular system (7T MRI scanning performed at Amsterdam UMC), (ii) a model of the left ventricle with biological valves (in collaboration with EMC Rotterdam, LUMC Leiden and Ghent University, Belgium).

The intracranial aneurysms are local enlargements of blood vessels occurring within the cerebrovascular system. Their rupture causes almost 500,000 annual deaths worldwide. A better understanding of fundamental mechanisms behind their growth and potential rupture may open new routes for timely prevention and treatment. In the literature, by performing the CFD of the patient-specific aneurysm geometries, various criteria have been proposed to identify a potential rupture location. These criteria include estimations of the time-averaged wall shear stress (TAWSS), oscillatory shear index (OSI), and vortex-saddle point structure with accompanying low-pressure region. To validate our present generation of the advanced CFD codes, we perform comparative assessment of numerical simulations with the state-of-art optical flow measurements techniques (Stereoscopic Particle Image Velocimetry (SPIV); Tomographic PIV (TomoPIV)) and clinical Magnetic Resonance Imaging (7T MRI) - under identical working conditions. The optical flow visualizations require a build-up of an optically accessible phantom with identical or scaled anatomical geometry obtained from the MRI or CT scans. We have developed a full cycle in making 3D rapid-prototyping printed transparent organic silicon phantoms from the 3D MRI and/or CT scans. In Figure 1, we compare obtained results from different experimental modalities: SPIV (2D-3C / all three velocity components measured in a plane), TomoPIV (3D-3C full volumetric measurements with complete velocity vector) and MRI (3D-3C but with limited resolution compared to optical measurements). We demonstrated that by combining MRI/CFD approach, which was tested with our optical measurements under identical clinical conditions, significant improvements in estimating the WSS distribution along the aneurysm wall can be obtained.

The second example is the analysis of the flow patterns in one of the heart chambers, the left ventricle (LV). Observation of changes in characteristic LV blood flow patterns is associated with early detection of potential heart failure. At present, two primary clinical techniques for analysis of the LV blood flow dynamics are the MRI and echocardiography. Each of the techniques suffers from some limitations, e.g., MRI measures full 3D blood flow patterns in time (so called 4D Flow MRI), but requires relatively long acquisition times (averaging over 100s of cardiac cycles) and has relatively low temporal resolution (20-30 phases per cardiac cycle). The clinically available echocardiography can acquire 15-100 frames per second, but not all vectors components can be measured. We perform a comparison of the current generation of MRI and ultrasound clinical techniques with our optical measurements on a human left ventricle model. Due to its superior spatial and temporal resolutions, results of SPIV and TomoPIV measurements can be used for further calibration and refinements of the clinical techniques, Figure 2. Additionally, we also perform the CFD simulations, which entirely mimic the experimental conditions. Here, particular challenges involve a dynamic motion of the left-ventricle surface, and the movement of the biological valves. We have developed a novel in-house simulation approach based on the radial-basis-function morphing method to include dynamic meshing (Wu and Kenjeres (2019)). The most interesting experimental results are shown in Figure 2. Finally, the CFD results are shown in Figure 3.

In conclusion, we stress the importance of combined experimental and numerical studies in providing detailed synergetic insights into physical transport phenomena in various biomedical applications.

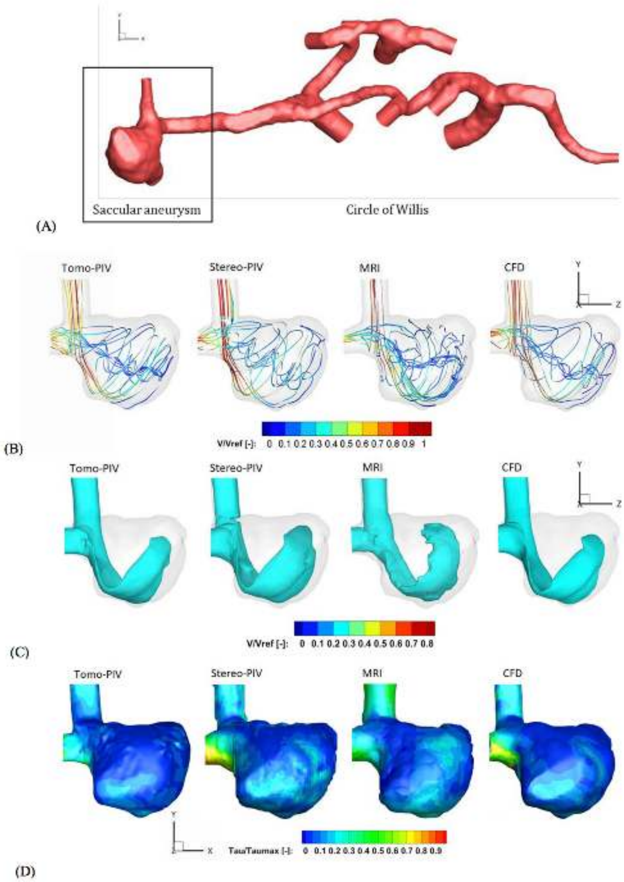

Figure 1. Comparison between different experimental modalities (SPIV (2D-3C), TomoPIV (3D-3C), MRI) and CFD for a patient-specific saccular aneurysm detected in the brain vascular system (Circle of Willis): (A) the location and geometry of the aneurysm (from MRI scans); (B) the 3D distributions of the pathlines coloured by velocity magnitude, (C) extraction of 3D isosurface of the velocity magnitude (|V| = 0.3 m/s), (D) distribution of the wall shear-stress (WSS) along the walls of the aneurysm; Courtesy of Kenjeres Lab (2019) and Amsterdam UMC.

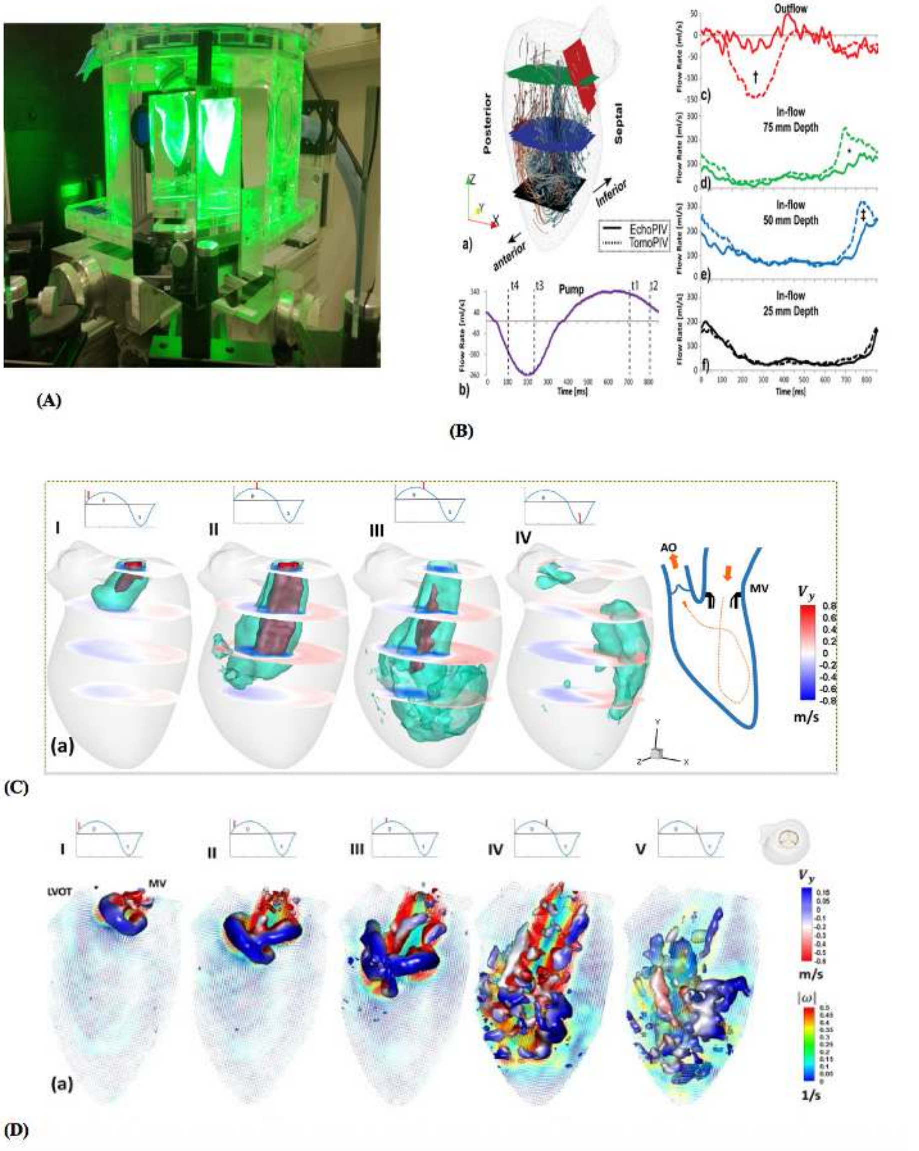

Figure 2. (A) The laser illumination of the working tomographic PIV experimental setup for the moving heart measurements; (B) Comparison between optical (TomoPIV) and ultrasound (US) measurements under identical working conditions; (C) the 4D reconstruction of the velocity field from the TomoPIV; (D) extraction of the coherent structures from the 4D TomoPIV measurements coloured by instantaneous axial velocity – superimposed with vorticity magnitude in the central vertical plane; (Refs: Saaid et al. (2019), Voorneveld et al. (2020))

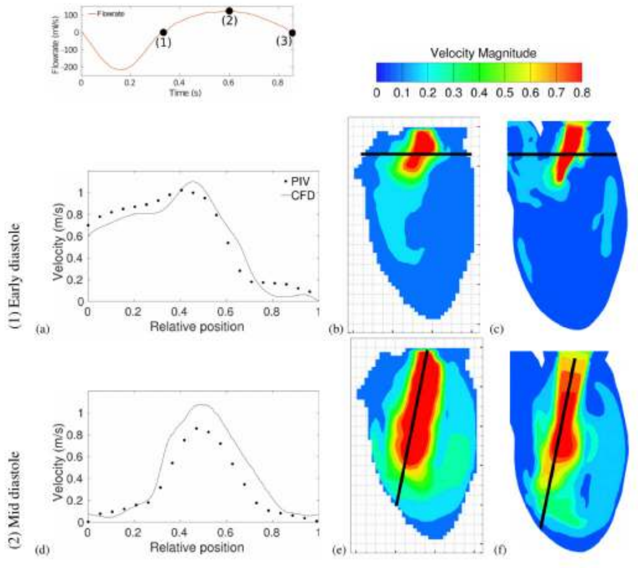

Figure 3. Comparative assessment of the newly developed CFD (based on the in-house developed radial-basis-function morphing moving mesh approach for dynamic changes of the left-ventricle surface and moving biological valves) (c-f) and tomographic PIV measurements (b-e): contours and profiles of the velocity magnitude at two characteristic time-instants of the cardiac cycle, (i) early diastole (-top) and (ii) middle diastole (-bottom) (Refs: Xu and Kenjeres (2019))

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Rewetting of hot surfaces: Explosive boiling as contact mechanism between liquid water and surfaces at elevated temperature

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Can liquid water touch a surface at, for example, 600 °C? If yes, how is this possible? And why is this relevant for the industry?

Quench cooling by water jet impingement is applied in a wide range of industrial fields where ultrafast cooling is necessary. Upon impingement onto a sufficiently hot surface, the water undergoes a phase transition from liquid to gas state (boiling). The combination of high convective forces generated by the water jet and the high heat of vaporization leads to high cooling potential. In the steel industry, this technique is applied in the Run Out Table (ROT, figure 1) to reach the desired microstructure and mechanical properties.

The ROT is located between the Hot Rolling and Coiling sections. During Hot Rolling, hot steel slabs are rolled to reach the desired thickness and width. Due to mass conservation, the steel slab increases its length from 20 meters to hundreds of meters long. Simultaneously, the steel slab is accelerated to speeds up to 80 km/h. Before coiling, the steel slabs must be cooled in the ROT from approximately 1200 °C to the desired final temperature, which can vary between 700 and 180 °C depending on the steel grade. In the ROT, hundreds of circular water jets impinge on the moving steel slabs, which are cooled in a matter of seconds. The high surface speeds, the large amount of water jets, and the violence of the boiling activity make this a very complex and chaotic process. Still, a high level of control is required.

Figure 1: Run Out Table: Multiple water jets impinging on the moving, red hot, steel slab.

The cooling speed and temperature distribution of the steel determine its microstructure and mechanical properties, making the ROT a crucial step in the steel making process. Failure to succeed on this step leads to rejection of the steel slab and its reprocessing as scrap, resulting in major economic losses.

Given the high surface temperature of the steel, the main boiling regime present in the ROT is film boiling. The high surface temperature leads to a high vaporization rate and the formation of a vapor layer, isolating the water from the hot surface. During stable film boiling, the surface heat flux is nearly constant and slightly decreasing with decreasing surface temperature. As a result, small surface temperature variations along the steel slab are homogenized by internal conduction, resulting in a self-regulating process. However, steel grades requiring low coiling temperatures might reach the rewetting temperature in the ROT: the surface temperature decreases to a point where the vapor film is broken. Rewetting (i.e. water-surface contact) then occurs and the heat flux increases drastically. Rewetting leads to a sharp increase in heat flux resulting in a fast decrease of the surface temperature, meaning that small temperature variations along the steel slab are exacerbated [1]. Uneven surface rewetting leads to uneven cooling and therefore poor product quality, non-reproducible processing, and deformation of the steel slabs. This makes rewetting one of the most relevant phenomena occurring during quenching in the ROT.

Experimental studies in literature have reported contact between liquid water and surface (rewetting) to occur at surface temperatures up to 900 °C [2]–[4]. Theoretically, at temperatures above the Thermodynamic Limit of Superheat (TLS, equal to 302 °C in the case of water [5]), liquid water cannot maintain a superheated state anymore. As a consequence, a sudden phase transition is bound to occur to the energetically favored vapor state, also denominated explosive boiling. The possibility of rewetting to occur at temperatures exceeding the TLS of water has been an open discussion in the field for years. If the reported rewetting temperatures are accurate, it is still unclear what mechanism allows water to maintain contact with a surface at such elevated temperatures. Some have hypothesized rewetting mechanisms involving intermittent dry and wet periods and explosive boiling [6], [7]. However, there is a lack of experimental data to prove these hypotheses due to the short duration and small scale of the rewetting phenomenon. During this project, detailed visualization of the rewetting phenomenon was made possible by using a borescope.

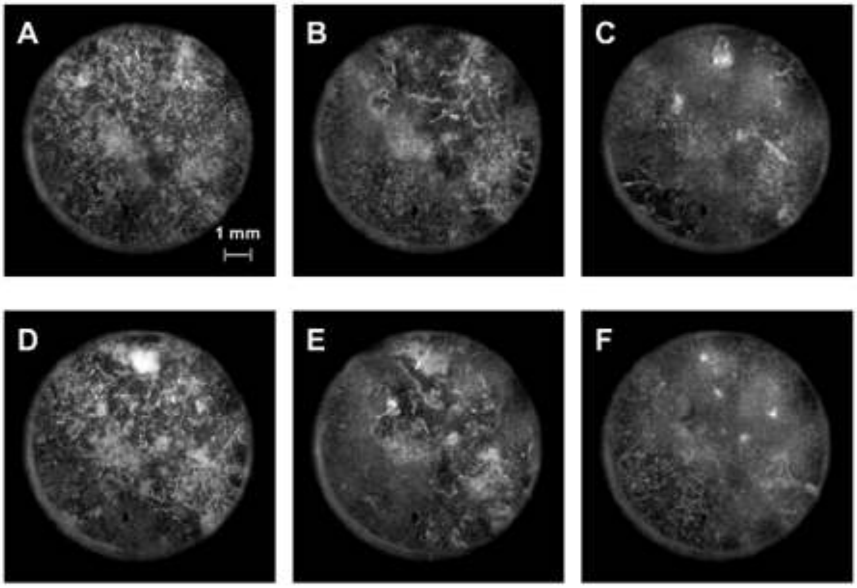

Figure 2. Intermittent boiling during sandblasted plate quenching; initial plate temperature of 650 °C and water jet at 25 °C. The circle corresponds to the 9 mm diameter stagnation zone. Time after jet impingement: A: 9.931 ms; B: 10.111 ms; C: 10.214 ms; D: 10.308 ms; E: 10.456 ms; F: 10.493 ms.

The experimental setup used during this project consists of a water tank connected to a circular jet nozzle. The water jet impinges into a sandblasted, preheated test plate, at initial temperatures up to 650 °C. A borescope is installed inside the water tank, aligned with the jet nozzle, and connected to a high-speed camera. As a result, the boiling activity in the jet stagnation zone can be recorded at 81 kfps and the nature of boiling during rewetting can be investigated in detail.

The high-speed recordings showed that when a water jet at 25 °C impinges onto plates at initial temperatures below 300 °C stable nucleate boiling activity occurs. At initial temperatures above 300 °C, the high-speed recordings showed vigorous and seemingly chaotic boiling activity. At this point, the great detail provided by the high-speed recordings became crucial. When observing this chaotic boiling activity at 2 fps playback speed (40000 times slower than reality), a pattern was perceived: bubbles nucleate simultaneously over the complete jet stagnation zone (figures 2A and 2B) and grow for a period of time before collapsing simultaneously, leaving the jet stagnation zone free of bubbles (figure 2C). After some time, bubbles nucleate in the complete stagnation zone again, repeating the process (figures 2D, 2E, and 2F). This is the first direct observation of intermittent boiling activity during quenching by water jet impingement.

The frequency of this intermittent boiling activity was estimated based on the high-speed recordings. The estimations resulted in frequencies between 2 and 40 kHz, depending on plate temperature, length scale, and surface finish. The analysis showed that the intermittent boiling activity occurs both in smooth and rough surfaces and only at initial plate temperatures above the Thermodynamic Limit of Superheat of water. The frequency at which the intermittency occurs decreases for decreasing surface temperature and follows correlations regarding single bubble growth theory when occurring in areas below 0.4 mm2. These results were carefully analyzed and correlated with theory and literature. The following hypothesis was presented (see figure 3) to explain the mechanism by which rewetting can occur at surface temperatures above the TLS.

Upon rewetting, the water temperature in the vicinity of the hot surface rises above the saturation temperature, leading to superheating (figure 3, step 1). If the surface temperature is higher than 300 °C, the water temperature reaches the TLS and the water suffers explosive boiling to the more favored vapor state: sudden bubble nucleation occurs in the complete jet stagnation zone (figure 3, step 2). The bubbles grow rapidly, leading to a bubble-rich state. At some point, the growth of the bubbles leads to contact with the subcooled, bulk water coming from the jet stream. Upon contact with the cold water, the bubbles implode (figure 3, step 3) and the cold water occupies the space previously filled by the bubbles, leading to a bubble-less state (figure 3, step 4). If the surface temperature is still sufficiently high, the water temperature rises and the sequence is repeated. This leads to a new boiling regime, denominated cyclic explosive boiling. For the first time, a rewetting mechanism hypothesis is presented and backed up with direct, detailed visualization of the boiling activity.

In the following stages of the project, the experimental setup was modified to allow quenching of moving, hot steel

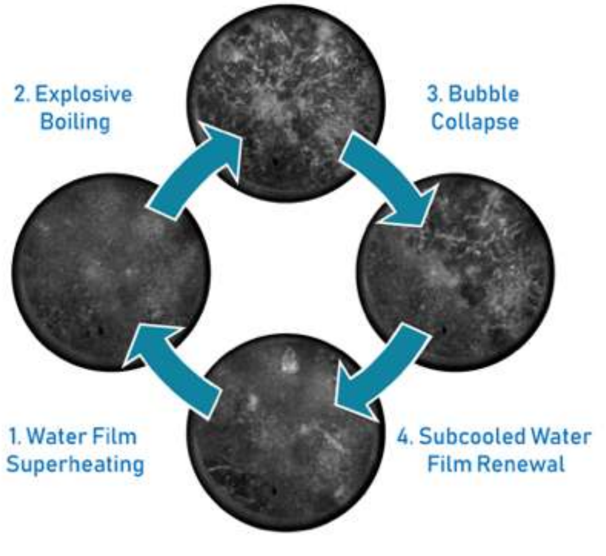

Figure 3. Rewetting mechanism hypothesis: cyclic explosive boiling.

plates. The use of a linear unit enabled the study of quenching of surfaces moving at speeds up to 8 m/s, higher than ever before and for the first time in a speed range comparable to the real application. The new setup combines the high speeds recordings here presented with heat flux estimations, resulting in a complete set of data with great potential to reveal the detailed physics of quenching in the Run Out Table.

For more information, feel free to consult our complete publication: https://doi.org/10.1017/jfm.2020.232

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Modelling non-isothermal non-adiabatic packed bed reactors

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Tubular packed bed reactors have been widely used in the chemical process industry for decades in various chemical conversion processes such as the selective oxidation of ethylene, oxidative coupling of methane and the synthesis of phthalic anhydride. Multi-tubular packed-bed reactors are generally preferred for exothermic reactions where a cooling jacket enclosing the tubular wall is used for controlling the reactor temperature. Highly exothermic systems employ a multi-tubular design where each individual tube has a low tube-to-particle diameter ratio to ensure sufficient cooling across the entire length of the reactor. The dynamics of the non-isothermal reactor are described by non-linear partial differential equations having an Arrhenius type dependency for the rate of reaction and the heat production terms. The intrinsic two-way coupling between temperature and concentration along with the self-dependency of temperature on the heat produced during exothermic reactions causes the system to exhibit many unique features, such as a small change in the inlet feed concentration or temperature that can cause a dramatic change in the reactor effluent conditions.

Here momentum transfer is coupled with heat and mass transport and the numerical method used is Direct Numerical Simulation. The Navier-Stokes equations are solved for the fluid phase transport and the temperature and species balance equations are solved for both the fluid and solid phase transport. The no-slip boundary condition is imposed along the surface of the particles and the tubular wall to solve for the velocity field. The continuity of fluxes boundary condition is imposed along the fluid-solid interface of the particles. For temperature, a constant value is fixed along the wall of the tubular column to ensure cooling across the bed. For concentration, the wall is assumed to be inert with the zero-flux condition. The reactor is mapped on to a 3-dimensional Cartesian grid where the fluid phase events and the solid phase events are solved simultaneously evaluated using their respective properties. The fluid phase and solid phase solutions are then coupled by applying the required boundary conditions using the Immersed Boundary Method [1]. This technique employs a quadratic interpolation where the values at the grid nodes close to the interface are modified to account for the boundary condition effects. This is done at the level of the discretized set of equations governing the transport in the two phases.

Here, the work of Das et al. [2] is extended where flow and heat transfer was studied in a cylindrical column packed with spherical particles using the Discrete Element Method (DEM). The artificially generated fixed bed consists of 340 spheres randomly packed in a slender tubular column using the DEM approach with the tube-to-particle diameter ratio being 5. Intra-particle diffusion of heat and mass along with a simple first-order irreversible reaction governed by the Arrhenius equation is considered [3] in the catalyst phase.

The velocity field of the fluid across the mid-plane of the packed bed reactor is presented in Figure 1. The dimensionless axial superficial velocity distribution across the cross-sectional radius of the reactor is presented in Figure 2 whose value is averaged across the length of the reactor. The velocity distribution yields a unique phenomenon referred to as ‘channeling’, where a large hump is observed close to the wall of the reactor. This arises from a combination of the packing of the spheres (where porosity reaches zero close to the wall) and the shear applied on to the fluid from the wall. The effect of flow-maldistribution is clearly visible in the figures presented below.

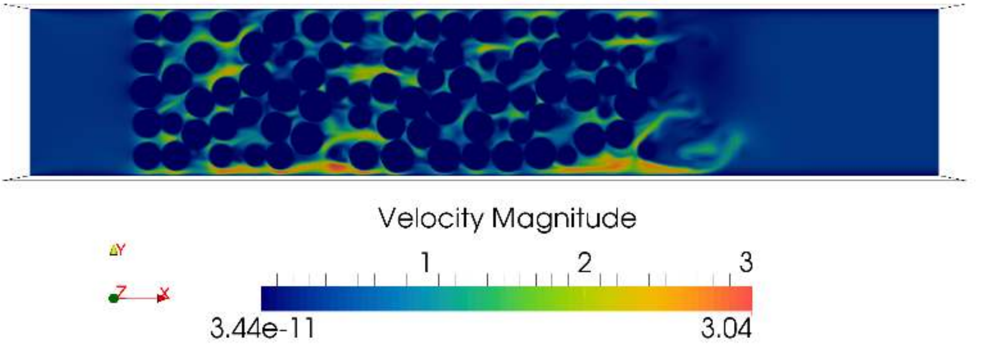

Figure 1

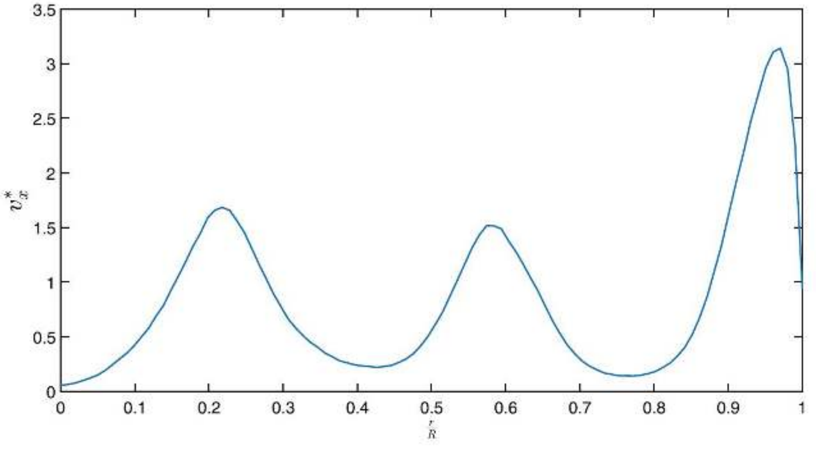

Figure 2

In Figure 3 and Figure 4, the concentration and temperature contour plots across the mid-plane of the reactor are presented where the rate of reaction is fixed such that the Thiele Modulus ϕ=R√(k/D_s)=3. Here the rate of reaction is three times the rate of diffusion within the catalyst particle. Due to the fast reaction, a large amount of heat is generated and this in return increases the temperature within the catalyst thereby enhancing the rate of reaction in return. Thus the system attains an auto-thermal operation condition wherein a feedback loop exists with the rate of reaction producing heat, in return enhances the rate.

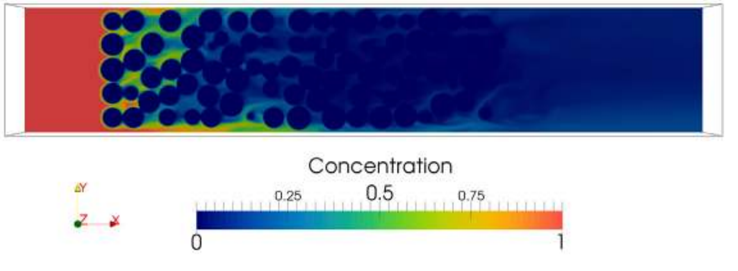

Figure 3

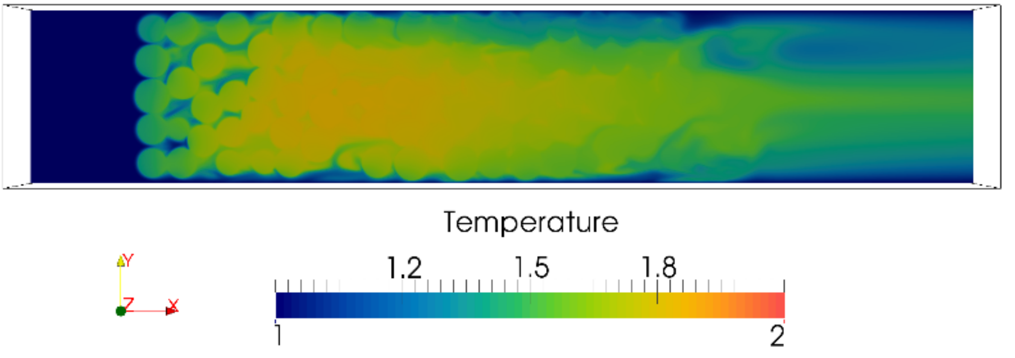

Figure 4

From the contour plots it can be seen that most of the reactant is converted away with the dimensionless concentration almost reaching zero at the outlet of the reactor. The dimensionless temperature yields that the reactor bed attains a value greater than the inlet feed temperature. It is assumed that the wall temperature equals the inlet temperature. Thus, the wall provides a cooling effect where the particles at the reactor exit are at a lower temperature than the particles in the middle of the bed. Plotting the temperature value within the fluid phase averaged using the velocity distribution, it can be seen that the temperature value reaches a maxima along the axial direction referred to as hot-spot. This hot-spot magnitude is dependent on the cooling effect provided by the wall. It is also influenced by the hydrodynamics where the flow-bypass provides a supplementary resistance to the heat removal mechanism across the radius of the bed. Figures 5 and 6 portray the temporal evolution of the bulk concentration and temperature values across the axial direction of the reactor bed, respectively.

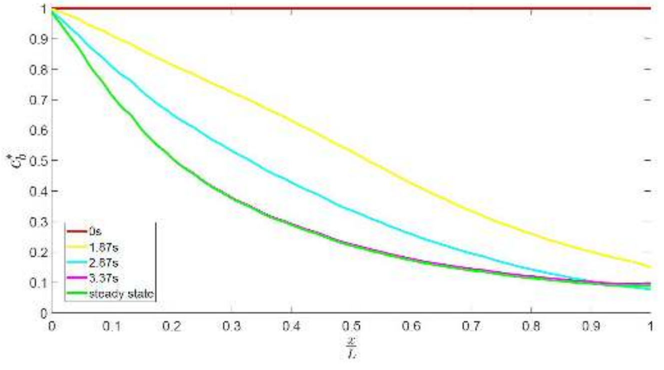

Figure 5

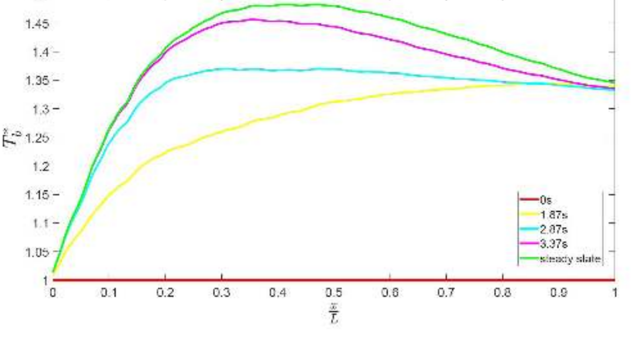

Figure 6

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Fast prediction of interfacial phenomena: the power of molecular dynamics simulations

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The rapid and economical prediction of the interfacial properties of liquids is necessary in many industrial applications such as in agriculture, inkjet printing, or oil recovery, where the screening and selection (by trial and error) of thousands of potential mixture components is required for the formulation of liquids adapted to a particular surface allowing for a certain purpose.

We developed a straightforward, low-cost, molecular dynamics-based approach for characterizing the wetting behaviour of liquids, speeding up the selection of adequate molecules that meet predefined wettability and spreading requirements [1]. The approach combines Owen and Wendt [2] theory with the concept of solubility parameters derived from molecular dynamics simulations. Figure 1(a) shows the experimental surface tension of typical liquids, polymers and surfactants used in inkjet printing, plotted against the surface tension values obtained using our approach. Similarly, in Figure 1(b), the calculated contact angles are plotted against experimental data. In both Figures, wetting behaviour computed numerically agrees with experiments. We demonstrated the importance of hydrogen-bonding interactions on the behavior of liquids when in contact with a polymeric surface and how it is possible to select or design suitable substrates for specific applications based on the underlying intermolecular interactions.

For example, PTFE is neither a hydrogen-bonding nor a polar substrate, which explains why most liquids do not spread on it. The approach is versatile, applicable to a mixture of miscible liquids, and can be extended to rough surfaces, by using for example the Wenzel model [3].

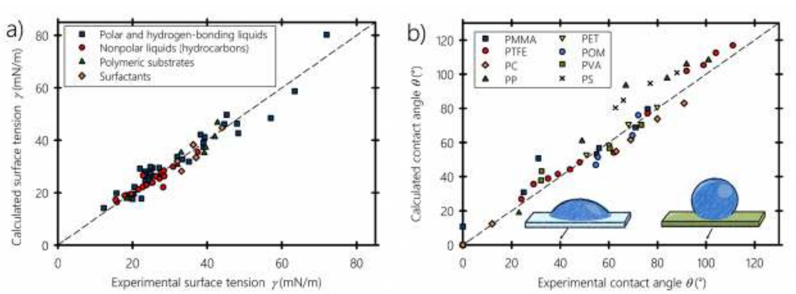

Figure 1: Calculated versus experimental (a) surface tension of various liquids, and (b) contact angle of liquids on different polymeric substrates. PMMA: polymethyl methacrylate, PTFE: polytetrafluoroethylene, PP: polypropylene, PC: polycarbonate, PET: polyethylene terephthalate, POM: polyoxymethylene, PS: polystyrene, and PVA: polyvinyl alcohol

Another challenge that we faced in this line of research is the surfactant adsorption on the nozzle plate. During the inkjet printing process, siloxane-based surfactants (EHTS) from the ink can adsorb on the silicon dioxide (SiO2) nozzle plate and thereby modify its wetting properties. This may deteriorate the quality of the printed image because a change in the plate wettability can lead to non-zero jetting angles as shown in Figure 2. In the first snapshot on the left side of Figure 2, it can be seen that the area surrounding the nozzle is clean, but after jetting for only 16 seconds the entire nozzle plate is covered in ink due to change in its wettability. The aim is therefore to gain a more detailed understanding of the underlying molecular interactions of the EHTS surfactant dispersed in a solvent when in contact with the silicone plate.

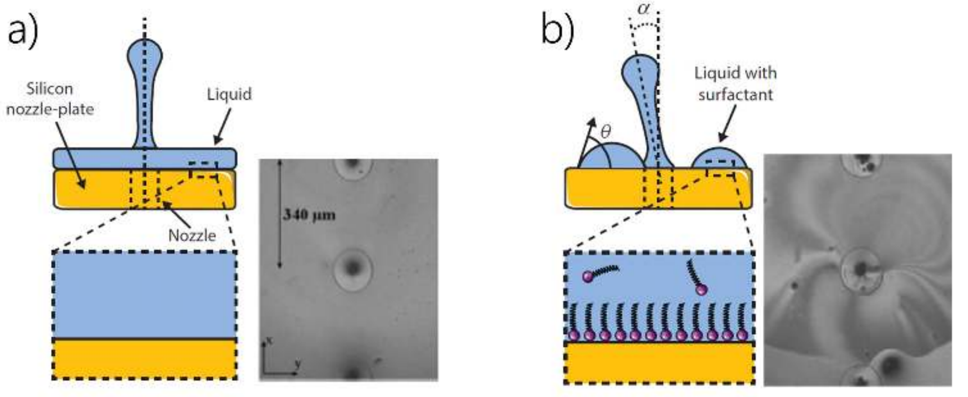

Figure 2: Schematic of the deposition of EHTS surfactant on the silicon substrate surface of the printhead, a) No surfactants, the jetting angle is normal to the nozzle plate, and b) Surfactants adsorb on the surface and create a monolayer that changes the wetting properties of the nozzle plate [6, 7].

A simplified atomistic model of the SiO2 surface was designed to determine its interactions with the siloxane-based surfactant and the various solvents employed. By using the Hansen theory [4, 5], we identified a set of solvents that are likely to prevent EHTS surfactant adsorption on the SiO2 surface. EHTS is miscible with these solvents, which is a necessary condition to prevent surfactants adsorption, otherwise, phase separation occurs, pushing the surfactant molecules to the SiO2-ink interface [4]. We found that polar solvents, such as acetone and triacetin, which are strongly attracted to the silicon oxide surface might form a shield that prevents siloxane-based surfactants adsorption. These selected solvents were tested experimentally using contact angle goniometry, ellipsometry and XPS, confirming the results obtained from the molecular dynamics simulations [6]. This study opens several prospects. For instance, it would be interesting to perform MD simulations to illustrate the behavior of siloxane surfactant-solvent mixtures in the vicinity of silicon oxide surface in order to obtain additional insights into the adsorption process.

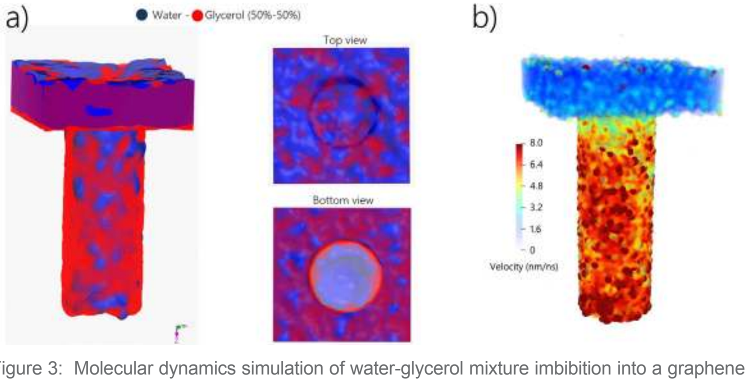

Figure 3: Molecular dynamics simulation of water-glycerol mixture imbibition into a graphene nanopore. a) Phase behaviour of water (blue)-glycerol (red) mixture during imbibition, and b) Velocity field of water-glycerol mixture. The graphene nanopore is transparent in the snapshots.

In our study, we also wanted to investigate the imbibition dynamics of miscible fluids into porous media, which is strongly affected by the fluid composition and the physicochemical properties of the pore. We used molecular dynamics simulations to investigate the influence of solvents and pore properties on the spontaneous ink imbibition. In Figure 3, we show the imbibition of a miscible mixture of water and glycerol into a graphene nanopore. Glycerol has high affinity to the graphene wall, creating a channel through which water goes into the pore. Simulations showed that glycerol enhances the imbibition if its percentage in the mixture is between 5% and 95% (w/w). For PTFE on the other hand, adding glycerol did not affect the imbibition because both water and glycerol have low affinity to the PTFE pore. Furthermore, MD enables investigating the influence of the dynamic contact angle and the slip-flow behavior on imbibition, by considering the mobility of the molecules near the pore wall. Studying the imbibition for pores with different oxidization degrees and chemical properties at the nanoscale provides future guidelines for the design of more optimized paper coatings for water-based inks as well as other applications related to micro- and nanofluidics. Looking forward, these molecular dynamics simulations could be adapted to investigate other similar systems, such as two-phased polymer melt flows and droplet dynamics in contact with superhydrophobic surfaces.

Acknowledgements

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Numerical modelling of ships navigating through mud

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Safe navigation in shallow water areas such as ports and waterways is ensured by setting a minimum distance between the ship's keel and the bottom, known as the under keel clearance (UKC). However, in such areas the bottom is often covered by a layer of mud. Under these circumstances, the UKC is no longer unequivocally determined and the prediction of the ship's controllability becomes more challenging. Selecting the solid bottom as reference would not ensure safe navigation because ships would frequently navigate through mud. On the other hand, selecting the water-mud interface as reference bottom would be too conservative since a contact between the ship's keel and the water-mud interface would hardly cause any damage to the ship.

An alternative approach for selecting the reference bottom is the so called "nautical bottom" approach. The nautical bottom is defined by PIANC [1] as the level where physical characteristics of the bottom reach a critical limit beyond which contact with a ship's keel causes either damage or unacceptable effects on controllability and manoeuvrability.

However, little is known about the link between ship's behaviour and mud characteristics, so in practice the nautical bottom is often defined as the level where mud reaches a critical density (e.g. 1200 kg/m3 for many harbours).

Model-scale experiments were carried out in the past to link mud properties and ship's manoeuvrability [2]. However, the large number of parameters to be addressed and the complex time-dependent non-Newtonian behaviour of mud make it very difficult both to obtain conclusive results and to apply model-scale results to full-scale. In this research we use CFD as the viable alternative to overcome these obstacles (Figure 1).

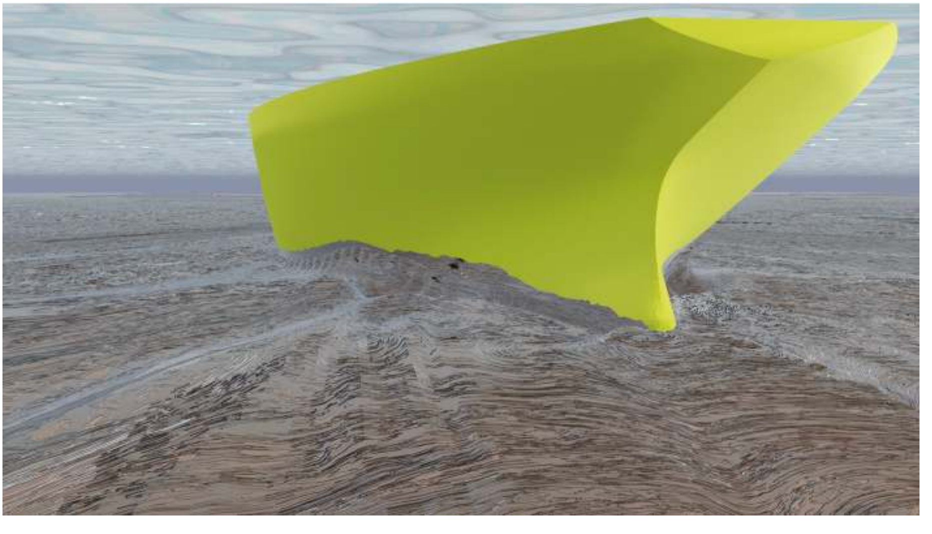


Figure 1: Rendering of a numerical simulation of a KVLCC2 hull navigating through a mud layer using ReFRESCO.

As already mentioned, mud is typically a non-Newtonian fluid. Rheological measurements showed that the Herschel-Bulkley model is suitable to describe the flow of mud (see e.g. [3,4]). Therefore the Herschel-Bulkley model has been implemented in a viscous-flow multiphase CFD code called ReFRESCO (www.refresco.org), developed by the Maritime Research Institute Netherlands (MARIN).

In practice, the Herschel-Bulkley model has been implemented as modification of the molecular viscosity, which becomes a function of the local shear rate. With zero or low deformation, structures at molecular level are formed and the fluid appears highly viscous. In contrast, when the fluid is stirred, the structure breaks down and viscosity decreases.

Before applying the code to simulate the flow around a ship, the code has been tested both to ensure that there are no coding mistakes and that the code can handle a flow dependent viscosity with strong gradients across the fluid domain.

Firstly, the code has been rigorously verified both for laminar single- and two-phase flows using the Method of Manufactured Solutions. Secondly, the code was tested on simple benchmark problems such as Poiseuille flow and the flow around a sphere (Figure 2). Comparison with results from literature revealed that the code is able to reproduce the drag force on objects in Herschel-Bulkley fluids.

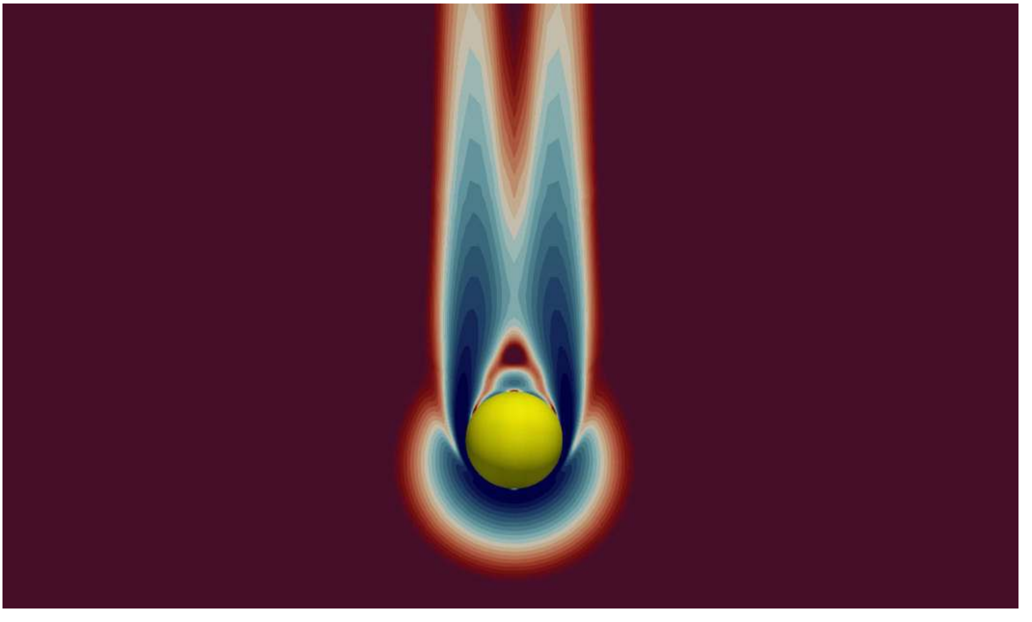


Figure 2: Contour diagram of viscosity for a sphere moving through a homogeneous Herschel-Bulkley fluid. Dark red and blue represent high and low viscosity, respectively. Flow is from bottom to top. The upstream Herschel-Bulkley fluid is undisturbed and presents large viscosity. When the fluid meets the sphere it is subjected to shear deformation which induces a structure break-down in the fluid. Viscosity is therefore lower near the sphere and in the wake region.

Current research is focussing on assessing how well standard RANS models such as k-omega and Spalar-Allmaras perform when applied to turbulent non-Newtonian flows. Preliminary simulations of the flow of Herschel-Bulkley fluids over a flat plate at high Reynolds number showed that different RANS models can produce completely different results. Current efforts are thus being made to study how standard RANS can be modified to account for non-Newtonian rheology.

Simultaneously, the CFD code is being applied to simulate the flow around a ship both in homogeneous mud (Figure 3) and in two-layer system with water on top and mud on the bottom (Figure 4). The goal of these simulation is to study the effects of mud rheology and UKC on the horizontal and vertical forces acting on the ship. Further research will be carried out to include such effects in a manoeuvring model.

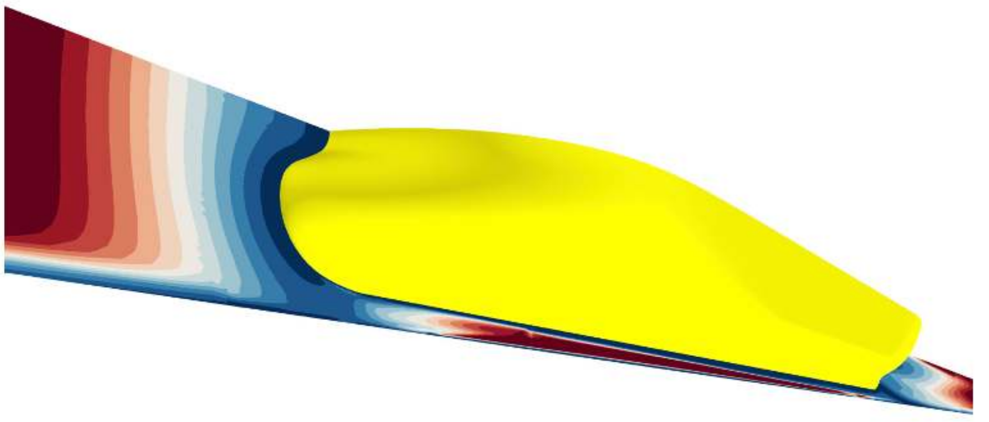


Figure 3: Contour diagram of viscosity for a ship moving through a homogeneous mud layer. As for the sphere in Figure 2, the high deformation induced by the presence of the ship tends to reduce the effective viscosity of mud. However, the presence of the solid boundary near the ship's bottom seems to induce the formation of a solid "plug" region, i.e. a region of nearly undeformed fluid with high viscosity.

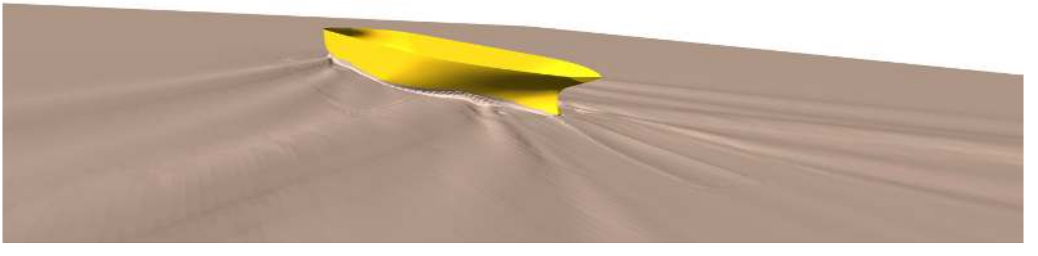
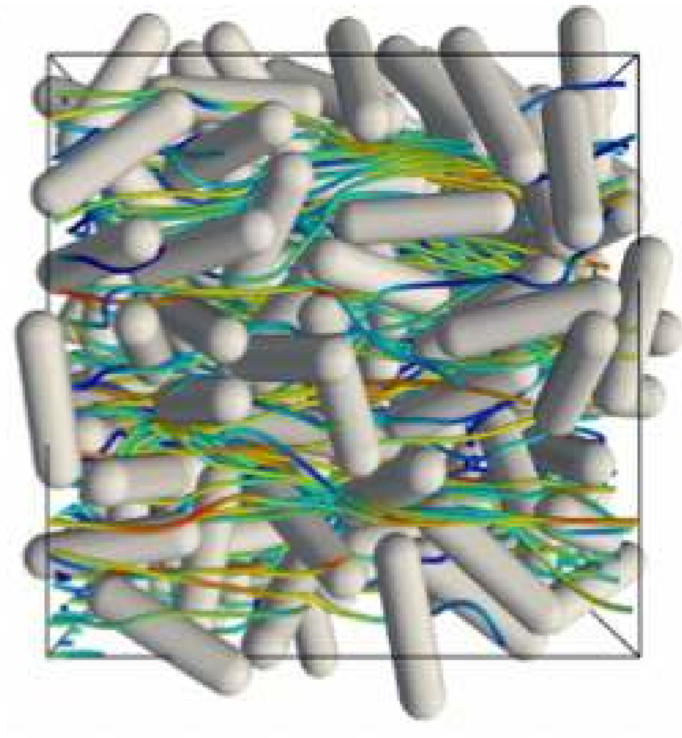


Figure 4: Wave pattern on the water-mud interface due to the passing of a ship with negative UKC. The wave pattern has a wide angle typical of shallow water navigation in subcritical regime

References

1. PIANC (2014) Report MarCom WG 121: Harbour Approach Channels - Design Guidelines, Tech. Rep. (2014).
2. Delefortrie, G., Vantorre, M. and Eloot, K. (2005) Modelling navigation in muddy areas through captive model tests. Journal of Marine Science and Technology 10, 188–202. doi:10.1007/s00773-005-0210-5.
3. Wurpts, R.W. 15 Years experience with fluid mud: Definition of the nautical bottom with rheological parameters. Terra et Aqua (2005).
4. Coussot,P. and Piau, J.M. (1994) On the behavior of fine mud suspensions. Rheologica Acta 33, 175–184. doi:10.1007/BF00437302.

RESEARCH



Research

The research programme of the JMBC has been ordered in three main research themes. The reason for this ordering is to present a combination of projects which have coherence, either in terms of physical models or in terms of mathematical methods.

The main themes are:

1. Complex dynamics of fluids
2. Complex structures of fluids
3. Mathematical and computational methods for fluid flow analysis

Fluid flows in the environment or in industrial applications are almost always characterised by some complexity. Frequently, it is this complexity that makes the flow an interesting topic of research. The first form of complex dynamics that comes to mind is turbulence, in contrast to laminar flow.
In particular aspects like laminar-turbulence transition, effects of thermal buoyancy, compressibility and rotation, density stratification and the interaction with chemical reactions are topics that are actively being studied by a number of the JMBC groups.

Also the presence of different phases, e.g. in the form of particles, bubbles or drops, may add to the complexity of flows. This class of flows, generally denoted as 'dispersed multi-phase flow' forms a strong focal point of research within the JMBC. Also, non-Newtonian and granular flows form a special class of complex flows that is being studied by a number of groups.

During the last two decades micro- and nanofluidics has become a topic that has attracted substantial attention, not in the least because of its important industrial and biomedical applications.

Advanced mathematical and computational techniques have become indispensable instruments for the description and understanding of complicated flow phenomena. The rapid increase of computational power has significantly stimulated the use of simulation techniques. In areas such as turbulent flow simulation, important progress has been made through refined modeling via Large-Eddy Simulation (LES), Direct Numerical Simulation (DNS) and stochastic methods. In other areas similar trends have become feasible, such as PDF modelling in combustion, and particle-based methods , like the Lattice-Boltzmann method.

Experimental techniques also play a crucial role in modern fluid-dynamics research. Many experimental methods are based on various forms of laser diagnostics, like e.g. PIV and PTV for flow measurements and CARS and LIF for measurements of temperatures and concentrations. Also, recording of ultrafast flow phenomena via high-speed camera techniques is playing an essential role in present-day fluid mechanics.

Within the JMBC, the various groups have built up extensive expertise on these aspects of experimental , theoretical and computational fluid dynamics. Within the framework of the network provided by the research school, stimulated by the contact groups, all groups benefit from this common reservoir of knowledge and expertise.

Review of progress in research projects

As usual in the scientific community, progress in the research projects is reported in the form of PhD theses, journal publications, contributions to conference proceedings, (chapters of) books, and in the form of presentations at conferences. The (refereed) scientific output of the JMBC groups is presented in the Annual Reports, which are downloadable from this website. In a number of industry-funded projects, some of the JMBC groups produce output in the form of special reports for industries and technological institutes. These reports are not included in the groups' output presented in the Annual Reports. For more information, please contact the relevant project leaders.

REPORTS OF INDIVIDUAL RESEARCH GROUPS

TU Delft

Mechanical Maritime and Material Engineering (3ME)

- Energy Technology (3ME-ET)
- Fluid Mechanics (3ME-FM)
- Multiphase Systems (3ME-MS)
- Maritime and Transport Technology (3ME-MTT)
- Complex Fluid Processing (3ME-CFP)

Chemical Engineering (CE)

- Transport Phenomena (CE-TP)
- Product and Process Engineering (CE-PPE)

Applied Mathematics (AM)

- Numerical Analysis (AM-NA)
- Mathematical Physics (AM-MP)

Applied Sciences (AS)

- Radiation Science and Technology (AS-RST)

Aerospace Engineering (AE)

Civil Engineering and Geosciences (CEG)

- Fluid Mechanics (CEG-FM)
- Geoscience and Remote Sensing (CEG-GRS)

Energy Technology

The Process & Energy department aims at enabling the energy transition by educating future (mechanical) engineers and by developing novel processes and equipment for the production and consumption of synthetic fuels, chemicals and materials. Its research covers fundamental aspects (thermodynamics and fluid dynamics) and technologies (energy technology and storage, process intensification and multiphase systems). Within the P&E department, the following sections actively participate in the J.M. Burgerscentrum:

Fluid mechanics

The Fluid Mechanics (FM) section at the Laboratory for Aero & Hydrodynamics performs research on the topics of turbulence and complex flows. The research is carried out at a fundamental level using modern experimental and numerical methods and has a clear connection to processes in an applied or industrial context. The research projects generally focus on six disciplines: turbulence, multiphase flow, combustion, microfluidics, biological flows, and fluid dynamics of sports. Experimental methods include particle image velocimetry and laser induced fluorescence; numerical methods include direct numerical simulation and large-eddy simulation.

Prof.dr.ir. J Westerweel

Prof.dr.DJEM Roekaerts

Prof.dr.ir. RAWM Henkes *(part-time)*

Prof.dr.ir. W van de Water *(part-time)*

Prof.dr.ir. G Ooms *(em)*

Energy technology

The Energy Technology section focuses its research and education efforts on the design and modeling of thermal energy conversion systems, with a focus on renewable energy. The section's research is performed with state-of-the-art numerical tools and experimental techniques.

Prof.dr.ir. BJ Boersma

PROJECT AIM

Eukaryotic cells interact with their surroundings via membranes and their sub-structures. Since these cells contain and are surrounded by fluids, the fluid mechanics involved during these interactions are critical in their behavior. In this study, we investigate the fluid-structure interactions of membrane-bound unicellular organisms, specifically the surface tension and fluid slip of lipid bilayers, and sensing and flow enhancement due to the fibrillar structures on flagella during locomotion.

PROGRESS

We developed the methodology for measuring drag of particles near membranes. We are currently writing a draft for our measurements on algal cells and their mutants lacking fibrillar ultrastructures.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Dols-Perez*, A., Marin*, V., Amador*, G. J., Kieffer, R., Tam, D., Aubin-Tam, M.E. (2019). Artificial cell membranes interfaced with optical tweezers: a versatile microfluidics platform for nanomanipulation and mechanical characterization. ACS Applied Materials & Interfaces, 11(37), 33620-33627. *Authors contributed equally.

PROJECT LEADERS

Dr. D.S.W. Tam, Prof. dr.ir. Jerry Westerweel

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Guillermo J. Amador

COOPERATIONS

Dr. Gert Jansen, MC Erasmus

FUNDED BY

Marie-Curie COFUND

FUNDED %

University	20 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	80 %
Scholarships	-

START OF THE PROJECT

2018

INFORMATION

Daniel Tam
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Flow manipulation to study coalescence of liquid/liquid mixture in a microfluidic device

Project leaders
Prof. dr. ir. Jerry Westerweel, Dr. Daniel Tam
Research theme
Complex dynamics of fluids
Participants
Teng Dong
Cooperations
-
Funded by
Shell Technology Centre Amsterdam
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
Information
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Project Aim

To develop a new generation of fluidic devices for the benefit of diagnosing the properties of single fluid or fluids mixture (water-crude oil mixtures).
The experimental research mainly forces on the breakup and coalescence dynamics of micro-droplets. In the project, the experimental conditions, including the fluid viscosity, the interfacial tension between fluids and microchannel size are varied to mimic the real conditions where the droplet coalescence takes place in the oil well.

Progress

Up to now the micro-fluidic device in which the drop coalescence is carried out has been designed and fabricated by soft lithographic technique. Currently commissioning work is conducted by partially improving the local structure of the micro-fluidic device and altering the fluid properties. For instance, the size of the micro-channel where the droplets are generated is being changed for better control of the drop size (50-200μm); various fluid pairs are being applied to study which factor (viscosity, interfacial tension, drop size etc.) dominates the coalescence behaviours in the device.

Dissertations

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Scientific Publications

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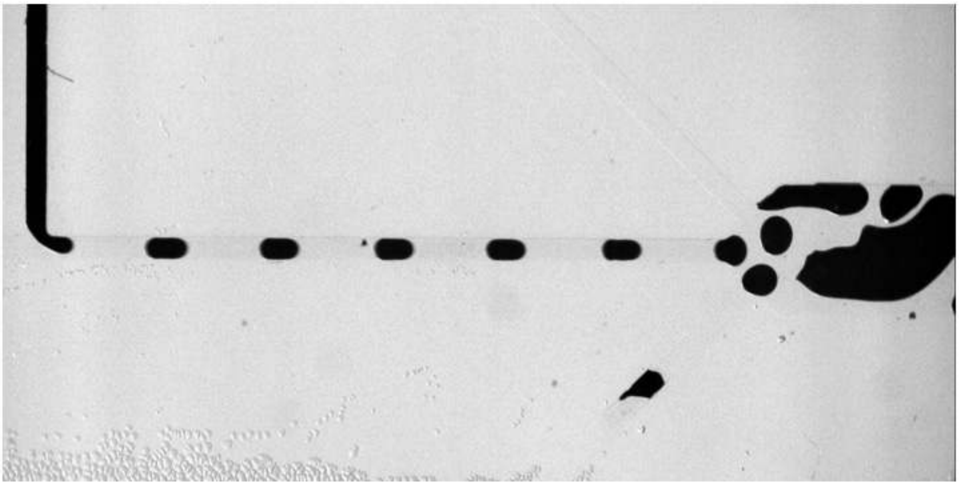
The droplet series in microfluidic device



Flow Manipulation to study coalescence of liquid/liquid mixture in a microfluidic device

Project Aim

To make a microfluidic device on which several diagnostic tools are designed to quickly screen various fluids and fluid mixtures. The study of coalescence and break up of droplets in fluid is of the primary focus. In this project, the fluid properties such as viscosity in different shear & strain rates and interfacial tension are combined on a single microfluidic device where it is easy to study oil-water bulk separation chemical conditions (pH and salinity).

Progress

Developed particle/droplet path optimization routine using non-linear optimization while minimizing flowrate and flowrate variation. Characterized the pressure pump to deliver the prescribed flowrate. Worked on finalizing a microfluidic chip for the research purpose using 3D printing. Currently, working on real-time particle tracking and active-feedback loop using model predictive control. Below is the figure of my current setup.

Dissertations

-

Scientific Publications

-

Project leaders

Prof. dr. ir. J. Westerweel, Dr. D. S. W. Tam

Research theme

Complex dynamics of fluids

Participants

Ankur Kislaya, Dr. Teng Dong

Cooperations

-

Funded by

Shell Technology Centre Amsterdam

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

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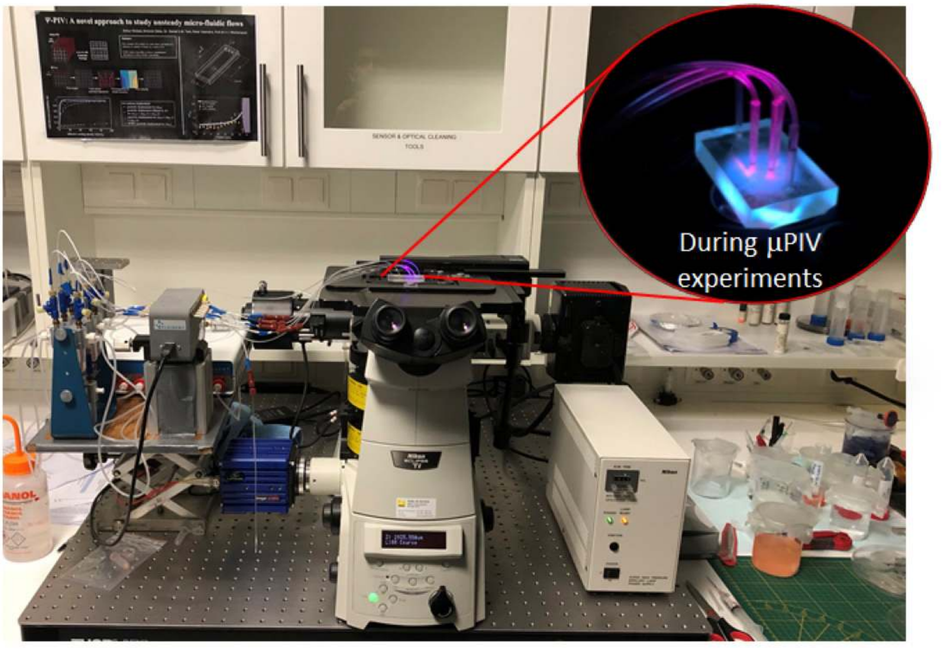

PROJECT LEADERS
RAWM Henkes, WP Breugem

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
MHW Hendrix

COOPERATIONS
-

FUNDED BY
Shell Global Solutions International BV

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2013

INFORMATION
R.A.W.M. Henkes
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R.A.W.M.Henkes@tudelft.nl

PROJECT AIM

A Pipeline Inspection Gauge (pig) is a cylindrical device that fits onshore or offshore pipelines for the transport of gas, oil, water in the oil and gas industry. The pig is launched at the inlet and received at the outlet. It is used for various purposes, such as water removal to prevent corrosion, removal of wax deposition along the pipe walls, removal of other solids, and inspection of the pipe wall condition. The use of a pig with an opening in the centre (a so-called by-pass pig) will allow some of the fast-moving gas to flow through the pig during the pigging operation. The aim of this PhD project is to develop an optimum way to control the speed of the by-pass pig.

PROGRESS

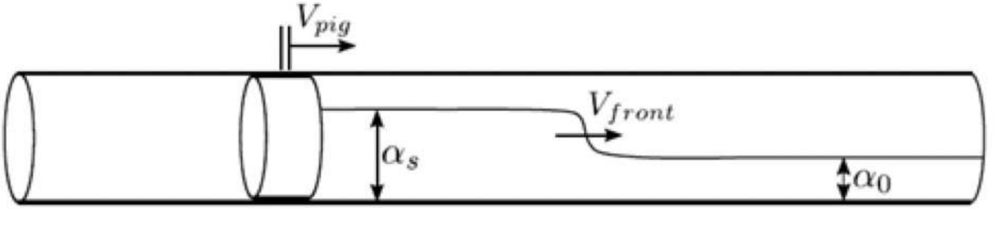
PhD student Maurice Hendrix has completed the computational model for the simulation of by-pass pigs. This is a one-dimensional model that solves the two-fluid equations for gas and liquid flow in a pipe. Test cases were carried out that demonstrate the good performance of the model. The writing of the PhD thesis was completed.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS

1. Hendrix, M.H.W., Sanderse, B., Breugem, Henkes, R.A.W.M. Simulation of slug propagation for by-pass pigging in two-phase stratified pipe flow, Proc. 19th Int. Conf. Multiphase Production Technology, pp. 317-330, 2019.

Simulation of a by-pass pig that is transported through a pipeline



Collective dynamics of biologically active fluids

Project Aim

Collective motion is ubiquitous in the natural world; from the flocking dynamics of animal groups to the micron-scale swarm behavior of single-cell organisms, and the metachronal coordination of beating cilia. On these small scales, hydrodynamic forces are dominant and determine the motion of micro swimmers, from single cells to swarms of millions of cells. This PhD project will investigate experimentally the interplay between hydrodynamics and cell motility.

Progress

- silicon wafers have been fabricated acting as a porous membrane where microorganisms will be trapped upon by means of a pressure gradient applied across the membrane in a custom designed microfluidic geometry that is able to operate under at least 1 bar of pressure.
- Initial prototypes of microfluidic geometries have been designed and fabricated and are ready to be tested in combination with the silicon wafers.
- literature review has been performed where specific key areas have been identified as possible routes of experimental endeavors.

Dissertations

-

Scientific Publications

-

Project leaders

Dr. D.S.W. Tam

Research theme

Complex dynamics of fluids

Participants

B. Mulder (PhD candidate),
D.S.W. Tam (PI), Jerry Westerweel (Promotor)

Cooperations

-

Funded by

ERC

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2019

Information

Daniel Tam
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Project leaders
Prof. dr. ir. Christian Poelma, Prof. dr. ir. Jerry Westerweel

Research theme
Complex dynamics of fluids

Participants
Saad Jahangir

Cooperations
City University London, Andritz Hydro, University of Rostock

Funded by
EU (Marie Sklodowska-Curie Actions)
TU Delft

Funded %

University	25 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	75 %
Scholarships	-

Start of the project
2015

Information
Saad Jahangir
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Project Aim
Investigation of cavitation in a converging-diverging nozzle using experimental techniques.

Progress
Partial cavitation regimes in an axisymmetric converging-diverging nozzle are investigated experimentally. This is done by bringing together four state of the art flow measurement modalities, based on Magnetic resonance velocimetry, X-ray computed tomography, Particle image velocimetry and High-speed shadowgraphy. Using such techniques, we are able to unveil the hidden flow features which affect the cavitation dynamics.

Dissertations
-

Scientific Publications
1. Jahangir, S., Wagner, E.C., Mudde, R.F., & Poelma, C. (2019). Void fraction measurements in partial cavitation regimes by X-ray computed tomography. International Journal of Multiphase Flow, 120, 103085.
2. Jahangir, S., Ghahramani, E., Neuhauser, M., Bourgeois, S., E Bensow, R., & Poelma, C. (2019). Experimental study of cavitation erosion around a surface mounted semi circular cylinder. 10th International Conference on Multiphase Flow10th International Cavitation Symposium, Rio de Janeiro, Brazil.

PROJECT AIM

The aim of the project is to investigate the liquid-liquid interfaces which are found in the core-annular flow of a very viscous oil and water, both experimentally and numerically. The focus is on the interaction between the interface waves and the turbulent water film layer along the pipe perimeter. Comparisons of the experimental and numerical results will give new insights into the properties of the flow, such as the levitation mechanisms and the drag experienced. Studying the influence of the fluid properties on the oil-core flow is another aim. That means that carrying out experiments with different values of the density difference, core-viscosity and interfacial tension. Furthermore, various turbulence models will be considered in the numerical calculations. These turbulence models need to be investigated further in order to legitimate their usage.

PROGRESS

Detailed CFD simulations were carried out with OpenFOAM for a horizontal pipe to determine the relation between the oil flow rate, the water cut, the pressure drop and the water holdup fraction. The structure of the turbulent water annulus was analysed. Furthermore a force balance was derived from the simulation results to understand the physics of the levitation mechanism that prevents the buoyancy working on the oil core to cause oil fouling of the upper wall, and instead maintains a stable core-annular flow. Also the pressure distribution along the wave oil-water interface was studied. A start was made with developing a proper experimental method to accurately obtain the interface structure and water annulus thickness from flow visualization experiments that will be carried out in the lab.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Van Duin, E., Henkes, R.A.W.M., Ooms, G., Influence of oil viscosity on oil-water core-annular flow through a horizontal pipe, Petroleum 5: 199-205, 2019.

PROJECT LEADERS

G. Ooms, R.A.W.M. Henkes, M. Pourquié

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Haoyu Li (aio)

COOPERATIONS

-

FUNDED BY

-

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	25 %
TNO	-
GTI	-
EU	-
Scholarships	75 %

START OF THE PROJECT

2018

INFORMATION

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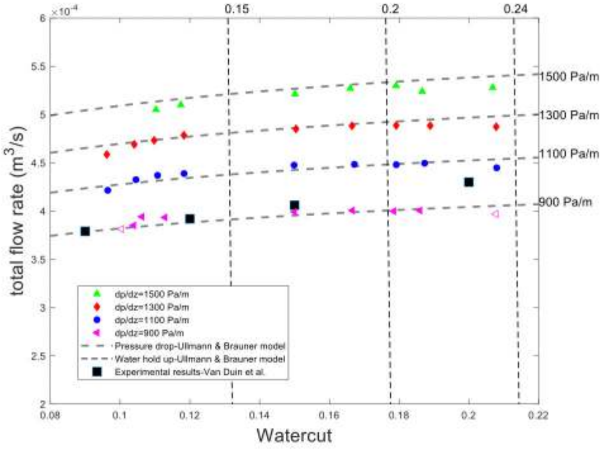

Relation between different flow patterns for horizontal core annular flow

PROJECT LEADERS
Daniel Tam
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Parviz Ghoddoosi Dehnavi, Abel-John Buchner, Junaid Mehmood, Bob Mulder
COOPERATIONS
Marie-Eve Aubin-Tam, Department of Bionanoscience TU Delft
FUNDED BY
ERC
FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

START OF THE PROJECT
2017
INFORMATION
Daniel Tam
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PROJECT AIM

Collective motion and synchronization arising within and between simple motile organisms occurs ubiquitously and is crucial to many biological and industrial processes. This project examines the origins of spontaneous coherent motion in three model biofluidic systems: (1) flagellar synchronisation of the alga C. Reinhardtii, (2) metachronal wave dynamics in the cilia of protist Paramecium, and (3) collective motion of swimming microorganisms in active suspensions. Using optical tweezers and a unique µ-Tomographic PTV, the 3D micro-scale motion of these microorganisms is tracked.

PROGRESS

- We developed a new velocimetry method based on optical tweezers in conjugate with a Kalman filter
- we performed direct numerical simulations (DNS) to confirm experimental results
- We developed a deep neural network (NN) model to do identification of the flagella kinematics from recorded image data.
- Long and short range interactions of Chlamydomonas reinhardtii with a solid boundary have been deduced.
- Via Markov Chain Monte Carlo simulation, the relevance of each type of interaction for overall population density distribution has been determined.
- The effect of viscoelasticity on the swimming speed and helical swimming trajectory of Chlamydomonas reinhardtii has been deduced within a 3D fluidic domain, building upon previous two-dimensional literature.
- 3D tracking data has been acquired for the hydrodynamic “puller” species C. Reinhardtii.
- µ-Tomographic PIV is used to characterize the background flow in the flow chambers.
- A tracking algorithm has been developed to study the pairwise interactions among C. Reinhardtii.

DISSERTATIONS

1. Anand Sudha (2019) Influence of viscoelasticity on the kinematics and hydrodynamic interactions of C.Reinhardtii. Masters Thesis, Technical University of Delft.

SCIENTIFIC PUBLICATIONS

1. Wei, D., Dehnavi, P. G., Aubin-Tam, M. E., & Tam, D. (2019). Is the zero Reynolds number approximation valid for ciliary flows?. Physical review letters, 122(12), 124502.
2. A-J. Buchner, K. Muller, D.S.W. Tam (2019) Hydrodynamic interactions of Chlamydomonas with a solid surface. 72nd Annual Meeting of the APS Division of Fluid Dynamics, Seattle, Washington, 23-26 November.
3. J. Mehmood, A-J. Buchner, K. Muller, D.S.W. Tam (2019) Experimental investigation of hydrodynamic interactions between motile green algae. 72nd Annual Meeting of the APS Division of Fluid Dynamics, Seattle, Washington, 23 - 26 November.
4. A-J. Buchner, K. Muller, D.S.W. Tam (2019) Hydrodynamics of Chlamydomonas reinhardtii near surfaces. JM Burgers Symposium, Lunteren, The Netherlands 21-22 May.
5. Mehmood, J., Buchner, A. J., Muller, K., & Tam, D. (2019). Experimental investigation of hydrodynamic interactions between motile green algae. Bulletin of the American Physical Society.

Project Aim

Fish schooling provides protection to individual fish against predators. The group dynamics of the school and interactions between fish are poorly understood. Previous empirical studies have been limited to tracking small schools (10-100 fish) in confined, 2D laboratory tanks. We investigate the 3D-dynamics of large schools of fish by using state-of-the- art 3D tracking methods recently developed in experimental fluid dynamics. In association with the Oceanium in the Rotterdam Zoo we will focus on a school of 1,000-3,000 fish in a 3,000 cubic meter tank, in which the school interacts with other fish and predators and track the inner dynamics of each fish in the school.

Progress

We have published a manuscript for the measurement technique. We are further improving a robust tracking method to track individual fish that is being extended from previous work. We have performed first processing of multiple data sets and preliminary data analysis.

Dissertations

-

Scientific Publications

1. K. Muller, J. Westerweel, Charlotte Hemelrijk, D.S.W. Tam Three-dimensional Tracking of Fish inside a Large School at the Rotterdam Zoo, Physics at Veldhoven, January 22-23 2019.
2. K. Muller, J. Westerweel, Charlotte Hemelrijk, D.S.W. Tam Kinematics of fish inside a Large School. Poster Presentation Bioday TUDelft. 02 July 2019.

Project leaders

Dr. D.S.W. Tam, Prof. dr.ir. Jerry Westerweel

Research theme

Complex dynamics of fluids

Participants

Ir. Koen Muller

Cooperations

Prof. Charlotte Hemelrijk, The Rotterdam Zoo

Funded by

NWO ALW open programma

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

Daniel Tam
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Sloshing of liquefied natural gas – variability and multiphase dynamics

Project leaders
Christian Poelma, Jerry Westerweel
Research theme
Complex dynamics of fluids
Participants
Mike van Meerkerk, Wout Cornel, Christian Poelma, Jerry Westerweel
Cooperations
-
Funded by
STW – Perspectief SLING
Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016
Information
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Wout Cornel
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Project Aim

Measure the instabilities on top of a single impact wave to relate the variability of the liquid free-surface to those of the impact pressure. The vapor-liquid free surface is dynamically mapped in 3D using a non-intrusive instantaneous measurement technique. Furthermore, impact experiments on controlled pre-aerated liquids are performed to study the bubble dynamics. The effect of liquid compressibility on the liquid loads during sloshing events is studied by varying the gas fraction and density ratio. The new MARIN multiphase wave lab enables us to study phase transitions during liquid impact.

Progress

Novel experimental techniques are developed for the complex measurements in the multiphase wave lab. Measurements with the three-dimensional, non-intrusive technique show the ability to measure small- and large-scale structures (e.g., ripples due to droplet impacts and hydraulic jumps) over a, relatively, large domain. The free surface measurement technique is used in a wave flume at the Environmental Fluid Mechanics Laboratory of the TU Delft. Also, velocities of pressure waves, propagating through aerated liquids, are measured by high-speed imaging of (micro)bubbles at different conditions. The pressure waves are generated in a well-controlled vertical tube set-up.

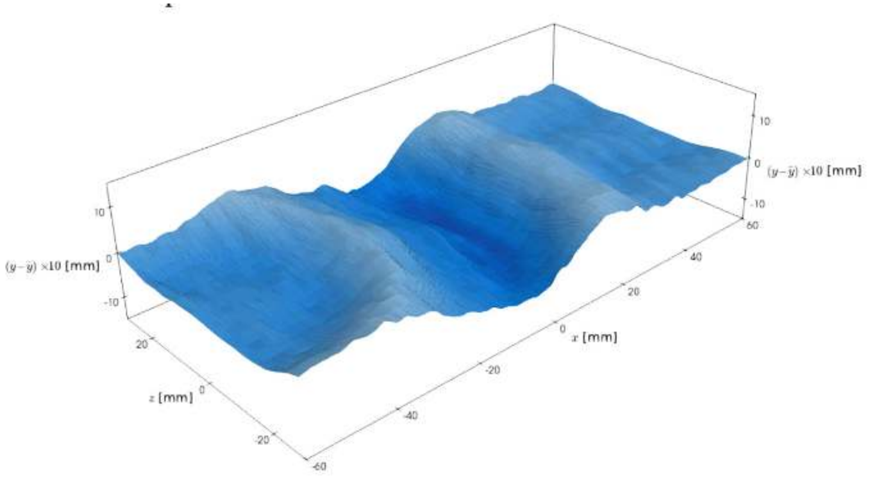
Dissertations

-

Scientific Publications

1. Schreier, S., Cornel W.A., Poelma, C., 2019. Dynamic response of sloshing pressure sensors. Proceedings of the 29th International Ocean and Polar Engineering Conference (ISOPE 2019).

Propagating free-surface ripples after droplet impact



Multiphase flow in an annulus

Project Aim

This project is a combined experimental/modeling study for the multiphase flow through an annulus. When gas reservoirs become older, the diameter of the production tubing becomes too large for the remaining gas production, and due to the resulting low gas velocities, liquids are no longer lifted with the gas, but instead they start to accumulate; this is the so-called liquid loading problem. To prevent this an additional pipe (so-called velocity string) is placed in the centre of the original pipe, which creates an annulus. As the cross sectional area of the annulus is smaller than the cross sectional area of the original pipe, the gas velocity will increase and liquid loading is prevented. The aim of the project is to create a design model, and validate this against lab experiments for the flow regime, pressure drop, and liquid accumulation.

Progress

The annulus flow facility was designed and built the Process & Energy lab. The vertical pipe-in-pipe has a length of 13 m, outer diameter of the inner pipe is 124 mm, and the inner diameter of the outer pipe is 100 mm. Air and water are the working fluids. Master student Pjotr Muis has designed and tested conductivity probes to measure the liquid film layer at both the inner and outer pipe walls. Post-doc Arnoud Greidanus has obtained measurement results for various values of the superficial air and water velocities in concentric and eccentric configurations for the annulus. The effect of inserting the liquid (at the inner or outer wall, or at both walls) was also studied. The results are described in a study report and in a master thesis.

Dissertations

-

Scientific Publications

-

Project leaders

R.A.W.M. Henkes, J. van 't Westende

Research theme

Complex structures of fluids

Participants

A. Greidanus (postdoc)

Cooperations

TNO

Funded by

TKI Project

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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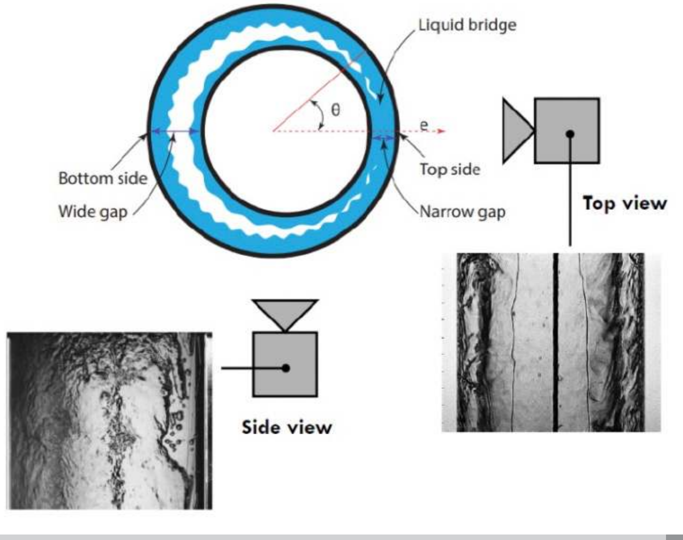
Flow visualization in the annulus



Experimental and numerical study of turbulent combustion in a lab-scale furnace

Project leaders
D.J.E.M. Roekaerts, M.J. Tummers
Research theme
Complex dynamics of fluids
Participants
Xu Huang, E.H. Van Veen
Cooperations
WS GmbH
Funded by
China Scholarship Council
Funded %

University	20 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	80 %

Start of the project
2013
Information
D.J.E.M. Roekaerts
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Project Aim

The objective of the project is to get better fundamental understanding of flameless combustion. Specifically, the project aims to determine the effects of fuel composition, operating conditions and nozzle geometry on the flameless combustion process in a lab-scale furnace. From visualization of the ignition and combustion characteristics in the furnace and measurements of the flue gas compositions, it will be determined under which conditions the flameless combustion regime can be established in the furnace. A set of selected flames will be studied in greater detail by measuring the velocity fields with PIV/LDA, the temperature with CARS and OH concentration with PLIF.

Progress

As follow up of the PhD study a numerical study was made using the experimental data of the Delft lab-scale furnace for validation. Two extensions of the Standard Eddy Dissipation Concept (EDC) models were analyzed: (1) the EDC model with modified fine structure constant value and (2) a New Extended EDC (NE-EDC) model, where model constants are space dependent and calculated directly based on local Reynolds number and Kolmogorov scale Damköhler number. It is concluded that the NE-EDC model accurately predicts flameless combustion.

Dissertations

-

Scientific Publications

1. N. Romero, H. Bao, X. Huang, K. Martin, E. Salazar, D.J.E.M. Roekaerts Simulation of Flameless Combustion in Delft Lab-Scale Furnace using EDC Model. In: Proceedings of the European Combustion Meeting, April 14-17, 2019, Lisbon, Portugal, 6 pages.

PROJECT AIM

This projects aims at providing computational fluid dynamics models for hydrothermal combustion, the combustion in supercritical water, i.e. at pressure higher than the critical pressure of water (22.1MPa). Appropriate thermodynamic, transport and flow models are developed and combined in simulations of representative reacting flow simulations and validated by experimental data.

PROGRESS

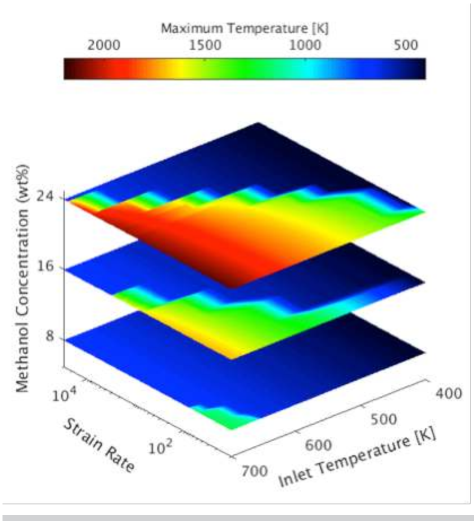
A comprehensive study has been conducted on methanol counterflow flames at hydrothermal conditions. Firstly, the effect of the real-fluid thermodynamic and transport properties on the flame structure are considered separately. The sensitivity of the flame to the mass diffusion coefficients was also investigated in order to conclude on a proper choice of the mass diffusion model. Secondly, the calculated results have been compared with the ETH Zurich experimental data, including flame temperature and the extinction limits. The turbulence scales in the ETH combustor were compared to the laminar counterflow flame thickness, to assess the turbulence chemistry interaction. Finally, an FGM (Flamelet Generated Manifold) table was generated from the combination of steady and unsteady counterflow flames calculations. The table has been used for simulations of the turbulent hydrothermal combustion in the ETH experimental setup. Results of a previous experimental study on supercritical water oxidation of the representative fuel species quinoline were also published.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Mengmeng Ren, Shuzhong Wang, Chuang Yang, Haitao Xu, Yang Guo, and Dirk Roekaerts. Supercritical water oxidation of quinoline with moderate preheat temperature and initial concentration. Fuel (2019) 236:1408-1414.
2. Mengmeng Ren, Shuzhong Wang and Dirk Roekaerts. Numerical study of the counterflow diffusion flames of methanol hydrothermal combustion: The real-fluid effects and flamelet analysis, J. Supercritical Fluids 152 (2019) 104552.



PROJECT LEADERS

D.J.E.M.Roekaerts

RESEARCH THEME

Complex structures of fluids

PARTICIPANTS

Shuzhong Wang, Xi'an Jiaotong University, China

COOPERATIONS

J.A. van Oijen, TU/e

FUNDED BY

China Scholarship Council

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT

2017

INFORMATION

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Coupled radiative and convective heat transfer in high temperature turbulent flows

Project leaders
R. Pecnik and D.J.E.M. Roekaerts
Research theme
Complex dynamics of fluids
Participants
Simone Silvestri
Cooperations
-
Funded by
TU Delft
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016
Information
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Project Aim

The presence of radiative heat transfer in turbulent flows can lead to Turbulence Radiation Interactions (TRI). Whereas influence of turbulence on radiative sources and flux has been studied widely the modification of the properties of the turbulent velocity and scalar fields by thermal radiative transport is less will studied. Our aim is to investigate the physical mechanism underlying TRI in its full generality in order to advance predictive models.

Progress

We implemented a fast Reciprocal Monte Carlo algorithm to accurately solve radiative heat transfer in turbulent flows of non-grey participating media that can be coupled to fully resolved turbulent flows, namely to Direct Numerical Simulation (DNS). The spectrally varying absorption coefficient is treated in a narrow-band fashion with a correlated-k distribution. The implementation is verified with analytical solutions and validated with results from literature and line-by-line Monte Carlo computations. The method is implemented on GPU with a thorough attention to memory transfer and computational efficiency.

Using this method we have studied the characterization of Turbulence Radiation Interactions (TRI) of a non-grey absorbing-emitting participating media in a turbulent channel flow bounded by two isothermal hot and cold walls. Building on the characterization of TRI, we have developed a closure model to predict heat transfer in high temperature, participating turbulent flows. It can be applied to most standard models available in literature, such as the one equation turbulent heat transfer transport model or the two equation $\overline{\theta'^2} - \varepsilon_\theta$ eddy diffusivity model leading to improved predictions.

Additionally, the Monte Carlo solver has been improved to fit higher duty turbulent simulations: (1) the bi-cubic spline interpolation for adaptive mesh coarsening has been switched to a pure texture memory “free” tri-linear interpolation; (2) the parallelization scheme has been modified to allow a larger use of GPU nodes; (3) the random number generator has been dropped in favor of a quasi-random Sobol sequence generator (implying that the MC used is now not a pure Monte Carlo scheme but a Quasi Monte Carlo scheme, QMC).

Dissertations

-

Scientific Publications

1. Silvestri, S; Roekaerts, DJEM and Pecnik, R. Assessing turbulence-radiation interactions in turbulent flows of non-gray media. Journal of Quantitative Spectroscopy and Radiative Heat Transfer, 233: 134-148, 2019. http://dx.doi.org/10.1016/j.jqsrt.2019.05.018.
2. Simone Silvestri and Dirk Roekaerts. Mixed Convection and Radiation Heat Transfer in Porous Media for Solar Thermal Applications. In book: Convective Heat Transfer in Porous Media, Yasser Mahmoudi, Kamel Hooman, Kambiz Vafai (editors), CRC Press, November, 20, 2019, Chapter 12, 40 pages, ISBN 9780367030803 - CAT# K405479. DOI: 10.1201/9780429020261-12.

On the scalability of dust explosion severity: A study of selected aspects

Project Aim

Despite tremendous research efforts in the last 30 years, dust explosions continue to pose a serious threat to the process industries. The aim of this project is to investigate the scalability of dust explosion severity. Explosion tests are carried out in 20-l and 1-m3 closed vessels using current international standards procedures. Alternative ways to investigate the combustion clouds are explored.

Progress

We have formulated a simplified theory of flame propagation in pipes, based on relative area for combustion heat release and wall heat loss. We have reviewed dust explosion experiments performed in industrial-scale pipes smaller or equal to 4 inches (or 100 mm) in diameter. The findings of the experiments have been interpreted in the light of the simplified theory. Our study reveals that dust explosion propagation has been consistently observed in pipes with a diameter as small as one inch. While the likelihood of flame propagation seems to decrease with pipe diameter and other “chemical” and engineering” factors, it remains a realistic scenario and therefore should be addressed in the design and operation of powder handling systems. In 2019 these results were published. In addition, articles on scaling of metal dust deflagrations and on venting of metal dust deflagrations were submitted to the Journal of Loss Prevention in the Process Industries.

Dissertations

-

Scientific Publications

1. Taveau, J., Lemkowitz, S., Hochgreb, S., Roekaerts, D. Dust explosion propagation in small diameter pipes. Process Safety Progress, Volume 38, Issue 3, e12033.
2. Taveau, J., Lemkowitz, S., Hochgreb, S., Roekaerts, D. Metal dusts explosion hazards and protection. 16th International Symposium on Loss Prevention and Safety Promotion in the Process Industries, Delft, June 16-19, 2019, The Netherlands.
3. Lemkowitz, S., Taveau, J. A model structuring dust, mist, gas/vapour and hybrid explosion behavior: the Chemical-Engineering Model. 16th International Symposium on Loss Prevention and Safety Promotion in the Process Industries, June 16-19, 2019, Delft, The Netherlands.

Project leaders

D.J.E.M. Roekaerts

Research theme

Complex dynamics of fluids

Participants

Jérôme Taveau

Cooperations

S.M. Lemkowitz (TU Delft ChemE)
S. Hochgreb (University Cambridge)

Funded by

Fike Corporation

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2014

Information

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Multiphase systems

Prof.dr.ir. C Poelma

The Multiphase Systems section, housed in the Laboratory for Aero & Hydrodynamics, studies fundamental and applied aspects of multiphase flows, inspired by industrial applications. Research is performed using state-of-the-art numerical tools (DNS, immersed boundary methods) and experimental techniques (e.g. MRI, X-ray, ultrasound imaging and particle image velocimetry). The current focus is on dense suspensions, in particular on its effects on e.g. the transition to turbulence.

Controlled jet formation and break-up of non-Newtonian jets for prilling applications

Project Aim

The aim is to investigate the break up of straight and spiralling jets in regards to the prilling process, and find ways to control drop size which is essential to produce a good quality prill (e.g. fertilizers). The multi-faceted approach contains: 1) rheological characterization of working materials, 2) simulating non-Newtonian filament thinning to investigate the formation of satellite drops and 3) experiments to validate theoretical and numerical predictions.

Progress

In the first year of the project, a slender jet model was programmed, which is capable of reproducing the thinning of a straight jet prior to break up (left figure). A separate model has been developed to predict the trajectory of a spiralling jet (right figure). A first experimental setup has been built and first experiments conducted. In addition, rheological tests of working fluids to be used in experiments are on-going.

Dissertations

-

Scientific Publications

-

Project leaders

Dr. Ir. Wim-Paul Breugem

Dr. Ir. Burak Eral

Research theme

Complex dynamics of fluids

Participants

Yavuz Emre Kamis

Cooperations

-

Funded by

Kreber BV

Funded %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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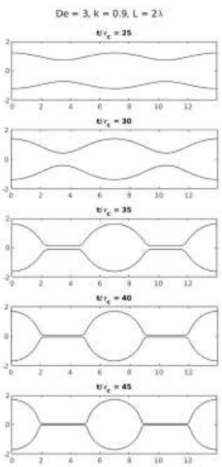

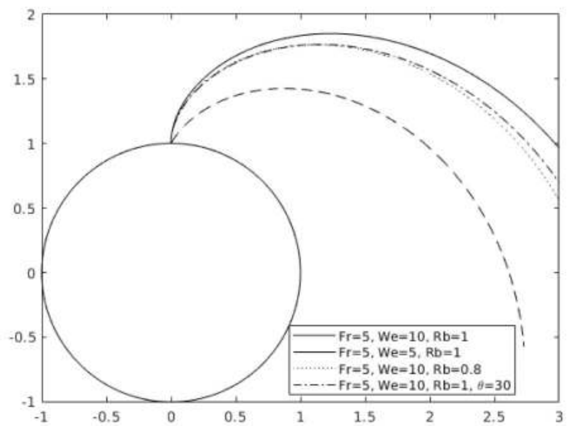

Project leaders
Prof. dr. ir. C.Poelma
Research theme
Complex dynamics of fluids
Participants
Christian Poelma, Willian Hogendoorn, Amitosh Dash, Sudarshan Sridharan, Bidhan Chandra, Udhav Gawandalkar
Cooperations
Transport Phenomena, TU Delft
Strömungsmechanik, The University of Rostock
Funded by
ERC
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2017
Information
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Project Aim

The aim of this project is to experimentally investigate the dynamics of opaque multiphase flows with different imaging modalities, such as ultrasound, magnetic resonance imaging, X-rays and advanced optical techniques. When combined, these modalities will be used to provide insight in three benchmark flows: (1) a turbulent flow with heavy particles, (2) a laminar flow with relatively large particles and (3) a laminar flow with small particles showing non-Newtonian behavior. These three flows represent archetypical flows from nature and industry, each pertaining to particular open questions in the field of fluid mechanics.

Progress

In 2019, experiments with Ultrasound Imaging Velocimetry (UIV) in pipe flow are continued, where the influence of particles on laminar flow is studied. In addition, high frame rate UIV is used to capture fast (e.g. higher Reynolds number) flows. Next to this, experiments with particles in a Taylor-Couette flow were performed. UIV and flow visualization were performed simultaneously to study global and local features of the flow.

Dissertations

-

Scientific Publications

1. Dash, Amitosh, et al. “Simultaneous Ultrasound Imaging Velocimetry (UIV) and Flow Visualization in Taylor-Couette flows: Validation of UIV in single-phase flows.” Proceedings of the 13th International Symposium on Particle Image Velocimetry. Universitat der Bundeswehr Munchen, 2019.
2. Hogendoorn, W. J., and Christian Poelma. “High frame rate flow measurement using Ultrasound Imaging Velocimetry.” Proceedings of the 13th International Symposium on Particle Image Velocimetry. Universitat der Bundeswehr Munchen, 2019.

Rheology of dense suspensions for 3D-printing of energetic materials

Project Aim

The aim of this project is to get a better understanding of the physical phenomena at the particle scale that are responsible for the non-Newtonian macroscopic rheology of a dense suspension in the nozzle of a 3D printer. Accurate modelling of the suspension rheology is needed for optimizing the printing process by tuning the process conditions and material properties. We will study the macroscopic rheology in relation to the suspension microstructure by means of fully-resolved simulations (DNS) of the suspension flow. In addition, experiments will be conducted to measure the rheological suspension behavior.

Progress

The project started in March of 2019. The first months have been used to study the literature and the existing DNS code for dense suspension flows. Next, the DNS code has been extended with a ghost-cell method for simulating the 3D-printing nozzle geometry. Also, a basic non-Newtonian fluid model has been implemented to study effects of non-Newtonian behavior of the suspension carrier fluid. Finally, exploratory experiments have been performed to assess the rheology of suspensions considered in our study.

Dissertations

-

Scientific Publications

-

Project leaders

dr. ir. WP Breugem, prof. dr. AEDM van der Heijden

Research theme

Complex dynamics of fluids

Participants

ir. W Peerbooms, dr. ir. WP Breugem, prof. dr. AEDM van der Heijden

Cooperations

-

Funded by

TNO

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	100 %
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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Modelling of turbulent hyperconcentrtated sediment transport in horizontal pipes

Project leaders
Wim-Paul Breugem
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Tariq Shajahan
Cooperations
-
Funded by
NWO
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
Information
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Project Aim

In dredging applications, deep sea mining and land reclamation projects typically large amounts of sediments are transported through pipes in the form of hyper-concentrated sediment-water mixtures or slurry. Depending on the flow and sediment concentrations, the different transport regimes can be identified. The goal of this project is to study this transport phenomenon by the development of accurate physics based prediction tools for the wide range of operating conditions in practice. To this purpose fully-resolved numerical simulations will be performed of turbulent sediment transport through a small scale horizontal pipe.

Progress

The initial part of this work has been focused on studying sedimentation. The results of the study were presented as a poster at the conference: Physics@Veldhoven 2019, a presentation to a national audience at the Burgers Symposium 2019 (awarded the young scientist award for the presentation) and a presentation to an international audience at ERCOFTAC DLES12 2019 Madrid. The results were submitted as journal publication to the journal ‘Flow, Turbulence and Combustion’ (currently under review). The subsequent work was focused on the study of sediment transport and the results were presented at the conference Physics@Veldhoven 2020.

Dissertations

-

Scientific Publications

-

Prof.dr.ir. J Westerweel

Prof.dr.ir. C van Rhee

Prof.dr.ir. TJC van Terwisga

SEAKEEPING AND MANOEUVRING - PROF. J WESTERWEEL

Research of the Chair of Ship motions and manoeuvring is at present focused on the following areas: 1. Non-linear behaviour of fast craft in waves; 2. Extreme wave events in relation to stationary floating structures; 3. Very Large Floating Structures at sea; 4. Prediction of manoeuvring forces based on CFD methods.

High speed ships traveling in waves experience large amplitude motions which can lead to strong non-linear effects in the loads on the hull girder. These non-linear effects are due partly to the large changes in the wetted part of the hull in waves and partly due to non-linear pressure effects. Extreme wave events (breaking waves etc.) can lead to high impact loads on stationary floating structures , e.g. bow loads on Floating Production and Storage vessels for the oil industry. Hydrodynamic analysis of such behaviour is now moving towards application of CFD methods to determine the local flow at the bow. In order to simulate open sea conditions, the CFD region will be connected to an outer region which will be described by potential flow methods. This will allow waves to enter the region local to the bow and reflected waves to travel away from the bow thus minimizing reflections from the CFD boundary. Very Large Floating Structures are being investigated world-wide for various applications such as airports and for floating cities. This research is aimed at developing a novel concept of a large floating structure based on the use of air cushions to support the structure and distribute the wave loads thus optimizing both motion behaviour and structural costs. Manoeuvring models for ships have traditionally been based on equations of motions using experimentally determined drag, mass and lift coefficients. This research aims to investigate the applicability of CFD methods in determining the hydrodynamic coefficients for existing mathematical models. Use is made of a RANS code developed by MARIN and modified to accomodate oblique flow.

PROPULSION AND RESISTANCE - PROF. T VAN TERWISGA (PART TIME)

Research at the Chair of propulsion and resistance is focussed on three areas: 1. Cavitating Flows; 2. Ship-Propeller-Engine system in Service Conditions; 3. Drag reduction through air lubrication.

Cavitation remains an important field of investigation in Marine Technology. Almost all propellers in operation show cavitation in some but mostly in all working conditions. Cavitation often is an important source of vibrations and sometimes even cavitation erosion. Cavitation on propellers should therefore be controlled as much as possible in both the design and during operations. As cavitation often appears to be extremely unsteady and unstable, this poses a continuing challenge to designers and research groups. The more so because an acceptable cavitation control and a high propulsive efficiency are often conflicting requirements. The Delft Cavitation Tunnel has proven to be a strategic tool for enhancing our understanding of the physics and engineering characteristics. There are currently two PhD projects addressing this issued: One on unsteady sheet cavitation (E.J. Foeth) and another on propeller radiated pressure fluctuations (E.v.Wijngaarden). Ship-Propeller-Engine system analysis and simulation is important to reduce e.g. radiated noise from the propeller and to reduce wear of the propulsion system during its operation. To this end, a close cooperation exists with the section of Marine Engineering. There is currently a PhD project concerned with the development of a model podded propeller for testing in operational conditions (G. Oosterhuis), and a recent PhD project on improved propulsion control for Naval Vessels (A.Vrijdag). Initiatives in the third area on Drag reduction through air lubrication are currently under way.

Project Aim

Hydrofoil craft provide fast and economical transport, in particular in dense urban areas such as the Netherlands. However, the challenge is to maintain comfortable and safe navigation, especially in presence of waves, while maximising robustness and minimising capital and maintenance cost. To address these issues, we investigate in this project novel approaches for hydrofoil lift control and height control, where we use concepts from flight-dynamics to study unsteady motions, such as the phugoid mode. For lift control we consider proven aeronautical mechanisms, in addition to novel concepts specific to hydrofoils.

Progress

The stability envelope and control design mechanisms are explored with a state-space model (SSM), with input from numerical and experimental data. Numerical simulations (PhD-2) focus on potential flow codes in combination with CFD, using finite-element methods and divergence-conforming isogeometric analysis (IGA). Special attention is on interaction of the hydrofoil flow with the free-surface in combination with waves, using turbulence modelling with residual-based variational multi-scale physics and a level-set approach to describe the free-surface. Surface tension is included to accurately predict air injection, ventilation and broaching. Experimental methods (PhD-1) will be used to provide input to the state-space model, and also validate the numerical results, employing a combination of flow visualization for the overall flow, and stereoscopic particle image velocimetry (PIV) for detailed quantitative whole-field measurements of the flow. Experiments are carried out at TU Delft in the towing tank and newly commissioned multiphase flow tunnel. Furthermore, reduced-order models (ROMs) will be explored to obtain fast and accurate means to exploit the numerical results for utilisation towards the design of new generation hydrofoil craft. A post- doc will work with our industrial and technological partners to implement this in a demonstrator. We expect that this research will lead to new and validated hydrofoil concepts with active lift and height control.

Dissertations

-

Scientific Publications

-

Project leaders

dr. ir. I.Akkerman, dr. ing. S.Schreier

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

-

Cooperations

-

Funded by

NWO, Stichting Bijboegfonds, Damen Shipyards, Flying Fish Mobility, MARIN

Funded %

University	-
FOM	-
STW	-
NWO Other	80 %
Industry	16 %
TNO	-
GTI	4 %
EU	-
Scholarships	-

Start of the project

2019

Information

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PROJECT LEADERS
Dr. ir. I. Akkerman
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
dr. ing. S.Schreier, dr. G. Jacobi MSc
COOPERATIONS
Damen Shipyards
FUNDED BY
Stichting Bijboegfonds, TKI
FUNDED %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019
INFORMATION
Ido Akkerman
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PROJECT AIM

Hydrofoil craft can provide fast and comfortable transportation of people. By exploiting existing waterways ("Blauwe Route") at a relatively high speed hydrofoil craft fill a unique niche between standard ships (slow), landbased transport such as cars (can not use Blauwe Route") and air-transport such as helicopters(expensive). This transportation niche is particular interesting in dense urban areas such as the Netherlands, but is also relevant in offshore crew supply and naval operations. Apart from the advantages provided by hydrofoil craft there are also some issues that limit its current use. The challenge is to maintain comfortable and safe navigation, especially in presence of waves, in a cost effective manner. Current solutions are to complex and fragile leading to high capital and maintenance costs. To address this issue, and make hydrofoil craft economically feasible, the TU Delft ship-hydrodynamics lab has started a research line investigating alternative hydrofoil craft and lift control concepts. The latter, alternative lift control, is the topic of "Lift control for hydrofoil craft" project.

PROGRESS

A top-level concept has been selected. The platform will have full-rake control of the foils allowing the entire foil to be replaced with alternative designs. Below is an artist impression of the platform.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Computational methods for moving and deforming objects in extreme waves

Project Aim

The aim of the project is extending the existing absorbing boundary conditions only for waves to account for the effect of currents. With this boundary condition implemented in the CFD method ComFLOW, the hydrodynamic studies of travelling ships in waves can be investigated more efficiently.

Progress

The performance of the extended boundary conditions is verified through a series of wave-current simulations, by comparing the numerical reflection coefficients with theory. Both following and opposing currents are considered. The extended boundary conditions can also find its application in the field of ships at a forward in waves. The heave and pitch motions of a Wigley hull moving in regular and irregular waves are simulated with our boundary conditions applied at the inflow and outflow boundaries of the domain. The numerical results are compared with the experimental data to validate the boundary conditions. Based on the validated waves and ship motions, the green water phenomenon on the moving object in extreme waves is demonstrated.

Dissertations

-

Scientific Publications

-

Project leaders

Dr. ir. Peter R. Wellens
(promotor Rene Huijsmans and Arthur Veldman)

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Peter van der Plas, Henk Seubers, Matin Hosseini

Cooperations

Marin, Force, Deltares, GustoMSC, Damen Shipyards, DNV

Funded by

China Scholarship Council

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project

2014

Information

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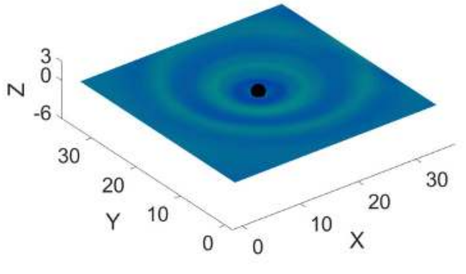

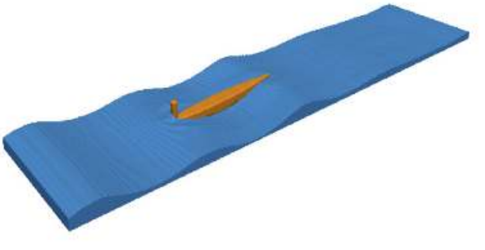

Wave scattering of very flexible floating structures

Project leaders
Dr.-Ing. Sebastian Schreier
Research theme
Complex dynamics of fluids
Participants
M. Zhang (TU Delft)
Cooperations
-
Funded by
CSC
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project
2018
Information
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Project Aim

The aim of the project is to determine the wave scattering properties of Very Flexible Floating Structures, which are able to follow the wave surface elevation almost perfectly due to their low structural bending stiffness.

Progress

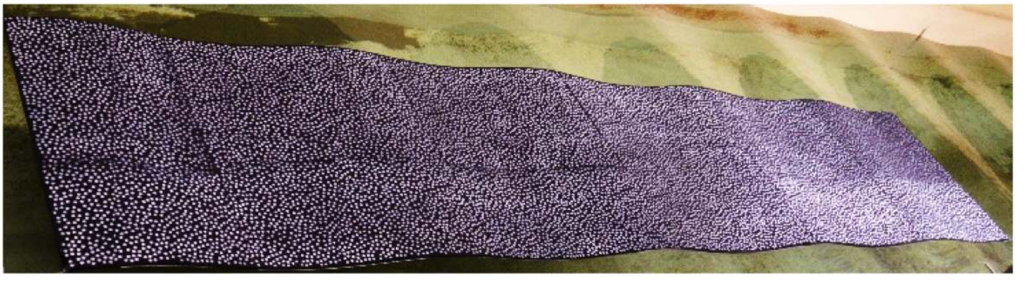
Based on a literature review on hydroelasticity a suitable theoretical approach to model structural response and influence on the surrounding wave of VFFS was selected. In a preliminary experiment in the towing tank, Digital Image Correlation (DIC) measurements of a VFFS provided a first set of reference data.

Dissertations

-

Scientific Publications

-



Model of VFFS with speckle pattern for DIC measurements in the towing tank of TU Delft. Wave propagating from right to left

PROJECT AIM

This research is to develop the computational algorithm to reduce the expence of the numerical computation. In the partitioned approach of computational hydroelastics, fluid and structure are computed in each domain respectively. Then two solutions are coupled through the interface, where sub-iterations are necessary. The sub-iterations are usually expensive. In this research, we propose to include few dominating eigenmodes of the structure in the Poisson equation that solves fluid pressures, which is termed as the interaction law. The iteration is reduced because the structure information is predicted and included in the fluid domain computation.

PROGRESS

A fluid-structure interaction speed-up algorithm is proposed, see figure 1. Only the dominating, not all, structure information is modeled as added mass effect and included in the Poisson operator.

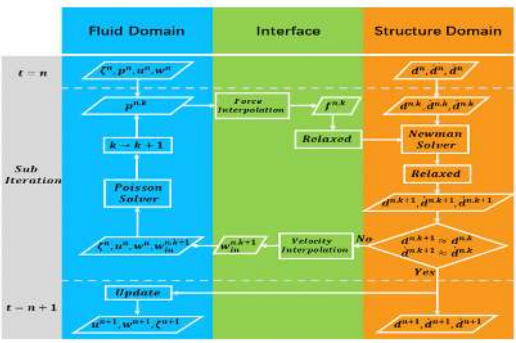
DISSERTATIONS

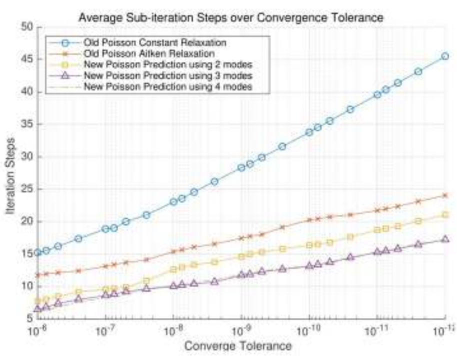
-

SCIENTIFIC PUBLICATIONS

-

The numerical test of rubber-barge in waves shows that the interaction law with only three eigenmodes, i.e., heave, pitch and first order bending can reduce the coupling error by one or two magnitudes in the first sub-iteration. Therefore, the necessary number of sub-step is reduced, see figure 2.





PROJECT LEADERS

Dr. Ir. P.R. Wellens

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Ir. Pengpeng Xu

COOPERATIONS

-

FUNDED BY

China Scholarship Council and Delft University of Technology

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT

2017

INFORMATION

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PROJECT LEADERS
Dr. Ir. P.R. Wellens
(promotor Prof. Dr. Ir. J.J. Hopman

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Ir. M. van der Eijk

COOPERATIONS
-

FUNDED BY
Delft University of Technology

FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019

INFORMATION
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PROJECT AIM

Investigating the effect of aerated water on the time course of the impact pressure caused by free surface events, i.e. freely moving geometries like ships encountering green water or slamming. This will be done by a self-developed novel numerical method. The method needs to be capable to resolve air entrainment during an impact.

PROGRESS

The relevance of compressibility of air and surface tension during a wave impact in which an air pocket gets entrapped is investigated. At model scale in the 2D dam-break simulation, the effect of compression wave in the air dominates the dynamics. The compression waves and subsequent pressure oscillations were in the same order of magnitude as the initial impact. The inconsistent mass-momentum coupling leading to unphysical free surface distortions as in the first figure is solved. A flux-corrected scheme is used for the density to ensure kinetic energy conservation in high density flows.

Furthermore, rigid-body motions are implemented using the same algorithms as for the free-surface flow for the displacement.

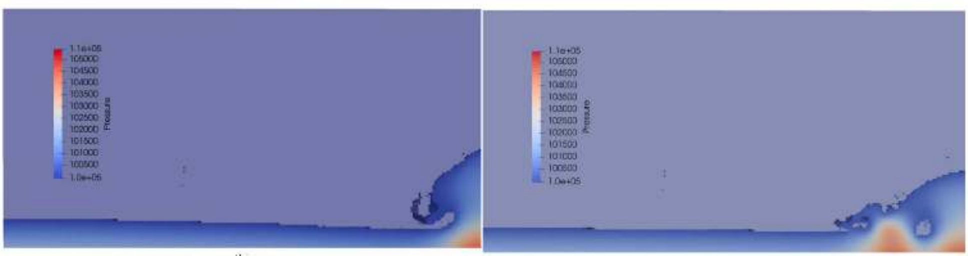
DISSERTATIONS

-

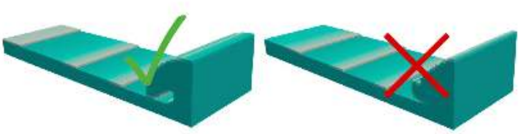
SCIENTIFIC PUBLICATIONS

-

Pressure during entrapment of air pocket by a dam-break



Consistent versus non consistent coupling of mass and momentum



Prof.dr.ir. JT Padding

Complex fluid processing research deals with the complex interaction between transport processes and the transformation of gases and liquids in industrial production processes.

Johan Padding's focus is on understanding and predicting the behaviour of multiphase and complex fluid flows on the mesoscale (0.1 μm – mm). According to Padding, most process limitations occur on this scale because a 'conflict' arises between transport mechanisms (flow, diffusion, migration and mixing) and transformations (reactions, aggregation and phase change). This is a problem when converting biomass into biofuel, for example, and with the electrocatalytic conversion of CO2. In addition to being full professor, Johan Padding also plays an active part in the TU Delft Process Technology Institute (DPTI) and the TU Delft consortium e-Refinery, which focuses on the sustainable production of chemicals and fuels.

Burak Eral focuses on understanding the fundamental principles governing out-of-equilibrium manufacturing/separation processes involving flow, phase transitions (particularly, crystallization) and complex fluids. Leveraging this fundamental understanding, he designs sustainable processes and materials transforming fine chemicals, pharmaceutical, energy and bioprocess/biomedical industries, combining experimental techniques (microfluidics, microscopy, rheology and scattering) and theoretical approaches (analytical/simulation techniques).

Remco Hartkamp focuses on interfacial fluid phenomena, in particular exploring solid-fluid interfaces down to the molecular scale to improve understanding of nanofluidic transport, electrochemical processes and energy storage.

Multiscale modelling of dense gas-fluidized flows of non-spherical particles

Project Aim

The aim of this project is to predict the hydrodynamics of dense fluidized systems containing elongated particles, using a multiscale modelling approach and experiments. The multiscale approach consists of: 1) fully resolved simulations (DNS) to obtain closures for translational and rotational drag for dense particle systems, 2) discrete particle model (CFD-DEM) simulations to validate the drag closures with matching experiments (PIV, MPT and XRT) and to obtain statistics of the particle stress tensor due to inter-particle collisions, 3) a novel Lagrangian method based on the particle stress tensor (CFD-CPM) for large scale simulations.

Progress

Closures for hydrodynamic forces on assemblies of axisymmetric, non-spherical particles are proposed (Figure a). CFD-DEM has been developed for rod shape particles using closures for drag, lift and torque obtained from DNS. CFD-DEM has been used to study non-spherical fluidization behavior in detail (Figure b). Validation of CFD-DEM has been performed by comparison with PIV and XRT experiments. The constitutive equations for collisional stress and collisional pressure are proposed from DEM simulations. A novel particle stress based continuum particle model (CFD-CPM) has been developed for spherical particles (figure c).

Dissertations

1. Direct numerical simulations of flow around non-spherical particles (S.K.P. Sanjeevi).
2. Elongated particles in fluidized beds: From lab-scale experiments to constitutive models (V. V. Mahajan).

Scientific Publications

1. A. Zarghami, H.R. Ashorynejad, and J.T. Padding, Hydrodynamics Forces on a Circular Particle near a Sinusoidal Corrugated Wall, Powder Technology 342, 789 (2019).
2. I. Mema, V.V. Mahajan, B.W. Fitzgerald, and J.T. Padding, Effect of lift force and hydrodynamic torque on fluidization of non-spherical particles, Chem. Eng. Sci. 195, 642 (2019).
3. A. Vila, S.K.P. Sanjeevi, J.T. Padding, and S. Pirker, Gas flow through static particle arrangements with a channel: Resolved simulations and analytic considerations, Chem. Eng. Sci. X 2, 100015 (2019).
4. B.W. Fitzgerald, A. Zarghami, V.V. Mahajan, S.K.P. Sanjeevi, I. Mema, V. Verma, Y.M.F. El Hasadi, and J.T. Padding, Multiscale simulation of elongated particles in fluidised bed reactors, Chem. Eng. Sci. X 2, 100019 (2019).
5. V.V. Mahajan, J. Mehmood, Y.M.F. El Hasadi and J.T. Padding, Fluid medium effect on stresses in suspension of high-inertia rod-like particles, Chem. Eng. Sci. X 3, 100030 (2019).
6. Y.M.F. El Hasadi and J.T. Padding, Solving fluid flow problems using semi-supervised symbolic regression on sparse data, AIP Advances 9, 115218 (2019).

Project leaders

Prof. dr.ir. Johan T. Padding

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Sathish K.P. Sanjeevi, Vinay V. Mahajan, Ivan Mema, Dr. Barry W. Fitzgerald, Dr. Ahad Zarghami, Dr. Vikrant Verma, Dr. Yousef M.F. El Hasadi

Cooperations

TU Eindhoven, (Hans Kuipers and Kay Buist, for MPT experiments)

Funded by

European Research Council (ERC Consolidator Grant)

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2014

Information

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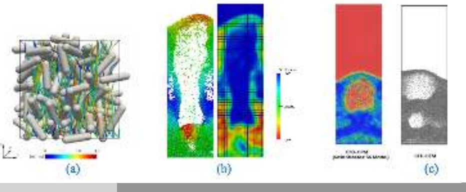

Hydraulic modelling of liquid-solid fluidisation in drinking water treatment processes

Project leaders
Prof. Jan Peter van der Hoek, Prof. Johan T. Padding
Research theme
Complex structures of fluids
Participants
Onno Kramer, Dr. Peter de Moel, Eric Baars, Leon Kors
Cooperations
Hogeschool Utrecht-ILC, Queen Mary University London, Waternet
Funded by
Waternet (Amsterdam)
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016
Information
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Project Aim

Improve drinking water treatment processes to make a contribution to a more sustainable society.

Progress

Development of accurate voidage prediction models for liquid-solid fluidisation processes calibrated with very precise experimental data-sets for a myriad of granules together with an army of BSc and MSc students. Good connection between operations-research and education.

Dissertations

-

Scientific Publications

1. Kramer, O.J.I., de Moel, P.J., Baars, E.T., van Vugt, W.H., Padding, J.T., van der Hoek, J.P., 2019. Improvement of the Richardson-Zaki liquid-solid fluidisation model on the basis of hydraulics. Powder Technol. 343, 465–478. https://doi.org/10.1016/j.powtec.2018.11.018.

High throughput experimentation for methane pyrolysis using molten salt reactors

Project Aim

Molten salt reactors may provide an efficient platform for methane pyrolysis and the production and valorization of solid carbon compounds, such as carbon nanotubes. The process is operated by bubbling methane gas into a tubular bed of molten salts. The two main goals of the project are (i) to design and construct an enhanced experimentation setup with diagnostic tools and (ii) to perform a large number of experiments on different combinations of parameters, e.g., specific salt (mixture), catalyst, temperature, bubble size, residence time, etc.

Progress

Initial trials were started with a low-temperature setup to obtain bubble characteristics, i.e., size, terminal velocity, trajectory, etc. In this regard, a capillary-based open microfluidic device (COMD) method, see Figure 1, has been implemented into the prototype, see Figure 2. The prototype consists of a stainless-steel base and quartz tube. Here, the bubble size will be determined on-demand by the gap distance (insertion of a very fine capillary quartz tube) at a constant flow rate of air.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. Johan T. Padding
Prof.dr.ir. J. Ruud van Ommen
Prof.dr.ir. Jerry Westerweel

Research theme

Complex structures of fluids

Participants

Dr. Hakan Nigar, Prof. Cor P.J.W. van Kruijsdijk (Shell)

Cooperations

Shell

Funded by

Shell

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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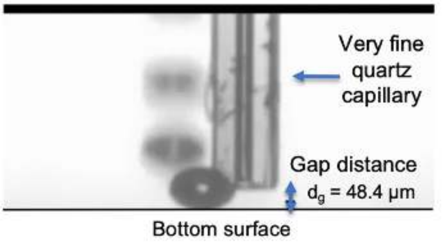

Figure 1. On-demand bubble size generator

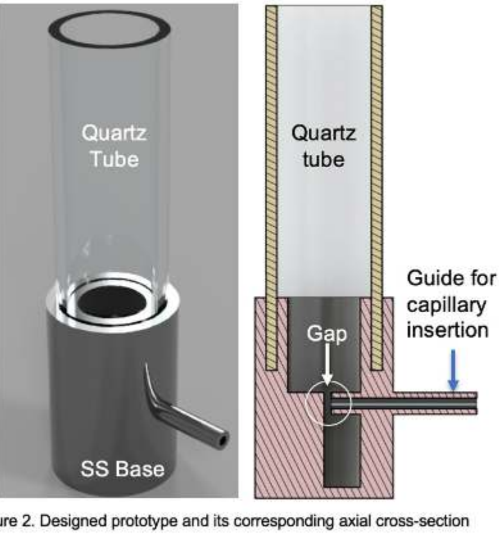

Figure 2. Designed prototype and its corresponding axial cross-section

PROJECT LEADERS
Prof. dr. ir. Johan T. Padding
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
ir. Stephan Sneijders
COOPERATIONS
TetraPak, DSM, Nutricia-Danone, Wageningen University
FUNDED BY
TTW, Industry
FUNDED %

University	-
FOM	-
STW	72 %
NWO Other	-
Industry	28 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017
INFORMATION
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PROJECT AIM

In an effort to gain better understanding of spray drying processes, a numerical model describing drying and collisions on droplet scale will be developed. The model should be able to predict the droplet drying rate, the morphological changes, and the agglomeration probability. The approach chosen is multidisciplinary and includes experimental work involving well-defined droplet drying and agglomeration studies, soft matter theory development and numerical modeling. The numerical framework should allow the study of droplet collisions and impacts considering multiple physical phenomena, e.g. rheology and evaporation.

PROGRESS

Smoothed particle hydrodynamics is used to model free surface flows for numerous applications. Therefore, the method seems suited for modelling droplet collisions and impacts as well. Since the aim is to study complex droplets (i.e. viscoelastic behavior) the method is being extended to allow modelling of viscoelastic fluids.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Project Aim

To gain insight into sub-millimeter separation of species we consider micron-sized aspherical particles subjected to creeping flow in a microfluidic device. Particles in confined flow can interact hydrodynamically with each other or with surrounding surfaces, altering their trajectories. To establish a quantitative relation between the shape of a particle and its trajectory we employ experimental and numerical methods. Experimental choices are guided by finite element computations, which are, in turned verified by experimental data. Both methods serve as means towards the development of a unified theory of shape-dependent motion at the microscale.

Progress

Regardless of their exact shape, particles with a single mirror plane have identical modes of motion: in-plane rotation and cross-stream translation along a bell-shaped path. Each mode has a characteristic time, determined by particle geometry. Furthermore, each particle trajectory can be scaled by its respective characteristic times onto two master curves. We propose minimalistic relations linking these timescales to particle shape. Together these master curves yield a trajectory universal to particles with a single mirror plane.

Dissertations

-

Scientific Publications

-

Shape-dependent flow disturbances determine shape-specific particle trajectories.

Project leaders

Prof. dr. ir. Johan T. Padding
Dr. ir. H. Burak Eral

Research theme

Complex structures of fluids

Participants

Rumen N. Georgiev

Cooperations

University of Hawaii at Manoa
Universiteit Utrecht

Funded by

NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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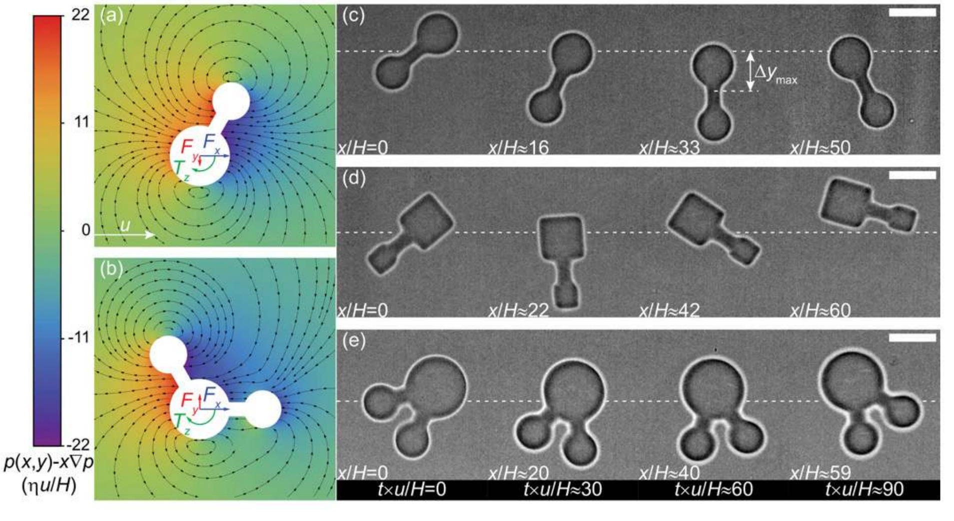

Project leaders
Prof.dr.ir. Johan T. Padding
Dr. Remco M. Hartkamp

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Rong Fan

Cooperations
-

Funded by
China Scholarship Council

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project
2017

Information
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Project Aim
The scope of the program is to study the interplay of transport phenomena (convection, diffusion) and reactions taking place near surfaces in structured reactors and porous media. The pore spaces in catalytic pellets may become so small that non-continuum (molecular) effects such as Knudsen diffusion start to play a role. On the other hand, the relevant scales where these phenomena take place are usually so large that detailed Molecular Dynamics simulations are also out of the question. In such cases it will be advantageous to use mesoscale particle-based simulations methods.

Progress
The SRD (Stochastic rotation dynamics) method for complex geometries has been developed. The measurements for parameters changing with reaction (temperature, pressure, reaction rate, etc) are underway.

Dissertations
-

Scientific Publications
-

Optimized and scalable CO2 reduction by tuning reaction environment and transport properties in gas diffusion cells

Project Aim

The goal of the project is to develop and use 3D models to resolve the pore-scale interplay of diffusion, migration, advection and mean field chemical kinetics in structured porous and bi-porous media. This will allow us to improve e.g. flooded agglomerate models, and to investigate electrokinetic effects in porous electrodes.

Progress

Primarily background reading, rudimentary models of simplified porous systems created in COMSOL for CO_2 reduction in gas diffusion electrode catalyst layer

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. Johan T. Padding
Dr.ir. J. Willem Haverkort

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Joseph (Joe) Blake

Cooperations

-

Funded by

NWO-TTW

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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Project leaders
Prof.dr.ir. Johan T. Padding
Dr. ir. Remco M. Hartkamp

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Esaar Naeem Butt

Cooperations
-

Funded by
Shell, Topsectors Chemistry, HTSM and Energy

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019

Information
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Project Aim

The main goal of this PhD program is to optimize an electrochemical reactor, maximizing the CO2 electro-reduction for the desired product of formic acid (HCOOH). The focused computational models would range from reactor to molecular length scale. Sensitive parameters at each length scale would be identified and optimized. The diffusion, migration and electro-kinetics phenomena in the electric double layer (EDL) region and on the surface of cathode are not well understood i.e. CO2 diffusion to the surface, ionic size repulsion effects. Special focus would be given in understanding these phenomena as they play a crucial role in overall electroreduction process.

Progress

A well-established Generalized Modified Poisson Nernst-Planck model was adopted and modified for the conversion of CO2 to formic acid. Current focus is on further modifications of the model to have a more precise image of the EDL. One such modification is the addition of convective flow in order to make the process industrially more relevant. Further analysis of different EDL specific phenomena would be carried out using Molecular dynamics.

Dissertations

-

Scientific Publications

-

Bubble dynamics in alkaline water electrolysis using the lattice Boltzmann method

Project Aim

This project aims at developing an open-source lattice Boltzmann model to study the nucleation, pinning, growth, and coalescence of a bubble on an electrode surface, or its detachment from that surface in an electrochemical system. The developed LB model would be capable of simulating multi-component and multi-phase (gas, liquid and solid) systems, and would be able to handle electric fields and charged components. Simulations can increase our understanding of the limiting processes, and help in optimizing and testing new electrode designs. An important output of the project is a predictive (statistical) correlation for bubble nucleation rates at the electrode surface.

Progress

Currently, literature review is being carried out. In order to get familiarized with the lattice Boltzmann method, a simple LB model was developed as a test case for the 1-D heat diffusion equation, which has since been improved step-by-step by including higher dimensions and accounting for other physical phenomena. An open-source LB porous media code by James McClure has been chosen as the starting point to further develop the model required for the current project.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. Johan T. Padding
Dr. Remco M. Hartkamp

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Arvind Pari (PhD candidate)

Cooperations

Dr. James McClure (Virginia Tech)
Prof. Cor P.J.W. van Kruijsdijk (Shell)

Funded by

NWO, Shell, Nouryon

Funded %

University	-
FOM	-
STW	-
NWO Other	72,2 %
Industry	27,8 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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PROJECT LEADERS
Dr. ir. Remco M. Hartkamp
RESEARCH THEME
Complex structures of fluids
PARTICIPANTS
Max F. Döpke, Johan T. Padding
COOPERATIONS
Othonas A. Moultos, Johannes Lützenkirchen, Bertrand Siboulet, Jean-François Dufrêche
FUNDED BY
TUD
FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2018
INFORMATION
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PROJECT AIM

Fluid properties within several molecular diameters of charged surfaces are known to be different to those found in the bulk region. Consequently, models that are derived for bulk fluids, such as the Navier-Stokes equations, break down in close proximity of charged surfaces. In this project we aim at shedding light onto fluid properties in this region and expanding existent models to include this non-uniformity of the fluids.

PROGRESS

In the first leg of this project, Molecular Dynamics simulations were used to study the adsorption of Na+ and Ca2+ on charged amorphous silica. We showed that Na+ ions can adsorb preferentially over Ca2+ ions, depending on the surface structure. We proposed that this occurs when the local surface structure sterically hinders the hydration shell of the Ca2+ ion, and developed a protrusion metric capable of successfully predicting this ion-specificity.

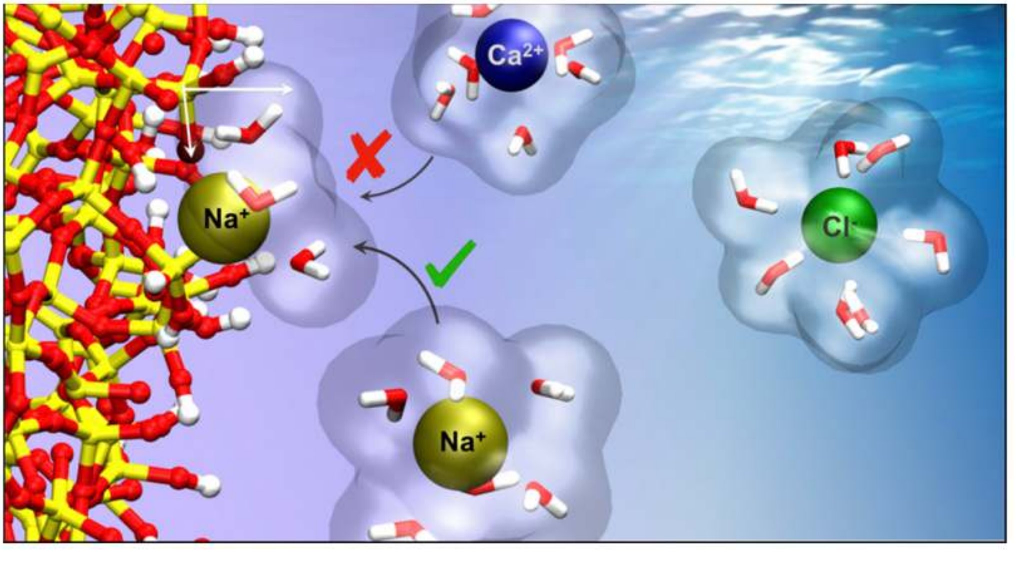
In the future we want to evaluate other local properties such as the dielectric permittivity and mobility of ions in the Electric Double Layer.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Döpke, M. F., Lützenkirchen, J., Moultos, O. A., Siboulet, B., Dufrêche, J. F., Padding, J. T., & Hartkamp, R. (2019). Preferential Adsorption in Mixed Electrolytes Confined by Charged Amorphous Silica. The Journal of Physical Chemistry C, 123(27), 16711-16720.



Non-Photochemical Laser-Induced Nucleation (NPLIN)

Project Aim

To study how light and induced flow fields due to local heating interact with molecules\molecular clusters and alter their crystallization pathways upon irradiation. This allows us to achieve controlled and predictive production of crystal. The current objective is to (a) prepare a review article discussing the dependence on laser intensity, nature of solvent and extent of crystallization (polymorphism, growth rate, etc..) (b) check bubble-induced nucleation mechanisms both by simulation and experiments. (c) perform Molecular Dynamics simulations on (pre-)nucleus formation at appropriate regions. (d) based on these results make predictions for specific experimental systems.

Progress

For 2020 the plan is to (a) prepare a review article, (b) benchmark the experimental setup for dynamics of a vapour bubble in a microtube with added solute, and (c) back up the experimental observations by using a suitable simplified numerical model.

Dissertations

-

Scientific Publications

-

Project leaders

Dr. ir. H. Burak Eral
Dr. ir. Remco M. Hartkamp
Prof. dr. ir. Johan T. Padding

Research theme

Complex structures of fluids

Participants

Nagaraj Nagalingam

Cooperations

-

Funded by

NWO-TTW

Funded %

University	-
FOM	-
STW	-
NWO Other	90 %
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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TRANSPORT PHENOMENA

Prof.dr.ir. CR Kleijn

Prof.dr. S Kenjeres, Dipl.-Ing

Prof.dr.ir. HEA van den Akker

Prof.dr.ir. K Hanjalic (em)

The Transport Phenomena group studies the transport of mass, momentum and heat, on different length and time scales, in physical, biological and and chemical processes related to advanced materials processing, energy conversion and storage, and health. The main interest is in transport phenomena around (solid-fluid, liquid-gas and liquid-liquid) interfaces, which we wish to understand, control and enhance.

The group uses both theoretical and computational models, and non-intrusive experiments based on laser and X-ray techniques.

Our expertise is in heat and mass transfer in multiphase flows, turbulent flows, microflows and biological flows.

A partial list of topics which we currently work on:

- Multiphase flow and dynamic contact line phenomena in digital microfluidics and Labs-on-Chips
- Dispersed multiphase flows in large scale chemical processing (bubble columns, fluidized beds, Fischer Tropsch)
- Magnetohydrodynamics in advanced liquid metal processing (welding, casting)
- Magnetic drug targeting
- Oil-water separation
- Turbulence modulation for enhanced heat and mass transfer

Project Aim

Steel production is an energy intensive process. Continuous casting of steel (metals in general) aims at high production speed at as low as possible energy usage. Stability of the flow in the casting process plays a vital role in product quality and process performance. Electromagnetic actuators can be used to control and stabilize the multiphase metal flow. Computational Fluid Dynamics (CFD) can play a vital role in understanding the interplay between fluid dynamics and electromagnetic forces. Moreover, it allows studying different actuator strategies. The work also involves fundamental scientific analyses and engineering design with groups at Helmholtz-Zentrum Dresden-Rossendorf, at the universities of Liberec and Bath and at different industry partners.

Progress

This year we continued developing the solver for the magnetohydrodynamic (MHD) purpose. Two important steps have been implemented: (i) the LES method with the dynamic Smagorinsky SGS model for turbulent modelling and (ii) the VOF method with the MHD extension for multiphase modelling. We successfully validated both parts, that in turn, allowed us to use them on practice. In particular, we have been investigating how the wall conductivity affects the turbulence characteristics and the dynamic behavior of the liquid metal free surface in the casting mold. These results are presented in figure 1.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr. Ir. C.R. Kleijn

Prof.dr. S. Kenjeres, Dipl.-Ing

Research theme

Complex dynamics of fluids

Participants

A. Blishchik (PhD Student)

Cooperations

TOMOCON project

Funded by

EU Horizon 2020/TU Delft

Funded %

University	25 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	75 %
Scholarships	-

Start of the project

2018

Information

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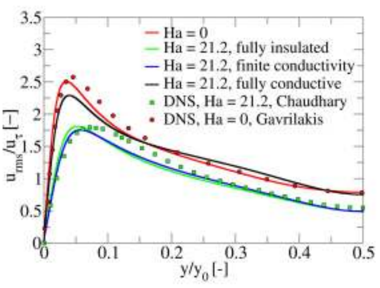
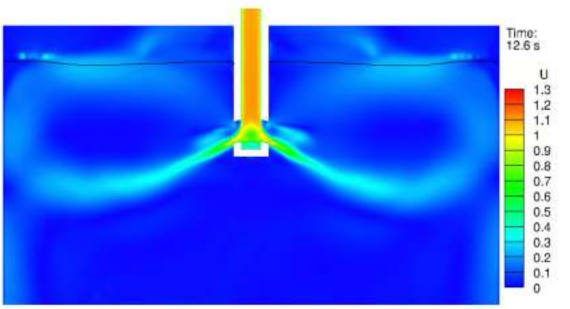
RMS profiles in the duct with different wall conductivity on the left of the picture. Velocity field and the free surface deformation (black line) on the right of the picture





Project leaders
Prof.dr. S. Kenjeres, Dipl.-Ing, Prof. Dr. H. J. Lamb (LUMC)
Research theme
Complex dynamics of fluids
Participants
Xiaolin Wu
Cooperations
Leiden University Medical Center
Funded by
TU Delft, China Scholarship Council
Funded %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	50 %

Start of the project
2018
Information
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Project Aim

The objective of this research is to experimentally investigate the instantaneous 3D flow and wall shear stress (WSS) within the patient specific arterial models by Stereoscopic PIV / Tomographic PIV techniques. In addition, the influence of realistic inflow conditions, fluid properties and mechanical properties on the flow and WSS will be conducted. This work can provide validation to the developed numerical models and medical imaging techniques.

Progress

A study of applying volumetric PIV technique in investigating aneurysmatic artery is carried out. As Fig. 1 shows, a transparent, in vitro, patient specific of intracranial aneurysm model was manufactured. The volumetric experimental technique - Tomographic PIV (TPIV) was used to visualize and quantify the blood flow inside this vessel model. A spatial resolution of 0.25 mm3 and a temporal resolution of 2.5 ms were achieved. From the reconstructed streamlines (see in Fig. 1), it can be seen that TPIV measurements has well represented the 3D flow in a patient specific intracranial aneurysm. Based on the reconstructed velocity field, WSS was calculated and compared to CFD. Overall, the WSS distribution of PIV results show good agreement with CFD (see Fig. 2). Quantitatively, the WSS magnitude obtained from PIV measurement is approximately 20% smaller than CFD simulation. Comparison with in vivo data will be performed next.

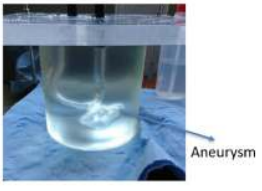
Dissertations

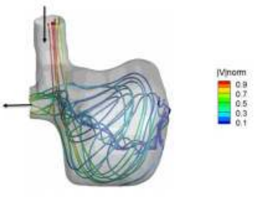
-

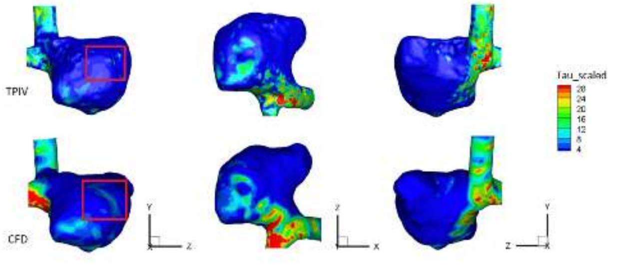
Scientific Publications

-

Intracranial Aneurysm in vitro Model (Left) and Streamlines from TPIV measurement (Right)







WSS magnitude at systolic peak derived from TPIV and CFD

PROJECT AIM

This study is aimed to quantify the characteristics of flow patterns in left ventricle (LV) via Computational Fluid Dynamics (CFD) and an Active Shape Model (ASM) derived from 4-D Computed Tomography (CT) images for 151 patients. Five characteristic 4D shape sets were generated from ASM model: the mean shape, and mode variations of +3 and -3 standard deviations (SD) along the first and second principal component of shape variation in the population. The vortex development pattern during cardiac cycle is investigated through these 5 shapes.

PROGRESS

We have reconstructed the LV geometry for five shapes. For each segmented geometry, separate unstructured grids consisting of tetrahedral cells were generated. The time step resolution of CT data was not fine enough for CFD simulation. Thus intermediate geometries were needed to volume smoothly passed through time steps. For solving the fluid flow domain with finite volume method, the Arbitrary Lagrangian-Eulerian (ALE) formulation of Navier-Stokes was used. The results are analyzed and compared for five characteristics shapes.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Khalafvand S. S., Xu F., Westenberg J., Gijsen F., Kenjeres S. (2019), Intraventricular blood flow with a fully dynamic mitral valve model", Computers in Biology and Medicine, Vol. 104, pp.197-204 (doi: 10.1016/j.compbiomed.2018.11.024).
2. Saaid H., Voorneveld J., Schinkel C., Bosch J. G., Westenberg J., Gijsen F., Segers P., Verdonck P., Kenjeres S., Claessens T. (2019), "Tomographic PIV in a Model of the Left Ventricle: 3D Flow Past Biological and Mechanical Heart Valves", Journal of Biomechanics, Vol. 90, pp.40-49, (doi: https://doi.org/10.1016/j.jbiomech.2019.04.024).

PROJECT LEADERS

S.S.Khalafvand, Prof.dr. S. Kenjeres, Dipl.-Ing

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Dr. S.S.Khalafvand

Prof.dr. S. Kenjeres, Dipl.-Ing

COOPERATIONS

ERASMUS Medical Center Rotterdam, Leiden University Medical Center (LUMC)

FUNDED BY

TU Delft, ZonMw: The Netherlands Organisation for Health Research and Development

FUNDED %

University	-
FOM	-
STW	-
NWO Other	80 %
Industry	20 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2015

INFORMATION

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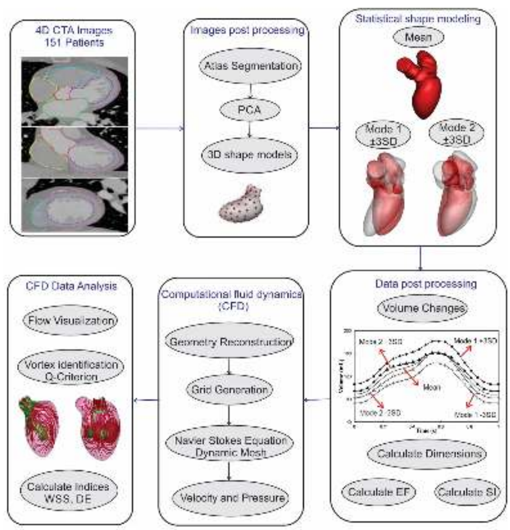

The overall methodology from CT images to blood flow visualization in LV

RADAR – Early Recognition of Aorta Dissection and Aneurysm Rupture

Project leaders
Prof.dr. S. Kenjeres, Dipl.-Ing
Prof. Dr. Hildo J. Lamb
Research theme
Complex dynamics of fluids
Participants
Ir. Romana Perinajova
Cooperations
LUMC
Funded by
Hartstichting
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
Information
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Project Aim

An aortic aneurysm is a life threatening disease. There is an urgent need for new biomarkers that could contribute to an earlier aneurysm detection, preferably before growth, to prevent fatal rupture. Aim of the project is to develop a multi-physics model (fluid-solid-growth) of the whole human aorta that would provide the structural (MRI) and mechanical information of the aortic wall as well as hemodynamic information, transmural pressure and oxygen concentration. Afterwards, with LUMC, define sex-specific physiological normal values and cut-off values for identifying pathological abnormalities based on new and existing data from 10-year follow-up (approx. 200 cases).

Progress

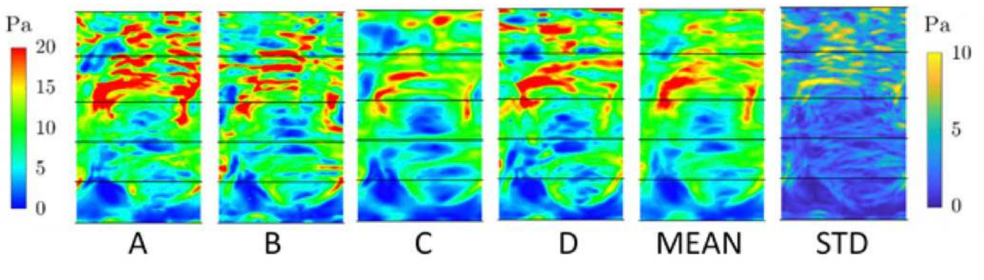
A study on the effect of small geometrical variability of the input surfaces for the simulations was performed. For a group of ten volunteers, four different segmentations of the MRI dataset was performed. Subsequently, CFD simulations were performed on these geometries with the same inlet conditions for all four geometries per volunteer. The acquired Wall Shear Stress (WSS) data were subsequently analyzed statistically. For this purpose, a flattening protocol was developed to project the WSS data from the 3D surface on a 2D plane surface. The analysis showed that the agreement between the surfaces is good in the ascending part and poor in the descending part of the aorta.

Dissertations

-

Scientific Publications

1. Hypoxic regions in the human cerebrovasculature can be identified by oxygen mass transport modeling, poster presentation at Physics at Veldhoven, annual meeting 2019, Veldhoven, The Netherlands.
2. The Role of Hemodynamics in the Rupture of an Intracranial Aneurysm, poster presentation at Burgers Symposium, annual meeting 2019, Lunteren, The Netherlands.
3. New Determinants for the Rupture Risk Assessment of the Intracranial Aneurysm, oral presentation at 8th International Conference on Computational Bioengineering 2019, Belgrade, Serbia.



The flattened WSS maps for Volunteer 1, from left to right WSS from the segmentation A-D, the map of the mean value of WSS based on the four segmentations and the Standard Deviation (STD

PROJECT AIM

The aim of the project is to provide a fundamental understanding of the hemodynamics inside human heart by means of MRI/Ultrasound based CFD simulations. The MRI based CFD simulations have the capability to reconstruct patient-specific simulation models of the heart. Such models can provide us a deeper understanding of the complex flow phenomenon and provide us with flow details which cannot be supplied by medical imaging alone.

PROGRESS

With series of images from measurements (MRI and PIV) and the RBF (radial basis functions) method, a cost-effective image (CT and/or MRI) based numerical simulation technique has been developed for the blood flow simulation in realistic patient-specific ventricles.

The numerically calculated velocity components and the vortex structure have been compared with available tomographic PIV as well as MRI measurements at characteristic time instants during a cardiac cycle. Obtained results are in a good agreement with experimental data at specific locations.

The obtained results provided detailed insights into energetics of the instantaneous flow features of the left ventricle model. The presented method can be applied for future analysis with the patient-specific geometries.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Fei Xu et al. (2019) "Blood Flow Patterns in a Model of the Human Heart" ICCB2019, Belgrade, 5th September 2019.

PROJECT LEADERS

Prof.dr. S. Kenjeres, Dipl.-Ing

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Fei Xu

COOPERATIONS

Erasmus Medical Center, Leiden University Medical Center, University of Ghent

FUNDED BY

ZonMw, The Netherlands Organisation for Health Research & Development, China Scholarship Council (CSC)

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2016

INFORMATION

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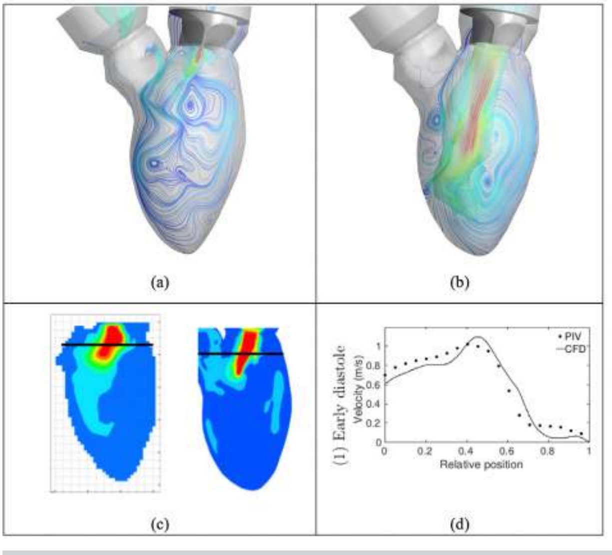

(a) Flow pattern at the initial stage of the diatole; (b) Mid-diastolic flow pattern; (c) Velocity magnitude comparison, left: Tomo-PIV, right: CFD; (d) Velocity magnitude comparison at location shown in (c).

Thermo-magnetic convection in the presence of the strong magnetic field gradients: experimental and numerical studies

Project leaders
Prof.dr. S. Kenjeres, Dipl.-Ing

Research theme
Complex dynamics of fluids

Participants
Prof.dr. S. Kenjeres, Dipl.-Ing, Prof. J. S. Szmyd,
Dr. E. Fornalik-Wajs

Cooperations
AGH University of Science and Technology, Krakow, Poland

Funded by
EC Marie Curie, TU Delft, AGH Krakow

Funded %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	50 %
Scholarships	-

Start of the project
2010

Information
S. Kenjeres
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Project Aim

This is a joint project between Transport Phenomena Section, Department of Chemical Engineering at the TU Delft and the Department of Fundamental Research in Energy Engineering, Faculty of Energy and Fuels, AGH University of Science and Technology, Krakow, Poland. The project is aimed at fundamental investigations of flow stability and wall heat transfer of paramagnetic fluids in presence of strong magnetic field gradients.

Progress

Experimental measurements of the integral heat transfer performed over a range of working parameters for a differentially heated cubical enclosure of a paramagnetic fluid subjected to magnetic gradients of different orientation and strength. The DNS studies of the flow and heat transfer were performed and compared to recent experimental data. Detailed insights into the mechanism of the wall-heat transfer enhancement or suppression were analyzed. Finally, the energy budgets were analyzed with the specific focus on the role of the magnetization production term.

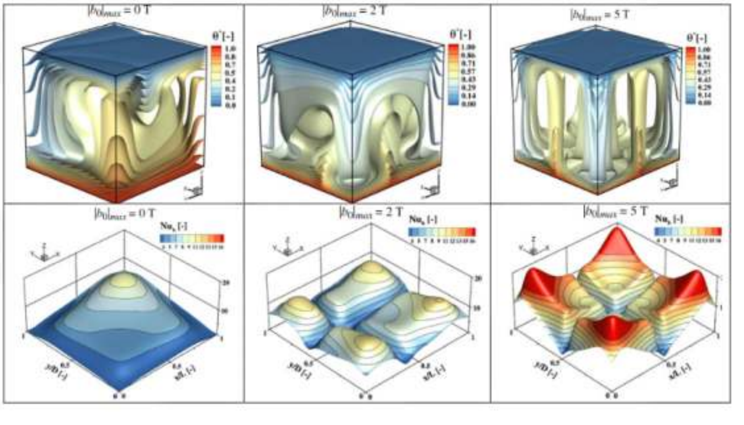
Dissertations

-

Scientific Publications

-

Top- the iso-surfaces of the temperature for different strengths of the imposed magnetic field, |b0|max = 0, 2, 5 T and a fixed value of Pr = 400 for a cubical enclosure filled with the paramagnetic fluid. Bottom- distributions of the local Nusselt number at the lower (hot) wall. The characteristic value of thermal Rayleigh number for the neutral case is RaT= 2x105, Kenjeres (2016).



Numerical modeling, simulations and experiments of blood and air flow with magnetic particles in simplified and realistic patient arterial and airway geometries: Towards optimized magnetic drug delivery

Project Aim

One of the main problems of chemotherapy is often not the lack of efficient drugs, but the inability to precisely deliver and concentrate these drugs in affected areas. Failure to provide localized targeting results in an increase of toxic effects on neighboring organs and tissues. One promising method to accomplish precise targeting is magnetic drug delivery. Here, a drug is bound to a magnetic compound injected into the blood stream. The targeted areas are subjected to an external magnetic field that is able to affect the blood stream by reducing its flow rate. We believe that mathematical modeling and numerical simulations can significantly contribute to further advancements of this technique.

Progress

We have developed a comprehensive mathematical model for simulations of a blood-flow under a presence of the strong non-uniform magnetic fields. The model consists of a set of Navier-Stokes equations accounting for the Lorentz and magnetization forces, and a simplified set of Maxwell's equations (Biot-Savart/Ampere's law) for treating the imposed magnetic fields. The model is validated for different patient-specific geometries (including a carotid artery and brain vascular system). First simulations of aerosol distribution within a human upper airway system were performed demonstrating that identical tageting concept can be applied for the upper and central human airway system too.

Dissertations

-

Scientific Publications

1. Kenjeres S. (2019), "On recent advances in experimental studies of flow patterns in patient-specific vascular geometries", The 4th International Conference on Multi-scale Computational Methods for Solids and Fluids, ECCOMAS MSF 2019, September 18 – 20, 2019, Sarajevo, Bosnia and Herzegovina (pp.1-4).
2. Kenjeres S., Bakker P. (2019), "Numerical modeling and simulations of magnetic drug delivery for the lung cancer therapy", The VIII International Conference on Computational Bioengineering, September 4-6, 2019, Belgrade, Serbia.

Project leaders

Prof.dr. S. Kenjeres, Dipl.-Ing

Research theme

Complex dynamics of fluids

Participants

Prof.dr. S. Kenjeres, Dipl.-Ing

Cooperations

Erasmus Medical Center Rotterdam
Leiden University Medical Center

Funded by

TU Delft, ZonMw

Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2014

Information

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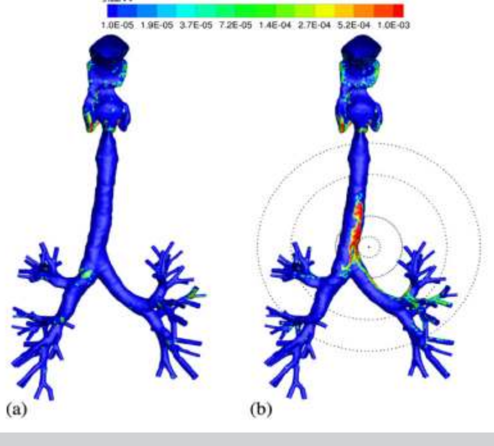

Contours of the local deposition efficiency (ζ) in the upper- and central-airways human respiratory system for the magnetic-core particles (dp = 3μm, St=4.3 × 10−2, Mnp=1.7 × 10−1) without (a) and with imposed magnetic field gradient (b), demonstrating potentials of the MDT, Kenjeres (2016)

Hybrid RANS/LES simulations of turbulent flows over hills and complex urban areas with dispersion of pollutants

Project leaders
Prof.dr. S. Kenjeres, Dipl.-Ing
Research theme
Complex dynamics of fluids
Participants
Prof.dr. S. Kenjeres, Dipl.-Ing, Dr. Nikola Mirkov,
Dr. Daoming Liu
Cooperations
University of Belgrade and Vinca Institute of Nuclear Science, Belgrade, Serbia, Safety and Emergency Laboratory, Shanghai Advanced Research Institute, Chinese Academy of Sciences, Shanghai, China
Funded by
TU Delft, CSC China
Funded %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	50 %

Start of the project
2010
Information
S. Kenjeres
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Project Aim

This project is aimed at the mathematical modelling and numerical simulations of environmental flows and turbulent dispersion of passive and reactive scalars. In this particular project we focus our investigation at turbulent flows over complex terrains and urban areas (street canyons) partially covered with vegetation and with different sources of the passive or reactive scalars.
In the last year, the special focus was on the dynamics of reactive scalars to mimic the ozone generation or depletion.

Progress

We developed a new class of the seamless hybrid RANS/LES approach suitable for the complex urban areas partially covered with vegetation. We successfully reproduced detailed laboratory-scale measurements for different geometrical configurations reported in literature. Also, the mechanism of the ozone generation/depletion in urban areas due to traffic emission is validated.

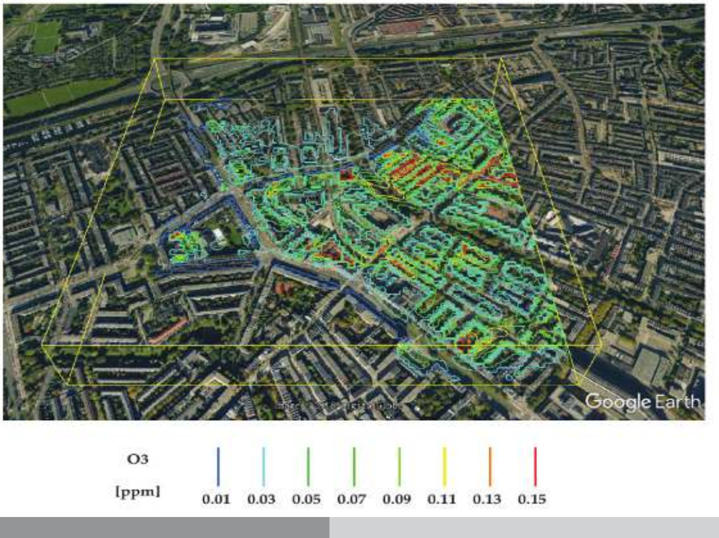
Dissertations

-

Scientific Publications

1. Kenjeres S. and Zwinkels, “Numerical modeling of the macroscopic behavior of a crowd of people under emergency conditions truggered by an incidental release of a heavy gas: an integrated approach”, Flow, Turbulence and Combustion, Vol. 103, Issue 4, pp.1081-1107, (doi: https://doi.org/10.1007/s10494-019-00053-9).

The mapping of pollution by iso-lines: concentration contours of O3 (indicating locations with enhanced ozone distribution as result of the chemical reactions) – in the horizontal plane at pedestrian level (z=2 m). Results of the integrated in-house developed CFD/CRD solver for the photochemical smog generation for a city of Rotterdam,
Liu and Kenjeres (2017)



Project Aim

The overall aim of this research project is to provide a fundamental understanding of natural and mixed convection flows in coarse-grained porous media and to provide detailed experimental data to validate and improve developed simulation models. To achieve this aim we have been conducting PIV (Particle Image Velocimetry), LCT (Liquid Crystal Thermography) and heat transfer measurements in natural and mixed convection flows in porous media composed of packed beds of spheres.

Progress

We have experimentally studied mixed convection flow and heat transfer in a vented, differentially side-heated cubical cavity filled with a porous medium consisting of relatively large spheres. Rayleigh numbers and Reynolds numbers are varied over the ranges $6 \times 10^6 < Ra < 7 \times 10^7$ and 240 < Re < 4250, respectively, for a fixed Prandtl number of Pr = 6.75, thus covering more than three decades in Richardson numbers Ri = Ra/(Re2 Pr). Heat transfer measurements were combined with measurements of the velocity and temperature fields. We observed three different flow and heat transfer regimes depending on the Richardson number (Fig. 1). For Ri < 10, the flow structure and the Nusselt number scaling are similar to those for the pure forced convection, i.e., the Nusselt number scales as Nu ~ Re0.61 independent of Rayleigh number. For Ri > 40, natural convection dominates the flow in the vicinity of the heating wall (Fig. 2). The Nusselt number becomes less sensitive to the Reynolds number and is mainly determined by the Rayleigh number. In the intermediate regime for 10 < Ri < 40, the upward directed natural convection flow at the heating wall competes with the downward directed forced flow leading to a minimum effective Nusselt number.

Dissertations

-

Scientific Publications

1. Ataei-Dadavi, I., Rounaghi, N., Chakkingal, M., Kenjeres, S., Kleijn, C. R., & Tummers, M. J. (2019). An experimental study of flow and heat transfer in a differentially side heated cavity filled with coarse porous media. International Journal of Heat and Mass Transfer, 143, 118591.
2. Ataei-Dadavi, I., Chakkingal, M., Kenjeres, S., Kleijn, C. R., & Tummers, M. J. (2019). Experiments on mixed convection in a vented differentially side-heated cavity filled with a coarse porous medium. International Journal of Heat and Mass Transfer, 149, 119238.

Project leaders

Prof. dr. ir. C. R. Kleijn
Dr. ir. Mark Tummers

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Iman Ataei Dadavi

Cooperations

Tata Steel, M2i

Funded by

STW, Tata Steel (through M2i)

Funded %

University	-
FOM	-
STW	50 %
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

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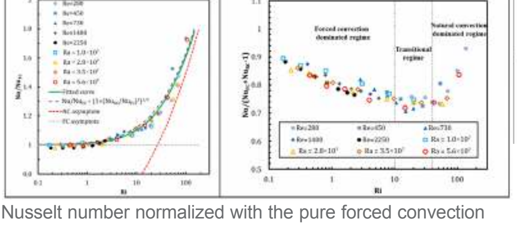
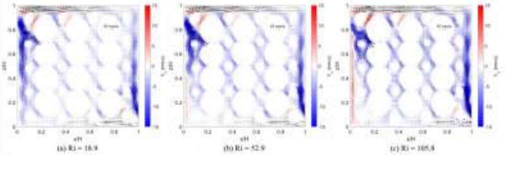


Nusselt number normalized with the pure forced convection Nusselt number as a function of Richardson number (left). Nusselt number normalized with the sum of pure forced convection and pure natural convection Nusselt numbers as a function of Richardson number (right).


Mean velocity fields at Re = 280 for different Richardson numbers

PROJECT LEADERS
Prof.dr. S. Kenjeres, Dipl.-Ing
Dr. ir. N. Bhattacharya (dept. ImPhys)
Prof. dr. ir. C. R. Kleijn

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Ir. Kevin van As

COOPERATIONS
-

FUNDED BY
NWO

FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2015

INFORMATION
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www.tudelft.nl/en/faculty-of-applied-sciences/about-faculty/departments/chemical-engineering/scientific-staff/sasa-kenjeres/research-team-people/kevin-van-as/

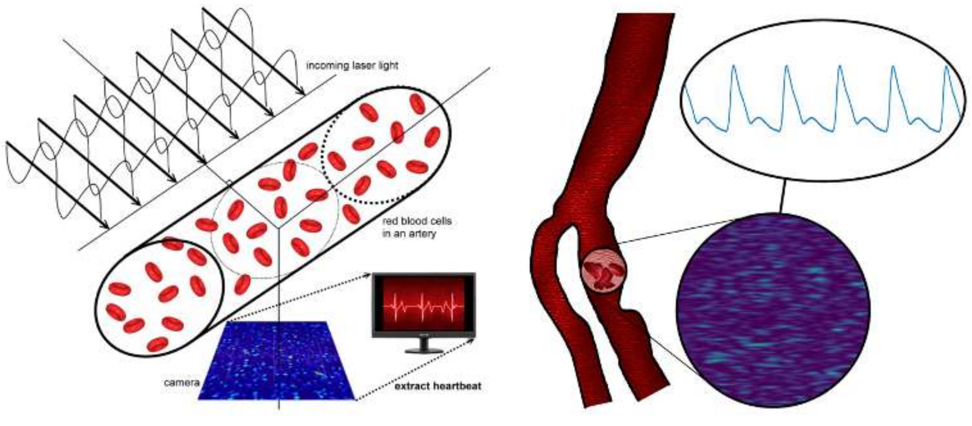
PROJECT AIM
Measuring inside turbid media – such as human tissue – is difficult, as they are non-transparent due to the heavy scattering of light. Coherent light scattering is a technique which makes use of the heavy scattering of the medium, and is thereby rapidly becoming a technique for non-invasive monitoring of patients. The challenge is that the technique is currently still only semi-quantitative. By performing interferometric Mie scattering computer simulations, in combination with computational fluid dynamics, we aim to improve our understanding of the technique and thereby make it a fully-quantitative technique.

PROGRESS
Our first paper on our altered topic has been published in Physical Review E, and was selected Editor's Choice. In this paper we introduce our own Mie optics code for computing the light scattering by spherical particles (representing red blood cells) to the world, and show its capability. Our second paper has also been written and submitted to Applied Physics Letters, and is currently awaiting review. In this paper we make a step towards using our technique for quantitative flowmetry. Our third paper is presently being written.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
1. van As, K., Boterman, J., Kleijn, C. R., Kenjeres, S., & Bhattacharya, N. (2019). Laser speckle imaging of flowing blood: A numerical study. Physical Review E, 100(3), 033317.

(left): Our set-up. Coherent light scatters of red blood cells and forms a noise-like interferometric diffraction pattern, called speckle. We wish to extract information from the speckle pattern.
(right): Complex patient-specific carotid artery with a stenosed region.



Low Prandtl number mixed convection flow in wall bounded coarse grained porous media – application to blast furnaces

Project Aim

The aim of the project is to provide a fundamental understanding of, and experimentally validated models for, the influence of coarse grained porous media on flow, turbulence and heat transfer in liquid steel. These insights and models will make it possible to design and to optimize new strategies for designing blast furnaces and cooling systems, leading to significant energy savings, increased productivity and improved product quality.

Progress

The numerical simulation of pore-structure resolved convection in a differentially heated cavity filled with coarse grained porous media (Figure 1), with-non uniform wall temperature is carried out using open source CFD solver, OpenFOAM. Natural convection at different Rayleigh numbers and different arrangements of wall temperature distribution, in a cavity filled with water and hydrogel beads is analyzed. The results are compared with fluid-only filled cavity. Variation in heat transfer (Figure 2) with change in spatial distribution of wall temperature is observed.

Dissertations

-

Scientific Publications

1. Chakkingal, Manu, et al. "Numerical analysis of natural convection with conjugate heat transfer in coarse-grained porous media." International Journal of Heat and Fluid Flow 77 (2019): 48-60.

Project leaders

Prof. dr. ir. C. R. Kleijn
Prof.dr. S. Kenjeres, Dipl.-Ing
Dr.ir. Mark Tummers

Research theme

Complex dynamics of fluids

Participants

Ir. Manu Chakkingal

Cooperations

Tata Steel, M2i

Funded by

STW, Industry

Funded %

University	-
FOM	-
STW	50 %
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

Manu Chakkingal
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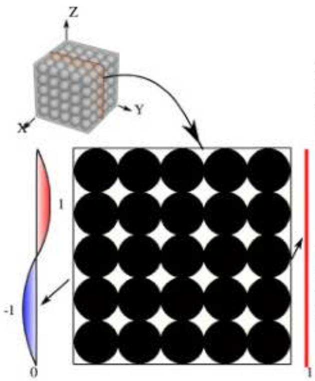
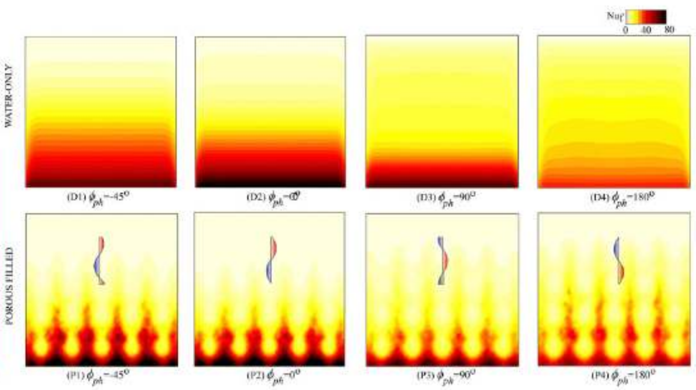
Cavity filled with coarse grained porous media and spatially varying wall temperature.



Change in local heat transfer (Nuf) with spatial distribution of wall temperature at Ra=107 ,water-only (row1) porous media (b) filled cavity.



Project leaders
Prof. dr. Ian M. Richardson
Prof. dr. ir. Chris R. Kleijn
Research theme
Complex dynamics of fluids
Participants
Amin Ebrahimi, M.Sc.
Cooperations
-
Funded by
NWO-I
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016
Information
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Project Aim

This project is devoted to the stability analysis of fusion welding processes. The primary aim of this research is to construct a novel, physically-based numerical approach for assessing the stability of a melt pool with two free surfaces, suspended between solid side walls and subject to excitation and variations in orientation and geometric boundary conditions. The proposed approach is envisaged to be applicable to any fusion welding processes, since the process can be defined by a set of boundary conditions and be controlled by introducing perturbation terms to the applied boundary conditions. The overall aim is to get a better insight into weld pool dynamic behaviour.

Progress

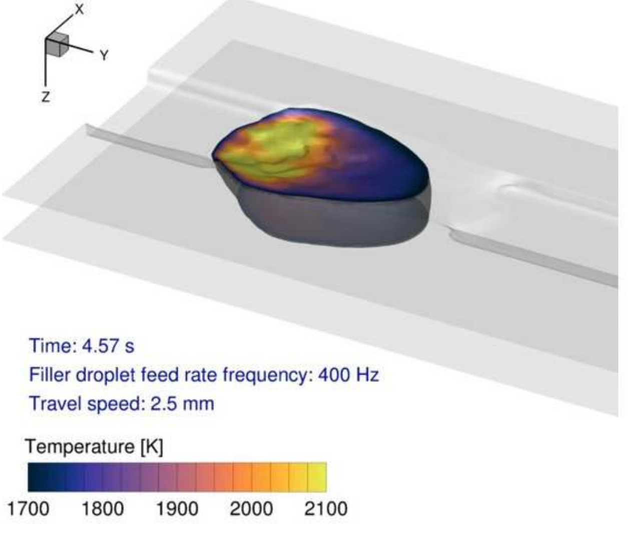
A general multiphase model was developed to predict heat and fluid flow during fusion welding and associated melt-pool surface oscillations. The model was employed to predict and characterize the oscillatory behavior of melt pools during gas tungsten arc welding (GTAW), gas metal arc welding (GMAW) and additive manufacturing. The effects of melt-pool surface oscillations on thermocapillary flow instabilities in laser melting of metallic alloys were studies. The proposed simulation-based approach can facilitate development, optimization and qualification of welding and additive manufacturing (3D-printing) and can reduce the costs associated with these tasks.

Dissertations

-

Scientific Publications

1. Ebrahimi, A., Kleijn, C. R., & Richardson, I. M. (2019). Sensitivity of Numerical Predictions to the Permeability Coefficient in Simulations of Melting and Solidification Using the Enthalpy-Porosity Method. Energies, 12(22), 4360.
2. Ebrahimi, A., Kleijn, C. R., & Richardson, I. M. (2019). The influence of surface deformation on thermocapillary flow instabilities in low Prandtl melting pools with surfactants. In Proceedings of the 5th World Congress on Mechanical, Chemical, and Material Engineering (MCM'19).



Project Aim

A thin liquid film that is formed between two bubbles, for instance in Scheludko-cell experiments, is non-planar in nature, and has finite initial features, i.e. film radius and film thickness. The dynamics and lifetime of semi-infinite non-planar thin liquid films, wherein the dynamics and film lifetimes are independent of the lateral length scale of the film, have been well studied in the literature. We study the influence of initial film features, i.e. film radius and film thickness, on the dynamics and lifetime of non-planar thin liquid films.

Progress

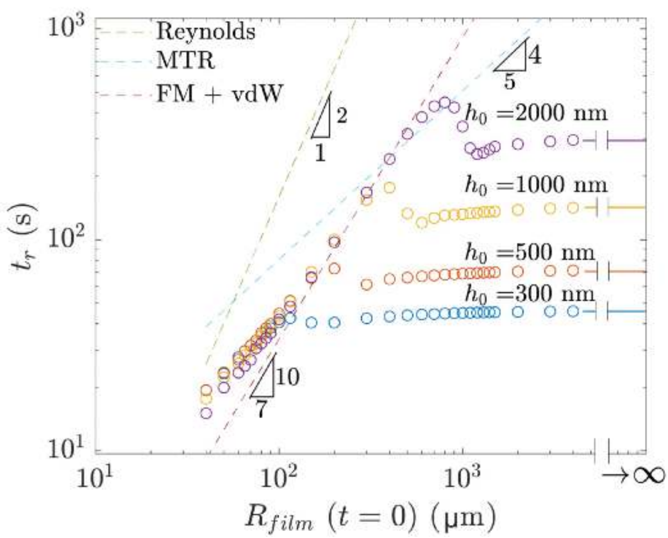
We combine the dynamics of thinning that proceeds through dimple formation as described by Frankel & Mysels (1962) and that of film rupture through van der Waals forces as described by Zhang & Lister (1999) to develop a theoretical model that describes the film lifetimes as a function of their initial radii and thicknesses. We also perform numerical simulations of an axisymmetric non-planar thin liquid film. We find the film drainage behaviour to be distinctive for small and large radii films. Our simulations reveal that for small films, their lifetimes depend only on the initial radii, independent of their initial thicknesses in fair accordance with our theoretical model. For large films, our simulated lifetimes become independent of the radii, and depend only on the initial film thicknesses, and can be well-described by our theoretical model developed for semi-infinite film radius.

Dissertations

-

Scientific Publications

1. Shah, M., Van Steijn, V., Kleijn, C., & Kreutzer, M. (2019), Thermal fluctuations in capillary thinning of thin liquid films, Journal of Fluid Mechanics, 876, 1090-1107, doi:10.1017/jfm.2019.595.



The lifetimes of a film as a function of initial film radius for different initial film thicknesses is shown. Green and blue dashed lines correspond to theoretical predictions by Reynolds' theory and MTR theory, whereas the red dashed line corresponds to our theoretical model that combines dynamics of dimple formation as predicted by Frankel & Mysels and that of van der Waals thinning as predicted by Zhang & Lister

Project leaders

Prof. Dr. Ir. C.R. Kleijn
Prof. Dr. Ir. M.T. Kreutzer
Dr. Ir. Volkert van Steijn

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

M.S. Shah (PhD Student)

Cooperations

ISPT/NWO

Funded by

ISPT/NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

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PROJECT LEADERS
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Prof.dr. S. Kenjeres, Dipl.-Ing

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Elin Vesper

COOPERATIONS
-

FUNDED BY
FOM and Tata Steel

FUNDED %

University	-
FOM	50 %
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017

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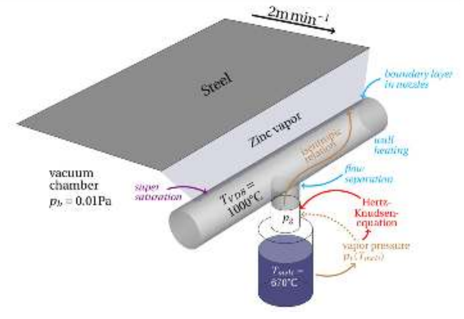
PROJECT AIM
Physical Vapor Deposition (PVD) processes are traditionally used at a small scale and for batch processes for zinc coating. For the up-scaling to a continuous process it is necessary to use multiple vapor jets (see fig.1) with a high mass flow rate. The project aims at understanding the physics of the metal vapor transport towards the surface. The three major aims in this project are: First ,the development of a hybrid solver coupling kinetic models and Direct Simulation Monte Carlo (DSMC). Second, modeling the flow inside the VDB and optimizing to achieve a high mass flow rate . Third, understanding the physics in a continuous PVD line, especially interacting jets (see fig. 2).

PROGRESS
The mass flow in a continuous PVD line is limited by the evaporation and the choked flow at the nozzles (see fig.1). The zinc vapor flow inside the VDB apparatus has been modeled using OpenFOAM. The simulated mass flow rate is in good agreement with the experiments. The interaction of planar, sonic jets has been studied (1) for free molecular flow using an analytic effusion solution (fig.2 (a) and (b)) and (2) in the rarefied regime up to continuum using DSMC (fig.2 (c) and (d)). The degree of rarefaction determines the onset, but not the location of the shocks, which emerge for all cases from the subsonic region between the two jets.

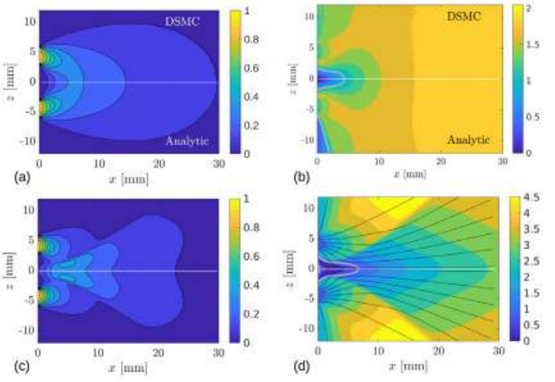
DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-

Geometry and modeling of a continuous Physical Vapor Deposition apparatus



Normalised density and Mach number contours for collisionless flow (a),(b) and for a stagnation Knudsen number of Kn=0.0665 (c),(d). Gray lines denote isoline for Ma=1, black lines the streamlines.



Project Aim

Experimentally study of the local mass transfer phenomena and its implications on the global transport process in a dense bubbly flow. Local experimental techniques, such as optical probes, are slow and intrusive. Laser-based techniques for simultaneous flow and mass transfer are relatively new and need to be further developed at local bubble level, before its use in dense flows. A multiscale approach is used: from bubble-bubble interaction studies to swarm flows. This is done by a combination of intrusive probes and non-intrusive (X-ray) imaging techniques.

Progress

The focus was on studying the interplay between the hydrodynamics and mass transfer in dilute bubble flows (gas fraction below 6%). Mass transfer of CO2 bubbles to water with up to 1M NaCl, was used, in order to better understand the effect of bubble shrinkage (due to CO2) and coalescence inhibition (due to electrolyte). Due to shrinkage, bubble size distribution becomes bimodal leading to large changes in the flow dynamics, with the appearance of large recirculation zones, as shown in the figure, which enhances mixing, leading to an higher mass transfer.

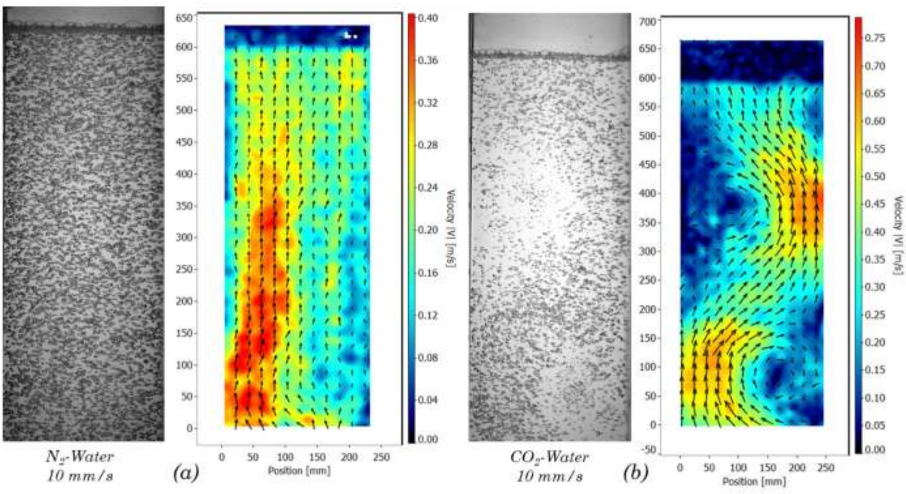
Dissertations

-

Scientific Publications

1. Mandalahalli, MM, Wagner, EC, Portela, LM, Mudde, RF. Electrolyte effects on recirculating dense bubbly flow: An experimental study using X-ray imaging. AIChE J. 2020; 66: e16696 (published online in August 2019).
2. Mandalahalli, MM, Wagner, EC, Portela, LM, Mudde, RF. Experimental data: Electrolyte effects on hydrodynamics in an airlift bubble column, 4TU Open data Publication.

Snapshot of bubble distribution (left) and Bubble Image Velocimetry (right) in a flat bubble column with superficial gas velocity Vsg =10 mm/s: (a) N2; (b) CO2.



Project leaders

Prof. Rob Mudde, Dr. Ir. Luis Portela

Research theme

Complex structures of fluids

Participants

Ir. Manas Mandalahalli (PhD/TUD)

Cooperations

Prof. Hans Kuipers (TUE)
Prof. Detlef Lohse (UT)
Prof. Martin van Sint Annaland (TUE)
Dr. Ivo Roghair (TUE)
Dr. Bert Vreman (Akzo Nobel)
Dr. Peter Veenstra (Shell)
Dr. Patrick Wenmakers (DSM)
Dr. Christoph Dittrich (SABIC)
Ir. Dirk van der Plas (Tata Steel)

Funded by

NWO-IPP i36

Funded %

University	-
FOM	50 %
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

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X-ray tomography and SPECT imaging of dynamic structures in opaque multiphase flow

Project leaders
Dr. Luis Portela

Research theme
Complex structures of fluids

Participants
Prof. Ruud van Ommen (TUD)
Ing, Evert Wagner (TUD)

Cooperations
-

Funded by
TU Delft

Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2007

Information
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Project Aim

To develop a fast X-ray tomography setup combined with SPECT particle tracking to measure velocities and structures inside opaque multiphase flows. The X-ray is sensitive to the phase distribution, whereas SPECT tracks radiating particles in a multiphase system. We collaborate with various groups within and outside of TUD, who use this unique measurement technique in their research.

Progress

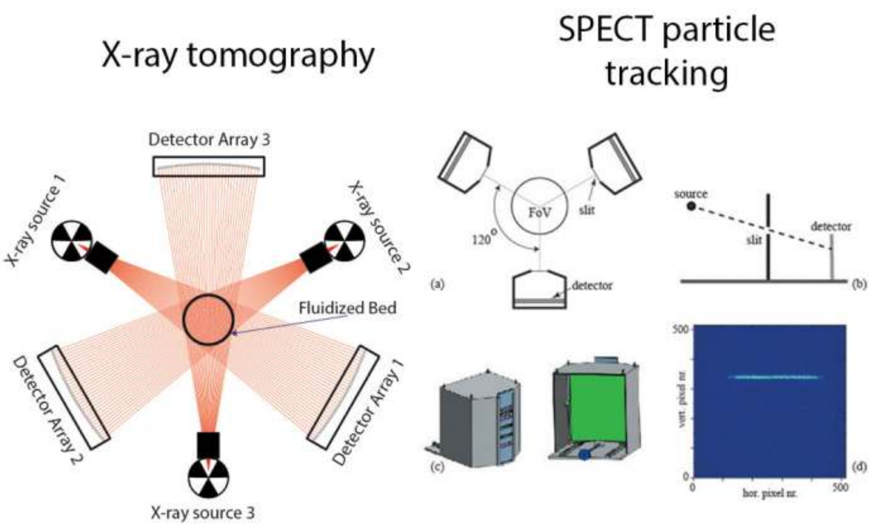
Work during 2019 include: gas distribution & bubble velocity measurements in collaboration with DSM; gas void fraction measurements in cavitation systems (TUD-3mE, Poelma); bubble size & velocity measurements in a fluidized bed comparing spherical and elongated particles (TUD-3mE, Padding). Together with CWI, we are further developing the algorithmic reconstruction techniques, with the goal of doing time resolved 3D reconstructions of bubbling fluidized beds.

Dissertations

-

Scientific Publications

1. Mean Flow Field Measurements in Cavitating Flow Using Magnetic Resonance Velocimetry Supported by X-Ray and Particle Image Velocimetry. Kristine John, Martin Bruschewski, Saad Jahangir, Willian Hogendoorn, Evert C Wagner, Robert F Mudde, Christian Poelma, Sven Grundmann. Bulletin of the American Physical Society 64.
2. Void fraction measurements in partial cavitation regimes by X-ray computed tomography. S Jahangir, EC Wagner, RF Mudde, C Poelma. International Journal of Multiphase Flow 120, 103085.
3. Fluidization dynamics of cohesive Geldart B particles. Part I: X-ray tomography analysis. J Ma, JR van Ommen, D Liu, RF Mudde, X Chen, EC Wagner, C Liang. Chemical Engineering Journal 359, 1024-1034.



Project Aim

This project is part of a large EU consortium on Tomography and Control , TOMOCON (website: www.tomocon.eu), which aims to bring "smart control" to the process industry. It is a proof of concept of tomography for real-time process-based control of a swirl fluid separator. Experiments will be combined with numeric simulations (by INTP) to develop a reduced order (mechanistic) model of the flow, which can be computed in real-time. A controller will be designed based on the model, and implemented in a loop built for the project, using Wire-Mesh Sensor, WMS, (by HZDR) and Electrical Resistance Tomography, ERT, (by TU Lodz) sensors to monitor the separation.

Progress

The flow facility was designed and it is currently under construction. Some experiments were performed in a simplified version of the facility (located at TU Lodz) to evaluate the performance of the Electrical Resistance Tomography when measuring the distribution of phases, and to start studying the behavior of the mixture in the presence of swirl. The results obtained are currently being processed. In parallel, a mechanistic model of the flow is being developed and RANS simulations using ANSYS Fluent are being performed.

Dissertations

-

Scientific Publications

-

Project leaders

L. M. Portela

Research theme

Complex dynamics of fluids

Participants

Matheus. M. Garcia

Cooperations

Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Institut National Polytechnique de Toulouse (INPT) Lodz University of Technology (TU Lodz), Teletronic Rossendorf GmbH CERG Fluides S.A.S., Frames Group B.V., Linde AG, Total S.A. Shell Global Solutions International BV

Funded by

Marie Skłodowska-Curie actions (TOMOCON)

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2019

Information

Matheus Martinez Garcia
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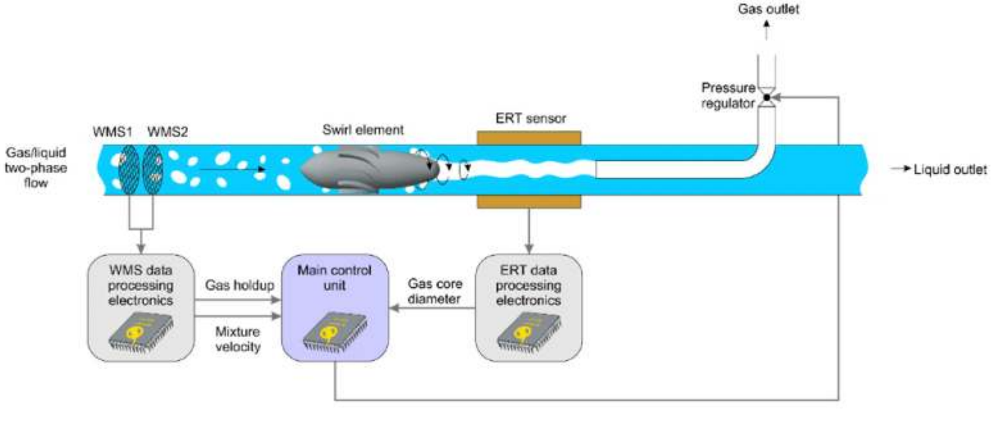
Schematic overview of the inline swirl fluid separator and its tomography-based control.



Flow structures and organization in turbulence: a structure perspective on turbulence dynamics

Project leaders
L. M. Portela
Research theme
Complex dynamics of fluids
Participants
Siddartha Mukherjee
Cooperations
-
Funded by
TU Delft
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2018
Information
Luis M. Portela
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Project Aim

Study the dynamics of turbulent flows from a structure perspective, using generalized correlation and Helmholtz decomposition concepts. The usual governing equations provide a point-wise description of the flow dynamics, involving local derivatives. A structural perspective can describe turbulence (and dynamical vector fields in general) at a higher level of abstraction, allowing us to grasp large-scale features and emergent behavior at a higher level of organization.

Progress

The basic theoretical and analytic framework associated with the use of generalized correlation and Helmholtz decomposition concepts was finalized and implemented into a computer code, which was used in homogeneous isotropic turbulence simulations. Our results show that high kinetic energy structures are jet-like and are externally induced by intermediate range vorticity, while high enstrophy structures are a superposition of externally-induced and self-induced velocity. Our results hint at an alternative view of turbulence organization, as an emergent phenomena, without a strict hierarchy of scales.

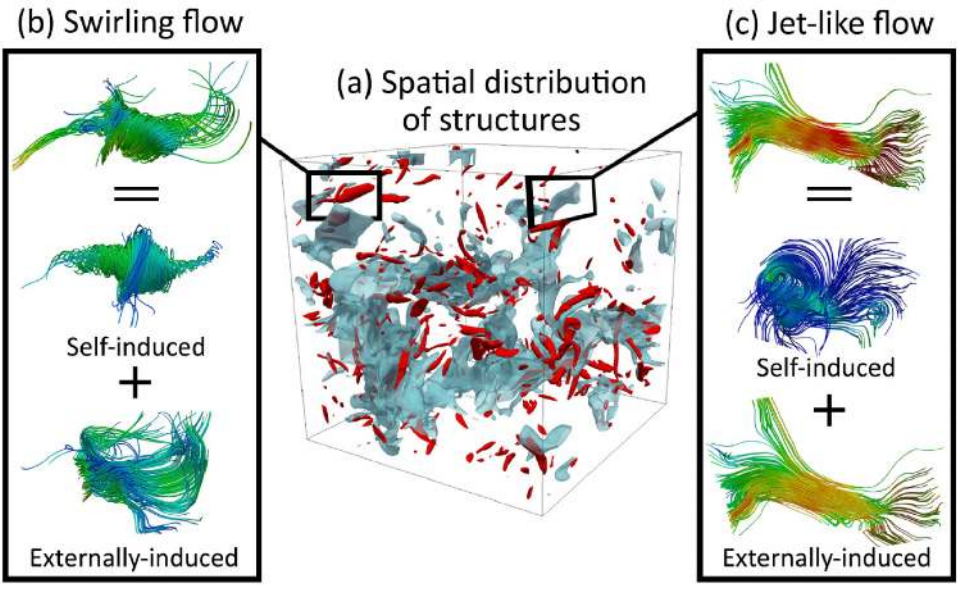
Dissertations

1. S. Mukherjee. Unravelling Turbulent Emulsions with lattice-Boltzmann Simulation, Chapter 4: A Structural View of Turbulence (to be submitted to Journal of Fluid Mechanics). Ph.D. Thesis. TU Delft, 2019.

Scientific Publications

-

Left: High enstrophy swirl structure. Right: High kinetic energy jet-like structure



PROJECT AIM

Use advanced numerical simulation techniques, like DNS and LES, together with some modelling, to isolate the different mechanisms in gas-liquid annular flow, in order to get a better understanding of its dynamics,. Use this understanding to develop simple engineering models. The project is a continuation of the Ph.D. work of Galileu Oliveira, who had to resume his activities as an engineer at Petrobras; he is now working part-time in the project.

PROGRESS

A space-time correlation analysis of the flow was performed, using DNS. Two different interaction mechanisms were mimicked, by imposing different boundary conditions at the interface between the gas core and the film at the wall: suppression of radial velocity (impermeable interface) and/or step change in the viscosity. The results show that the film dynamics is controlled by the turbulence dynamics in the buffer layer in the gas core, as indicated, e.g, by the shear-stress propagation velocity, shown in the figure.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. G. H. Oliveira and L. M. Portela. Core-Film-Wall Interactions in Annular Pipe-Flow: A Numerical Study Using Space-time Correlations. Proceedings of the 10th International Conference on Multiphase Flow, held in Rio de Janeiro, Brazil, May 19-24, 2019.

PROJECT LEADERS

L.M. Portela

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Galileu Oliveira (Petrobras engineer)

COOPERATIONS

Petrobras

FUNDED BY

Petrobras

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2015

INFORMATION

L.M. Portela
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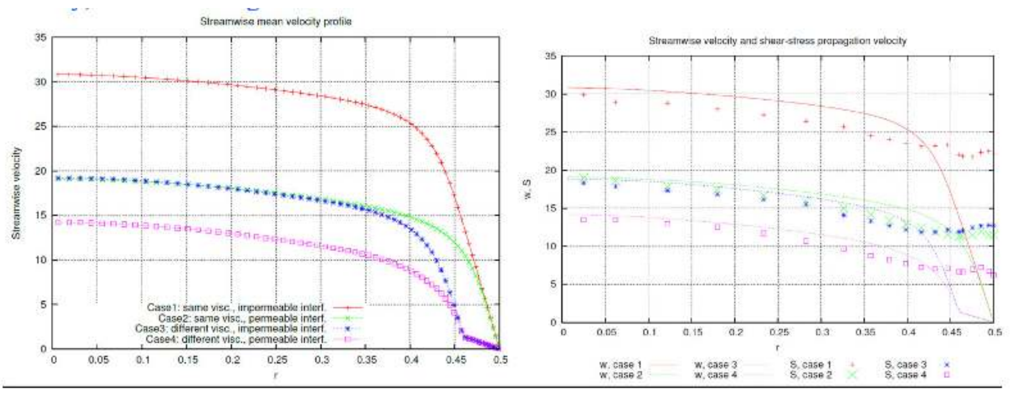
Streamwise velocity and shear-stress propagation-velocity obtained from the space-time correlation. The interface is located at a non-dimensional radial position r=0.46 and the velocities are expressed in wall-units.



Interplay between hydrodynamics and mass transfer in bubbly flows: From dilute to dense

Project leaders
Luis M. Portela
Research theme
Complex dynamics of fluids
Participants
Debasish Sarker
Cooperations
Nouryon, DSM, Sabic, Shell, Tata, NWO
Funded by
NWO
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019
Information
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Project Aim

Understand and quantify the effect of the gas fraction distribution on the overall mass transfer, through its effects on the interfacial area and hydrodynamics. Untangling their effects will provide a better understanding of the physics of dense bubbly flow. Experiments are performed in a pseudo-2D bubble column filled with water, with different patterns of N2 and CO2 bubbles injected at the bottom. Optical-based and X-ray imaging techniques, along with a pH probe to measure the dissolved CO2, are used.

Progress

The focus was on experiments for dilute bubbly flow. The gas injection pattern was fixed with a combination of three groups of needles (Fig. 1). Synchronized optical shadowgraphy and particle/bubble image velocimetry techniques were employed, to simultaneously obtain (i) the bubbles distribution, (ii) the bubbles velocity and (iii) the liquid velocity. An additional high-speed video camera records the detail information of the bubbles at the sparger. An example of the results obtained is shown in Fig. 2.

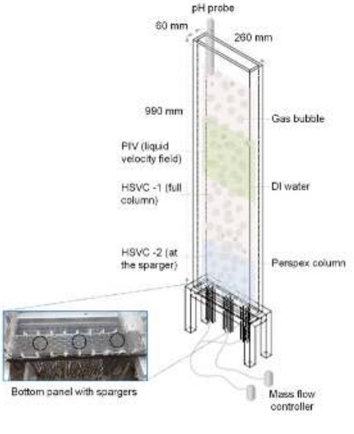
Dissertations

-

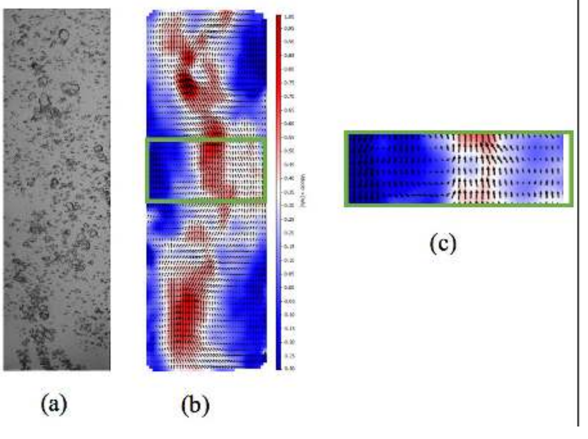
Scientific Publications

-

A rectangular 2D bubble column.



Bubble shadowgraphy (a), bubble velocity field (b), and liquid velocity field (c), for N2 injection through all plumes, at Vg = 0.0157 m/s.



PROJECT AIM

Use sophisticated numerical simulation techniques, like DNS and LES, to improve the modelling and simulation of sediment transport using simpler engineering simulation tools (like two-fluid models and simple quasi-1D models).

PROGRESS

The consequences of the particle dynamics on two-fluid models was carefully evaluated and quantified, using point-particle DNS. The results show that the particle Reynolds stresses closely resemble the fluid Reynolds stresses, indicating that algebraic particle Reynolds stress models are more suitable than models based on the concept of "particle eddy-viscosity". A paper was submitted to International Journal of Multiphase Flow.

DISSERTATIONS

1. H. H. Shin. Resuspension Model for Point-Particle Direct Numerical Simulation of Sediment Transport in Turbulent Open Channel Flow. Ph.D. Thesis. Polytechnic School, National University of Asuncion, Paraguay.

SCIENTIFIC PUBLICATIONS

1. H. H. Shin, L. M. Portela, C. E. Schaerer and N. Mangiavacchi. Point-Particle Large-Eddy Simulation of Sediment Transport and Resuspension. Proceedings of the 10th International Conference on Multiphase Flow, held in Rio de Janeiro, Brazil, May 19-24, 2019.

PROJECT LEADERS

L.M. Portela, Christian Schaerer, Norberto Mangiavachi

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Hyun Shin (Ph.D. student)

COOPERATIONS

State University of Rio de Janeiro
National University of Asuncion

FUNDED BY

-

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT

2015

INFORMATION

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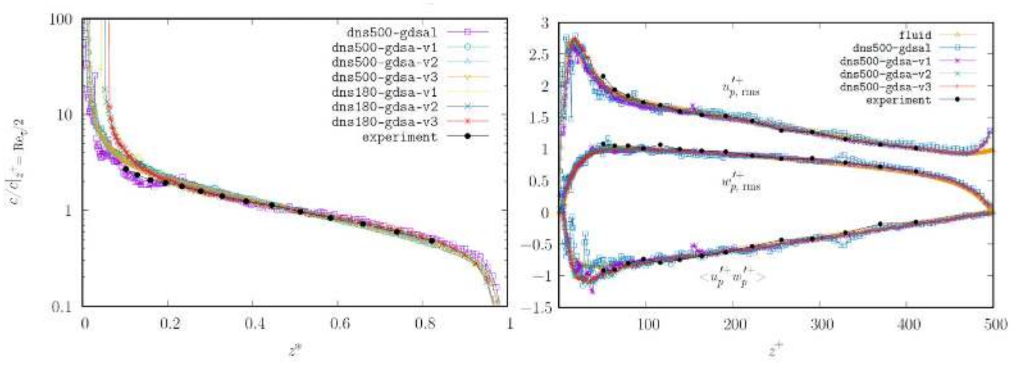
Profiles of particle concentration (left) and particle Reynolds stresses (right), for different particle-force and wall-resuspension models



Computational scale-up/scale-down simulator for industrial fermenters

Project leaders
L. M. Portela
Research theme
Complex dynamics of fluids
Participants
Peng Wei
Cooperations
DSM, TUD Biotech Dept., University of Stuttgart, University of Liege, Syngulon, Centrient Pharmaceuticals
Funded by
ERA CoBiotech
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2018
Information
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Project Aim

The project is embedded in a large EU consortium, ComRaDes (Computation for Rational Design: From Lab to Production with Success). The overall goal of the consortium is to develop a model-based platform to ramp up the scale-up/scale-down techniques currently used in bio-fermenters, which are based on empirical criteria. The focus of this project is on the systematic development of an integrated computational fluid/reactor dynamics (CFD+CRD) simulator, which will be built using ANSYS Fluent.

Progress

The existing simulator, for a bubble-gassed stirred reactor with a dual-impeller, developed in the predecessor of this project, was expanded, in order to compute the dissolved-oxygen and the strain-rate lifelines (time-series "seen" by the micro-organisms), which can play an important role in the metabolism. Grid sensitivity and accuracy tests were performed and some preliminary results were obtained.

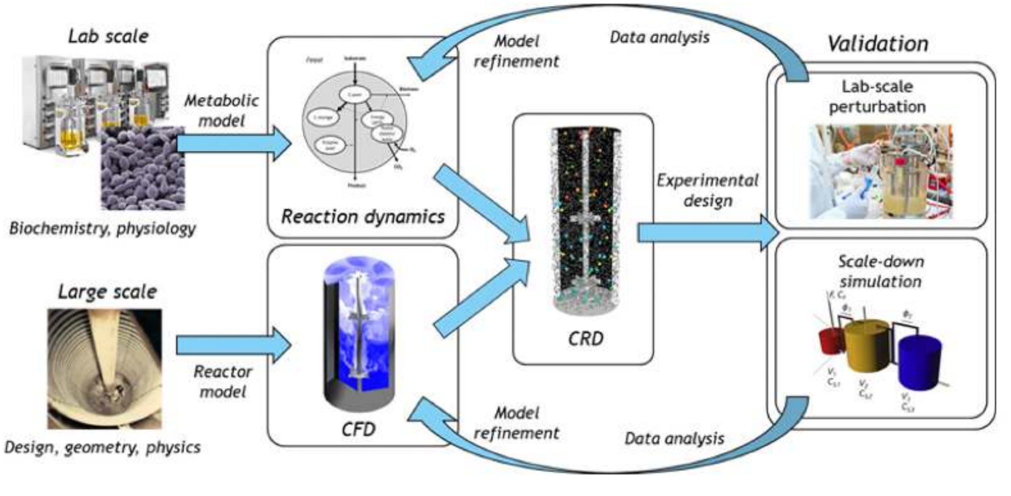
Dissertations

-

Scientific Publications

-

Schematic representation of the goals and approach used in ComRaDes



PROJECT AIM

Develop physically-based simple engineering models for the deposition of asphaltenes in pipelines.

PROGRESS

The previously developed simplified population balance model was extended, leading to a transport equation for the particle size distribution over the entire cross-section and length of the pipe. The resulting equations were solved using a quasi-1D approach and the Direct Quadrature Method of the Moments. The validity of the quasi-1D approach was checked by comparison with ANSYS Fluent, and the deposition results of the particle model were compared with a benchmark test case for an actual oil well.

DISSERTATIONS

1. M. Barazandeh. Quasi-1D Modelling of Particle-Laden Internal Turbulent Flows with Nucleation, Agglomeration and Breakup: Application to ASphaltenes Deposition in Oil Wells. M.Sc. Thesis. Delft University of Technology.

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

L.M. Portela

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Marisa Bazzi, Mohsen Barazandeh

COOPERATIONS

Petrobras

FUNDED BY

-

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT

2015

INFORMATION

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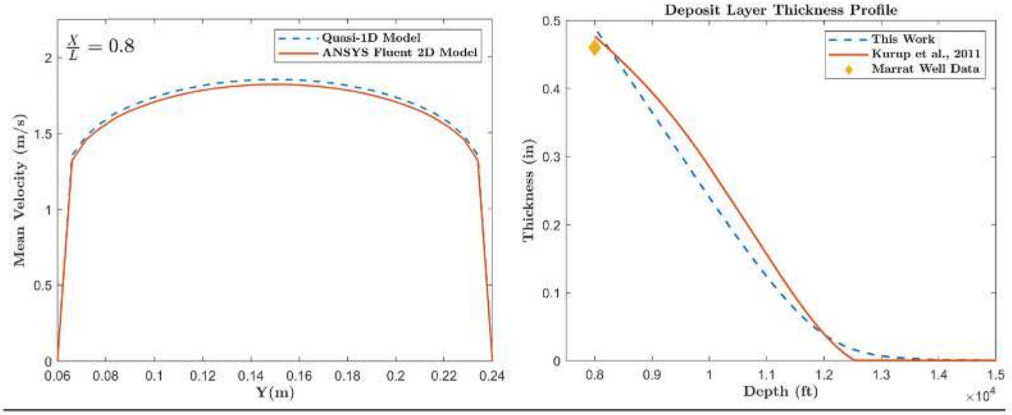
Left: Comparison between the turbulent fluid velocity profiles for the quasi-model and ANSYS Fluent, in a 2D flow contraction, from 0.3 m to 0.15 m over a distance L=100 m. Right: Comparison with a benchmark test case, in a vertical oil well, of the thickness of the deposition layer after two months of oil production, showing a good agreement both with the experimental data and an empirical model fitted to the well data (Kurup et al. Energy & Fuels 25, pp. 4506-4516, 2011).



LOCAL pH AND ION CONCENTRATION IMAGING FOR ELECTROCHEMICAL CO2 REDUCTION

PROJECT LEADERS
Chris Kleijn, David Vermaas

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Lorenz Baumgartner

COOPERATIONS
-

FUNDED BY
EU

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

START OF THE PROJECT
2018

INFORMATION
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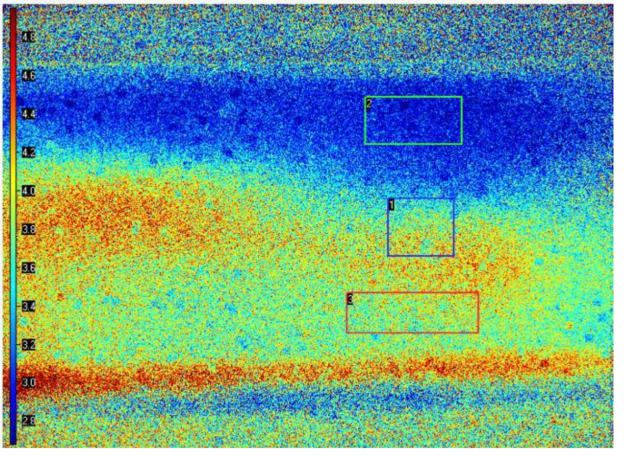
PROJECT AIM
- Improve understanding of transport phenomena in CO2 electrolyzers to facilitate up-scaling
- Online imaging of local pH and ion concentrations with Fluorescence Lifetime Imaging (FLIM).

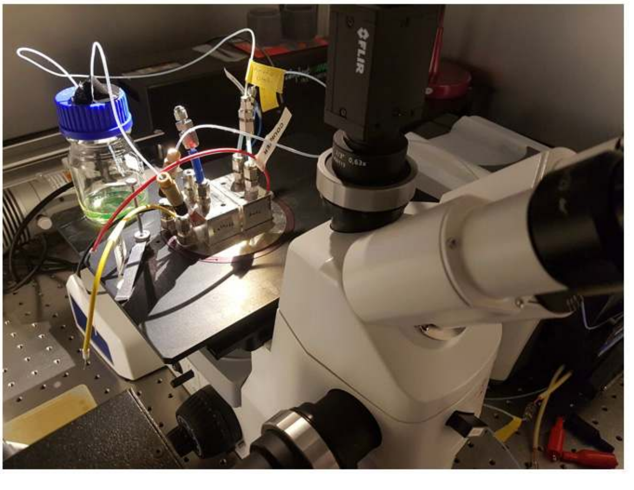
PROGRESS
- Demonstrated proof of concept with water electrolysis cell
- Selected suitable fluorescence dyes and FLIM equipment for further experiments.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-



Measurements of fluorescence lifetime allow to image the local pH values. The release of OH- ions at the cathode in a water electrolysis cell (bottom of image) leads to an increase in fluorescence lifetime (red).



The integration of an electrochemical flow cell with a time-resolved fluorescence microscope allows online imaging of local reaction environments

Membrane Electrode Assemblies (MEAs) for stable alkaline CO2 electrolysis

Project Aim

The anion-exchange membranes which are currently used in CO2 reduction cells carry some flaws such as lack of stability in alkaline conditions, or ion-selectivity and a cause for ohmic losses. Solving these issues could potentially make CO2 reduction an economically viable process. Charged inorganic nanoporous materials can be used as an alternative to polymeric IEMs. Their usage for ion transport is a fairly unexplored concept and relies on the ion selectivity in the double layer. This project will explore the relation between pore size, applied potential, surface charge of a material and selectivity of the developed membrane, with the aim of incorporating it into a CO2 reduction cell.

Progress

As I started in mid-November, 2019 was solely dedicated to literature analysis

Dissertations

-

Scientific Publications

-

Project leaders

David Vermaas, Bernard Dam

Research theme

Complex structures of fluids

Participants

-

Cooperations

TOeLS Project

Funded by

TKI and Shell

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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Project leaders
Dr. Valeria Garbin

Research theme
Complex dynamics of fluids

Participants
Dr. Brice Saint-Michel

Cooperations
Imperial College London (Chem. Eng.), University of Patras (Chem. Eng

Funded by
European Research Council (ERC)

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2016

Information
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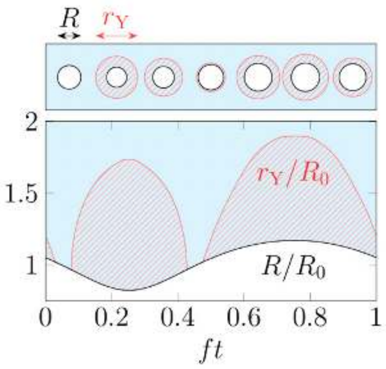
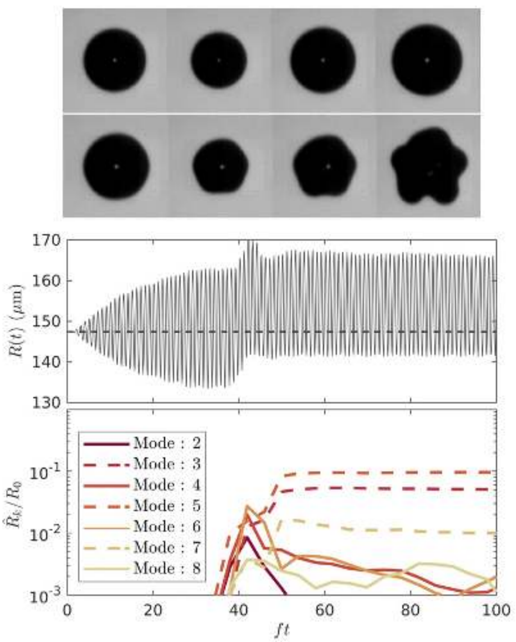
Project Aim
Yield-stress fluids behave as solids under a critical stress and naturally entrap bubbles. Driving the bubbles into oscillations is routinely used to remove bubbles from these fluids but the assisted release mechanism remains unclear. Our project investigates theoretically, numerically and experimentally how oscillating bubbles interact with such fluids. We wish to obtain a relevant, quantitative bubble release criterion; we also wish to use the oscillating bubbles as local probes of the fluid.

Progress
The numerical and theoretical analysis has been published in 2019. We compared linear and non-linear bubble oscillations dynamics both using a recent visco-elasto-plastic model to describe the yield-stress fluid. It defines a bubble release criterion release and the extent of the yielded region rY. Experiments have been conducted in a model fluid and the bubble properties (radius, position, shape) carefully measured. They underline the merits of the numerical model in the linear regime and its limitations for bubble release.

Dissertations
-

Scientific Publications
1. M. De Corato, B. Saint-Michel, G. Makrigiorgos, Y. Dimakopoulos, J. Tsamopoulos and V.Garbin, “Oscillations of small bubbles and medium yielding in elastoviscoplastic fluids”, Physical Review Fluids 4(7), 073301 (2019).





Prof.dr.ir. R van Ommen

Product and process engineering

The Product and Process Engineering (PPE) of the ChemE department of TU Delft views chemical engineering as an expanding field full of opportunities to create devices, processes and products. With expertise in reaction engineering, fluid mechanics and transport phenomena, we create solutions for soft-matter, nanotechnology, energy and lab-on-chip applications, often together with chemistry, physics and life-science groups. For us, engineering implies out-of-the-box thinking and design, from a sound basis in natural sciences with mathematics rigor. We are interested both in computational approaches and experimental work.

An important part of our work is related to the flow of droplets and bubbles in microchannels, with the aim of doing fun chemistry inside or outside those drops and bubbles. Each droplet can be seen as a miniaturized reactor that moves through a network on a chip as would a test tube through a chemistry lab. These flows are laminar, but the free interfaces bring in nonlinearities and instabilities, often driven by surface tension. Much of this work is done in cooperation with the group of prof. Chris Kleijn. There are lots of interesting chemistries that we deal with, ranging from catalysis to immiscible polymers.

Volkert van Steijn explores the use of aqueous polymer solutions to form droplets in an environment free of organic solvents and surfactants. Such droplets offer great potential for biomedical applications as they are fully biocompatible. In addition, he investigates the possibilities of using microfluidic devices for cell cultures.

Pouyan Boukany uses nanofluidics-based devices for providing quantitative insights into the fundamental mechanism of drug delivery, disease treatment, gene therapy and response of individual cells to therapeutic/biomolecular reagents. In addition, he aims to understand the molecular dynamics of complex fluids using DNA as a model and advanced visualization techniques.

Ruud van Ommen is devoting an important part of his research efforts to dense gas-solid flows, where the solid phase consists of nanoparticles. In these systems, the nanoparticles cluster to form large, high-porosity agglomerates with fascinating interactions and flow properties. The aim is to chemically coat all individual nanoparticles in these agglomerates. He also studies gas-solid fluidized beds and three-phase systems with micron-sized particles, especially monitoring and structuring of these systems.

Gabrie Meesters is focusing his research on particle technology and product development. Complex multiphase flows involving particles and/or droplets are investigated, often in collaboration with industry. The relation between processing conditions and final products properties is a crucial part of this work.

PROJECT AIM

To develop a better understanding of agglomeration behavior in spray drying processes, by studying the drying and collision behavior of drying droplets. Develop relations of drying temperature, dry matter content, and initial droplet size to the spatio-temporal concentration gradient and the resulting morphology. Develop relations of drying temperature, dry matter content, and initial droplet size to the collision behavior of partially-dried droplets against solid objects. Additionally, the aim is to reduce the droplet size of testing to small droplets (< 200 μm) and higher temperatures to better mimic spray drying.

PROGRESS

Two collision setups are in being designed for testing the collisions.

Falling droplet dryer: A monodisperse stream of droplets falls through a glass column. A countercurrent nitrogen flow is present that can be heated before entry. Objects can be inserted into the side of the glass column to collide with the drying droplets. Particle ejector: A particle ejector has been made and is used to eject solid particles against a drying droplet on a substrate. An example is shown in Fig 1. Sticking conditions were investigated by comparing the theory for liquid bridge formation from sintering with the sticking conditions found for various stickiness measuring methods. The concepts of contact time between two sticking particles and the temperature elevation above the glass transition temperature are used to assess stickiness. For studying the droplet evaporation of small droplets at higher temperatures we use droplet microfluidics. The used configuration is liquid-in-gas microfluidics. Water droplets were successfully made in a flow-focusing junction. Solute-containing droplets had problems with sticking to the channels of the chip. Wall modification through chemical coating and structuring has been used to decrease liquid-wall adhesion. Successful modification lead to weakened binding of the two chip layers, which causes leakages. Hence, this approach has been unsuccessful. A processing method using Optical Coherence Tomography scans is used to determine the diffusion coefficient gradient in an evaporating droplet with several micron-resolution. When the relation of concentration to viscosity is known a concentration mapping can be done using this relation and the Stokes-Einstein equation.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

Dr. Ir. Volkert van Steijn
Prof. Dr. Ir. Ruud van Ommen

RESEARCH THEME

Complex structures of fluids

PARTICIPANTS

E.J.G. Sewalt (PhD candidate)

COOPERATIONS

FPE-WU, P&E-TUD, STW, Nutricia Research, DSM, Tetra Pak, General Electric

FUNDED BY

STW, Nutricia Research, DSM, Tetra Pak.

FUNDED %

University	-
FOM	-
STW	73 %
NWO Other	-
Industry	27 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2017

INFORMATION

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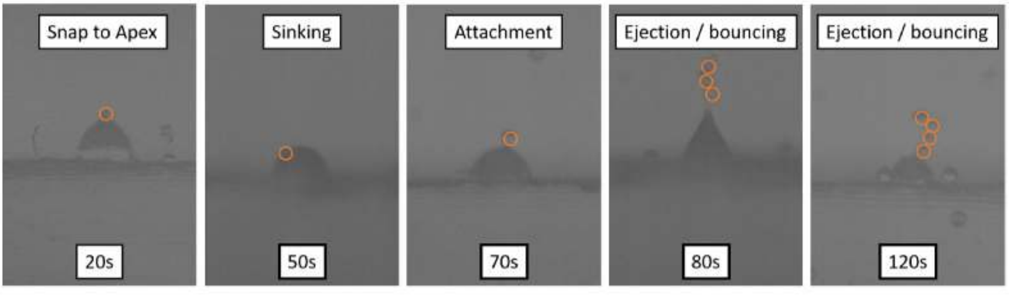
Collisions of glass spheres (125-150 μm) against droplets with maltodextrin DE12 15 wt% (di = 400 μm) on a superhydrophobic substrate. A description of the collision event is shown as well as the drying time at room temperature.



Large scale modelling of electrochemical reduction of carbon dioxide to ethylene

Project leaders
Ruud van Ommen, Volkert van Steijn
Research theme
Complex dynamics of fluids
Participants
-
Cooperations
-
Funded by
NWO (Project: Electrons to chemical bonds)
Funded %

University	-
FOM	-
STW	-
NWO Other	70 %
Industry	30 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019
Information
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Project Aim

Investigate gas-liquid reactors for the use of electrochemical reduction of carbon monoxide. Study the effect of gas evolution on the reactor performance and access how the reactor design and operating conditions dictate the reaction environment. Translate this knowledge to a large scale approach.

Progress

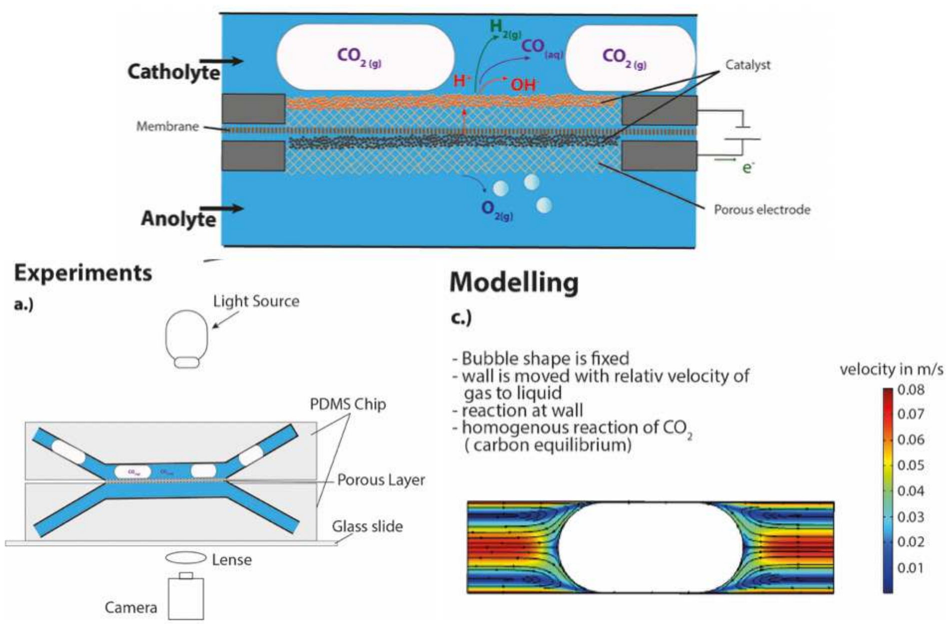
Experimental set-up and numerical model to study the effect of gas-liquid Taylor flow in electrochemical cells.

Dissertations

-

Scientific Publications

-



Development of droplet micro reactor for industrial relevant microbe screening

Project Aim

This project aims at development of a Lab on a Chip platform for performing high throughput screening of microbes under industrially relevant conditions. In current biotechnology practice screening of microbes is done in batch mode, while most industrial reactors operate in fed-batch mode. It is well established that the performance of microbes in nutrient rich environments differs from the performance in nutrient poor environments, explaining the limited success in microbe development. We address the lack of equipment to screen at fed-batch conditions by developing a microfluidic device where mutants grow in droplets, which can be periodically fed with nutrients to establish fed-batch conditions. By doing so, we wish to provide the same physiological environment to microbes during screening as it would have during the growth in the industrial fermentor.

Progress

This part of the project is dedicated to addressing the feeding part. Once the microbes are trapped inside a droplet it is important to develop a robust method to feed this cell containing droplet with nutrient droplets. In order to add defined volumes and concentration of nutrients, a droplet on demand method is established. This method ensures on demand generation and transport of monodisperse droplets which would form these nutrient droplets. The droplet on demand generator consists of a T shaped junction. This junction is modified with a nozzle of a smaller size and height. The junction also includes a trap which confines the droplet. The height difference of the trap and main channel ensures the droplet is contained in the trap due to minimization of the surface energy. Fig.1 shows the droplet on demand formation process. Initially both oil /water pressure are balanced such that the interface rests at the nozzle. When the water pressure increases slowly the interface starts moving in the trap and fills the trap. In case the droplet phase exceeds the trap the curved edges and higher curvature in the trapping area enables relaxation of the droplet phase. Once the trap volume is completely filled, the oil pressure is increased to pushed the droplet out. This single DOD generator design is also scaled out to produce 8 droplets on demand in parallel. The generator is also been characterized for different pulse pressures, working fluids and waiting time between the generated droplets. A Further scale out to 64 parallel DoD generator shows that all generators produce droplets with a volume between 91% and 105% of the predesigned volume. We conclude by presenting a simple droplet-based assay in which the DoD generator enables sequential supply of reagent droplets to a droplet stored in the device, illustrating its potential to be used in droplet-based assays for biochemical studies under non-steady operation.

Dissertations

-

Scientific Publications

-

Project leaders

Dr. Ir. Volkert van Steijn, Prof. Dr. Ir. Michiel .T. Kreutzer, Dr. Walter van Gulik

Research theme

Complex dynamics of fluids

Participants

Kartik Arun Totlani (PhD Student)

Cooperations

-

Funded by

NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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Kartik Arun Totlani
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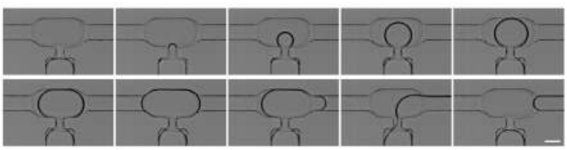

Grey scale images showing formation of Droplet on demand

Understanding the role of actin networks on uptake of small molecules to mammalian cells during electroporation

Project leaders
Dr Pouyan E. Boukany

Research theme
Complex structures of fluids

Participants
-

Cooperations
-

Funded by
ERC

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2017

Information
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http://cheme.nl/ppe/people/boukany.shtml

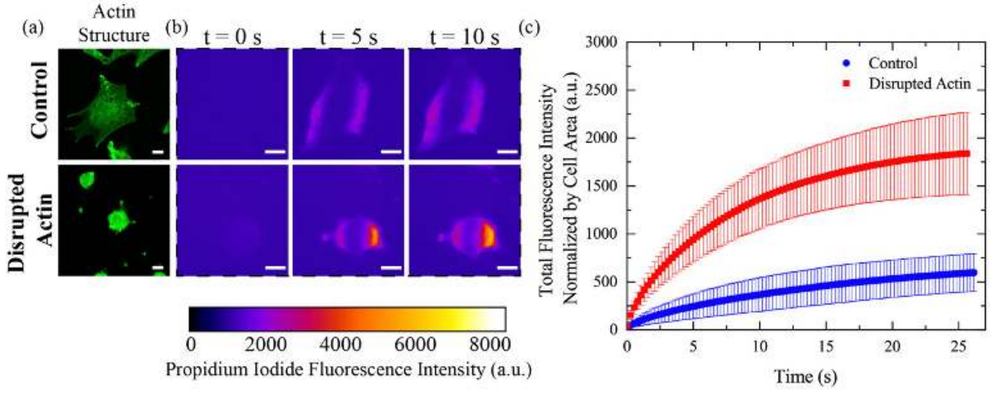
Project Aim
This project aims at studying the role of actin networks, one of the cytoskeletal proteins present beneath the cell membrane on the uptake of small molecules to living cells during electroporation. Current theoretical frameworks for studying electroporation have been developed for simplified membrane systems like lipid bilayers and the predictions are inconsistent with the experiments done on living cells. We aim to provide experimental data, for living cells and cells with disrupted actin networks that will provide information for developing more accurate theoretical frameworks for predicting cellular responses to external electric fields.

Progress
To study the role of actin, we compare the fluorescence intensity emitted by propidium iodide (a marker molecule which emits a strong fluorescent signal when it enters the cell) during electroporation from Chinese Hamster Ovary(CHO) cells with intact actin network and chemically disrupted actin network. Our experiments show that disrupting actin networks prior to electroporation can result in increased uptake of propidium iodide to CHO cells during electroporation. We also perform the same experiments at different temperatures to correlate our data to the classical nucleation theory of electroporation.

Dissertations
-

Scientific Publications
1. Perrier, Dayinta L., et al. "Response of an actin network in vesicles under electric pulses." Scientific reports 9.1 (2019): 1-11.

(a) Structure of actin networks (in green) from control CHO cells and cells with disrupted actin. (b-c) Uptake of propidium iodide after applying an electric pulse of 800V/cm for 500 µs.



Improving fluidization and conformal coating of ultrafine pharmaceutical powders in fluidized beds by ALD (atomic layer deposition)

Project Aim

1] Developing novel approaches to enhance the fluidization of cohesive pharmaceutical powders.

2] Optimizing operating conditions (vibration/stirring/air jet) to get proper fluidization, so as to improve coating quality of ultra-fine powders.

4] Minimizing the formation of agglomerates.

5] Improving bulk powder properties (e.g., flowability and dispersibility).

6] Unraveling the dynamic mechanism of the formation of agglomerates in the fluidized bed reactor.

Progress

1] Set-up and modification of the experimental device – an ALD (atomic layer deposition) coating within a vibrated fluidized bed reactor.

2] Explored the fluidization behavior of serval kinds of ultra-fine powders under the coupled effects of vibration and gas (Nitrogen) flow.

3] Completed the characterization of particles' physics properties before and after coating (particle size distribution/morphology analysis).

Dissertations

-

Scientific Publications

1. Zhang, D., La Zara, D., Quayle, M. J., Petersson, G., van Ommen, J. R., & Folestad, S. (2019). Nanoengineering of Crystal and Amorphous Surfaces of Pharmaceutical Particles for Biomedical Applications. ACS Applied Bio Materials, 2(4), 1518-1530.

Project leaders

Prof. Ruud van Ommen

Research theme

Complex dynamics of fluids

Participants

Fuweng Zhang, Damiano La Zara, Feilong Sun

Cooperations

AstraZeneca

Funded by

AstraZeneca, Health Holland

Funded %

University	20 %
FOM	-
STW	-
NWO Other	-
Industry	60 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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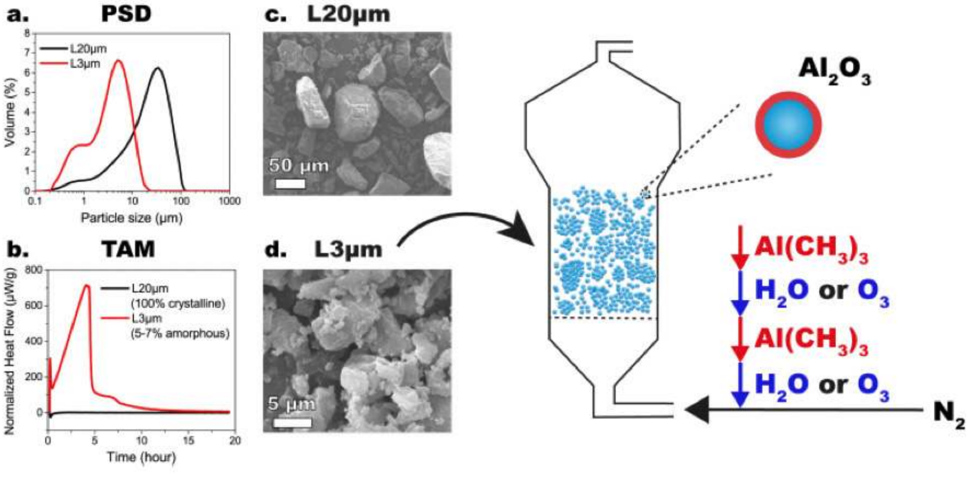

Numerical analysis

Prof.dr.ir. C Vuik

Prof.dr.ir. CW Oosterlee

The research program of the Numerical Analysis group of TUD belongs to the field of computational science and engineering. We concentrate on the development and application of computing methods to the applied sciences. The focus is on mathematical models relying heavily on partial differential equations, such as occur in fluid dynamics. But we also consider similar mathematical models arising in other fields, for instance materials science and reservoir engineering, usually in cooperation with domain experts. A specialty is problems involving partial differential equations with moving internal boundaries, such as occur in bubbly flows and in phase transition problems. To diminish computing time in large-scale applications, iterative methods for solving large systems of algebraic equations are developed further, using deflation, multi-block, preconditioning and multigrid techniques.

Finally, these methods are implemented on modern hardware, clusters of PC's, GPU's and FPGA's. In order to achieve good results also HPC research is done in our group.

PROJECT AIM

The purpose is to improve efficiency of solution methods in computational fluid Dynamics, porous media flow and related applications. The DICCG (deflated preconditioned conjugate gradients) method will be developed further. The method will be generalized such that reliable termination criteria can be applied. Domain subdivision methods will be developed to make DICCG applicable.

PROGRESS

The SEPRAN code is parallelized and works efficiently on parallel platforms. More and more users are simulating with the parallel version. This leads to useful feedback in order to enhance the solver. Theoretically the deflation acceleration is compared with an additive coarse grid correction and a balancing Neumann Neumann preconditioner. It appears that the deflation method leads to the fastest convergence, whereas the work per iteration is less or equal to the other methods. Many (in)compressible Navier-Stokes equation solvers use a splitting method to solve the discretized equation. In many applications, especially in bubbly flows, the pressure equation takes most of the time to be solved. One of the reasons is the jump in the density in gas and water. Multi grid methods can be used but some difficulties remain if the size of the bubbles is very small. In this project the pressure equation is solved by the deflated ICCG method. After optimization it appears that the resulting method is 4-5 times faster than the ICCG method. We plan to make a better choice of the projection vectors and try to combine it with domain decomposition and parallel computing.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

C. Vuik, A. Segal

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

C.Vuik, A. Segal, J.M. Tang,
R. Nabben

COOPERATIONS

TU Eindhoven, Sepra, TNO-Science and Industry, TU Berlin

FUNDED BY

TUD, TNO-TPD, BRICKS

FUNDED %

University	25 %
FOM	25 %
STW	-
NWO Other	-
Industry	25 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

1996

INFORMATION

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PROJECT LEADERS
C. Vuik
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
C. Vuik, S. Maclachlan, Geenen, A. Segal, P. van Slingerland
COOPERATIONS
TNO-Science and Industry
Utrecht University, Sepra Tufts University USA, Marin
FUNDED BY
STW, TUD, TNO-Science and Industry, Nuffic-HEC, Marin
FUNDED %

University	25 %
FOM	-
STW	-
NWO Other	-
Industry	75 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
1992
INFORMATION
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PROJECT AIM

New preconditioners for the discretized Navier-Stokes equations will be developed. Parallel deflation methods will be included.

PROGRESS

The discrete Navier-Stokes equations are solved by the SIMPLE(R) iteration method. To decrease the very large number of iterations, we have proposed multigrid and Krylov accelerated versions: GCR-SIMPLE(R). The properties of these methods are being investigated for simple two-dimensional flows and three-dimensional flows in industrial glass melting furnaces. These methods are generalised to a colocated discretization and combined with the deflated multiblock approach and parallel computing. Now we try to generalize these solvers to our FEM discretization (SEPRAN) and compare our methods with the recently developed methods given by Elman, Wathen, Sylvester, Benzi, Reusken and Schilders. It appears that MSIMPLER, a new variant of SIMPLER, leads to the fastest results. We also develop a solver based on the Schur complement and multigrid. This method is scalable and leads to very good results for geophysical applications. The GCR-simple solver is also implemented and tested in MARIN software. This lead to a speed-up with a factor 5.

DISSERTATIONS

1. G.B. Diaz Cortes. POD-Based Deflation Method For Reservoir Simulation Prof. dr.ir. C. Vuik and Prof.dr.ir. J.D. Jansen.
2. A. Lukyanov. Meshless numericalmethods applied to multiphysics andmultiscale problems Prof.dr.ir. C. Vuik.

SCIENTIFIC PUBLICATIONS

1. B. Sereeter and W. van Westering and C. Vuik and C. Witteveen (pdf, bibtex) Linear Power Flow Method Improved With Numerical Analysis Techniques Applied to a Very Large Network Energies, 12, pp. 1-15, 2019.
2. B. Sereeter and C. Vuik and C. Witteveen (pdf, bibtex) On a comparison of Newton-Raphson solvers for power flow problems Journal of Computational and Applied Mathematics, 360, pp. 157-169, 2019.
3. A.S. Markensteijn and C. Vuik and J.E. Romate (pdf, bibtex) On the Solvability of Steady-State Load Flow Problems for Multi-Carrier Energy Systems IEEE PowerTech Conference, 2019, Milan, Italy Editors: D. Zaninelli and F. Zaninelli and S. Leva IEEE, pp. 1-6, 2019.
4. M. HosseiniMehr and R. Arbarim and M. Cusini and C. Vuik and H. Hajibeygi (bibtex) Algebraic Dynamic Multilevel Method for Fractured Geothermal Reservoir Simulation SPE Reservoir Simulation Conference, 10-11 April, 2019 Galveston, Texas, USA SPE, pp. 1-16, 2019.
5. R. Tielen and M. Moeller and C. Vuik (pdf, bibtex) Efficient multigrid based solvers for B-spline MPM 2nd International Conference on the Material Point Method for Modelling Soil-Water-Structure Interaction, Anura3D, MPM Research Community Deltares, Delft pp. 161-165, 2019.
6. D. Lahaye and C. Vuik (bibtex) Globalized Newton-Krylov-Schwarz AC Load Flow Methods for Future Power Systems In: Intelligent Integrated Energy Systems: The PowerWeb Program at TU Delft Editors: P. Palensky and M. Cvetkovic and T. Keviczky pp. 79-98 Springer, Berlin, 2019.

7. M. Atsma and C. Vuik (pdf, bibtex) Determining water speed of ships: Establishing the delivered power needed as a function of the ship's speed in relation to the water Delft University of Technology Delft Institute of Applied Mathematics Report 19-04, 2019 ISSN 1389-6520.
8. A.S. Markensteijn and J.E. Romate and C. Vuik (pdf, bibtex) A graph-based framework for steady-state load flow analysis of multi-carrier energy networks Delft University of Technology Delft Institute of Applied Mathematics Report 19-01, 2019 ISSN 1389-6520.

Numerical analysis of dynamic response of flexible structures in the ocean environment

Project leaders
Matthias Möller
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Hugo Verhelst, Matthias Möller
Cooperations
Inria Sophia Antipolis – Mediterranée, TU Delft Department of Maritime and Transport Technology
Funded by
University
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019
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Project Aim

Develop computational methods for the modelling of very thin, flexible, floating membrane structures within the framework of Isogeometric Analysis (IgA). The focus of the project is primarily on the development of models for structural analysis of complex membrane structures (e.g. with holes or reinforcement frames) and their wrinkling response. Besides, ideal flow models will be used to investigate the transient response of these structures in waves.

Progress

The PhD-candidate continued his master thesis research with the start of this project. The isogeometric shell model has been reimplemented in a generic assembler in the Geometry and Simulation Modules (G+Smo) and nonlinear material constitutive relations have been derived and implemented. Additionally, the work on pseudo continuation methods was continued and applied to the case of wrinkling.

Dissertations

-

Scientific Publications

1. Verhelst, H. M. (2019) Modelling Wrinkling Behaviour of Large Floating Thin Offshore Structures: An application of Isogeometric Structural Analysis for Post-Buckling Analyses. MSc. Thesis, Delft University of Technology, 2019.

Project Aim

The aim is to develop efficient parallel iterative solvers for the Helmholtz problem. In order to estimate the layered structure of the earth crust seismic methods are used. The layer structure is used as input for porous media flow simulations.

Progress

A special preconditioner has been developed, which in a special combination of Krylov subspace and multigrid methods has resulted in a hundredfold increase in computing speed for the Helmholtz equation, describing wave propagation. Application in seismics has been very successful, and has generated much interest from the oil exploration industry, especially after a comparison with an industrial code in an application to a practical problem posed by industry. For the first time, realistic three-dimensional applications become feasible. This has already been realized on a single-processor machine for medium-sized problems. The 3D code for the seismic simulation package has been parallelized. Furthermore, a comparison with analytic solutions will be made. The fast solver technique will be generalized to a finite element discretization of the Maxwell equations, for radar simulations.

Dissertations

-

Scientific Publications

1. J. Vandenplas and M.P.L. Calus and H. Eding and C. Vuik (pdf1, pdf2, bibtex) A second-level diagonal preconditioner for single-step SNPBLUP Genetics Selection Evolution, 51:30, pp. 1-16, 2019.

Project leaders

C. Vuik, C.W. Oosterlee

Research theme

Complex dynamics of fluids

Participants

C. Oosterlee, C. Vuik, D. Lahaye, A. Sheikh

Cooperations

TUD Chem.Tech, Philips, Shell, NLR, TU Berlin

Funded by

SenterNovem, NLR, Nuffic

Funded %

University	25 %
FOM	-
STW	-
NWO Other	-
Industry	75 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2001

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PROJECT LEADERS
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RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
D. Ibrahim, F.J. Vermolen, C. Vuik, W.K. van Wijngaarden-van Rossum
COOPERATIONS
-
FUNDED BY
Deltares
FUNDED %

University	25 %
FOM	-
STW	-
NWO Other	-
Industry	75 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
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PROJECT AIM

Develop numerical methods for industrial flow problems.

PROGRESS

A numerical method to cope with pressure boundary conditions on a extraction well has been constructed and analysed. The method is based on a finite-element discretization over the well where the integral boundary condition is evaluated as a boundary value problem. Oscillations are suppressed by the use of SUPG-techniques. Furthermore, a theorem has been formulated and proved about the shift of the spectrum of eigenvalues to the finite-element operator resulting from a standard and SUPG discretization of the boundary value problem. Besides this result, a model for the placement of bacteria has been coupled to the actual fortification model for soils. Next to this work, an experimental validation for the two-dimensional case of the model has been performed and a paper has been submitted about this issue to Transport in Porous Media. Furthermore, Menel Rahrah has started her PhD-project on DSI financed by STW. She works on poro-elasticity models to model the interaction between mechanical vibrations and fast flow of water through the soil at building sites.

DISSERTATIONS

1. L.A. Lopez Pena. Computational derivation of conditions for upscalability of bioclogging in pore network models Prof.dr.ir. C. Vuik and Dr.ir. F.J. Vermolen and Dr. B.J. Meulenbroek.

SCIENTIFIC PUBLICATIONS

1. X. Li and J.K. Ryan and R.M. Kirby and C. Vuik (pdf, bibtex) Smoothness-Increasing Accuracy-Conserving (SIAC) Filtering for Discontinuous Galerkin Solutions over Nonuniform Meshes: Superconvergence and Optimal Accuracy Journal of Scientific Computing, 81, pp. 1150-1180, 2019.
2. M. Singh and C. Vuik and G. Kaur and H.-J. Bart (pdf, bibtex) Effect of different discretizations on the numerical solution of 2D aggregation population balance Equation Powder Technology, 342, pp. 972-984, 2019.

Isogeometric analysis of two-phase flows with the Cahn-Hilliard phase field model

Project Aim

Develop an efficient isogeometric analysis framework for the simulation of multi-physics problems. Concrete problems to be considered are two-phase flow problems solved by the Cahn-Hilliard phase field model.

Progress

The PhD-candidate finished a prototypical implementation of a two-phase incompressible flow solver based on the isogeometric analysis approach (NURBS-based) and validated it against standard benchmarks (static bubble, rising bubble) for the Navier-Stokes –Cahn-Hilliard equations. The candidate is working on improving the implementation concerning efficiency and generality and on finishing the PhD project.

Dissertations

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Scientific Publications

1. Hosseini B.S., Möller M. (2020) Phase Field-Based Incompressible Two-Component Liquid Flow Simulation. In: van Brummelen H., Corsini A., Perotto S., Rozza G. (eds) Numerical Methods for Flows. Lecture Notes in Computational Science and Engineering, vol 132. Springer, Cham.

Project leaders

S. Turek, M. Möller

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Babak S Hosseini, M. Möller

Cooperations

-

Funded by

-

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2011

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High-Order MPM with application in fluid flow simulation

Project leaders
M. Möller, C. Vuik
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Roel Tielen, M. Möller
Cooperations
Deltares
Funded by
University
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
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Project Aim

Development of an improved Material Point Method (MPM) that overcomes the main shortcomings of this hybrid particle-mesh method in its standard variant, namely, the poor spatial and temporal accuracy due to grid crossing errors, inaccurate numerical integration, low-order finite element basis functions and low-order time integration schemes. These limitations shall be overcome by using high-order B-Spline basis functions inspired by the Isogeometric Analysis (IgA) approach, conservative function reconstruction techniques combined with 'exact' numerical quadrature and more accurate grid transfer as well as time integration schemes.

Progress

In the second year, the PhD-candidate has focussed on efficient solvers for IgA discretisations of the Poisson and the convection-diffusion-reaction equation. He has developed p-multigrid solvers that make use of ILUT techniques as the smoother, which show complete independence of the iteration number on the mesh widths 'h' and the approximation order 'p'. They furthermore work well for multi-patch discretisations with a slight dependency on the number of patches. A local Fourier analysis of the developed solvers has been completed demonstrating the good interplay of smoother and coarse grid solver. The approach has been combined to an 'hp'-multigrid method. The PhD-candidate has recently started to implement a multi-dimensional MPM algorithm that adopts multi-variate B-Spline spaces for the discretisation of the governing equations on the background grid. In the third year, the PhD-candidate has continued his research on efficient solvers for IgA. He has developed p-multigrid solvers (using ILUT as a smoother) showing independence of the iteration number on the mesh widths 'h' and the approximation order 'p'. A spectral analysis demonstrated the good interplay of smoother and coarse grid solver, even on multipatch geometries. Different coarsening strategies have been investigated, i.e. a direct projection, making the resulting p-multigrid method competitive to state-of-the art solvers in IgA. The PhD-candidate has implemented an MPM algorithm and successfully applied his solver within this algorithm.

Dissertations

1. E.D. Wobbes. Algorithmic improvements of the material-point method and Taylor least-squares function reconstruction Prof.dr.ir. C. Vuik and Dr. M. Moeller.

Scientific Publications

1. E. Wobbes and M. Moeller and V. Galavi and C. Vuik (pdf, bibtex) Conservative Taylor least squares reconstruction with application to material point methods International Journal for Numerical Methods in Engineering, 117, pp. 271-290, 2019.
2. J. Quoc-Anh Tran and E. Wobbes and W. Solowski and M. Moeller and C. Vuik (pdf, bibtex) Moving least squares reconstruction for B-spline Material Point Method 2nd International Conference on the Material Point Method for Modelling Soil-Water-Structure Interaction, Anura3D, MPM Research Community Deltares, Delft pp. 35-41, 2019.
3. E. Wobbes and M. Moeller and R. Tielen and C. Vuik and V. Galavi (pdf, bibtex) Comparison between Material Point Method and meshfree schemes derived from optimal transportation theory 2nd International Conference on the Material Point Method for Modelling Soil-Water-Structure Interaction, Anura3D, MPM Research Community Deltares, Delft, pp. 173-178, 2019.

Project Aim

GPUs stands for graphic processing units and SPH for smoothed particle hydrodynamics. SPH is a meshless method for Lagrangian particles suited for modelling fluids with highly-deformable, even fragmented interfaces. Advanced simulations of violent-impact flows like slamming gravity waves on structures require numbers of particles of O(108) and are effectively accelerated by GPU parallelism. To strike the optimum between algorithmic efficiency, simulation quality and compute efficiency, physics, mathematics and computer science are interwoven horizontally. The aim is to identify state-of-the-art SPH solvers best equipped for defined classes of problems.

Progress

All project milestones are disseminated on Twitter (https://twitter.com/sph_delft), on a dedicated YouTube channel (http://bit.ly/sph_tube) and on the webpage the Numerical Analysis group at the Delft Institute of Applied Mathematics (https://www.tudelft.nl/ewi/over-de-faculteit/afdelingen/applied-mathematics/numerical-analysis/).

Dissertations

-

Scientific Publications

1. M. Moeller and C. Vuik (pdf, bibtex) A conceptual framework for quantum accelerated automated design optimization Microprocessors and Microsystems, 66, pp. 67-71, 2019.

Project leaders
C Vuik

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
G. Lipari, PhD

Cooperations
Shell Technology Centre, Bangalore, India

Funded by
Shell

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

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2018

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PDE-Based parameterization techniques for isogeometric analysis applications

Project leaders
M. Möller
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Jochen Hinz, Matthias Möller
Cooperations
Johannes Kepler University Linz, Austria; Technische Universität Dortmund, Germany; RWTH Aachen, Germany
Funded by
EU
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

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Project Aim

Develop efficient algorithms for the generation of analysis-suitable multi-patch volumetric B spline parameterisations within the framework of isogeometric analysis. The focus is placed on complex geometries as they arise in industrial applications and, in particular, on twin-screw compressors (project partner TU Dortmund) and similar rotary devices (collaboration with RWTH Aachen on extruder geometries.

Progress

The PhD-candidate has developed a fully functional framework for the (semi-)automatic generation of analysis-suitable multi-patch parameterizations for isogeometric analysis (IgA) simulations. The IgA-framework makes use of an elliptic grid generation approach and utilizes advanced reparameterisation and solution techniques to produce high-quality planar parameterisations for stationary and rotating screw machine geometries. The PhD-candidate has extended the framework to volumetric geometries of twin screw machines and devised a mixed formulation approach that enables the straightforward handling of multi-patch topologies. The developed techniques were successfully applied in the numerical simulation of co-rotating twin-screw machine extruders.

Dissertations

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Scientific Publications

1. Shamanskiy A., Gfrerer M., Hinz J. & Simeon B. Isogeometric Parameterization Inspired by Large Elastic Deformation. Accepted for publication in: Computer Methods in Applied Mechanics and Engineering.
2. Hinz J., Helmig J., Möller M. & Elgeti, S. (2019). Boundary-Conforming Finite Element Methods for Twin-Screw Extruders using Spline-Based Parameterization Techniques. Computer Methods in Applied Mechanics and Engineering (2019): 112740.
3. Hinz J., van Zwieten J., Möller M. & Vermolen F. (2019). Isogeometric Analysis of the Gray-Scott Reaction-Diffusion Equations for Pattern Formation on Evolving Surfaces and Applications to Human Gyrification. Submitted to: Interfaces and Free Boundaries special issue focusing on Free Boundary Problems in Biology.
4. Hinz J., Möller M. & Vuik C. (2019). An IGA Framework for PDE-Based Planar Parameterization on Convex Multipatch Domains. Accepted for publication in: IGAA 2018 proceedings.

PROJECT AIM

The project aims at modeling the contraction and formation of hypertrophic scars in burn injuries in order to improve treatments so that the formation of hypertrophic scar tissue, as well as contractures are prevented.

PROGRESS

The models are based on continuum scale, where cells are simulated as averaged quantities and where plastic deformations of the skin are dealt with via morpho-elasticity. Finite element studies have been carried out, where an uncertainty quantification was performed. Next to the continuum scale models, we develop semi-stochastic agent based models.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. F Vermolen, P van Zuijlen Can mathematics and computational modeling help treat deep tissue injuries? Advances in wound care 8 (12), 703-714.
2. F.J. Vermolen, A. Gefen. Mathematical modeling tools and software for BME applications. Encyclopedia of biomedical engineering. Reference module in biomedical sciences. 2019, pages 56-63, https://doi.org/10.1016/B978-0-12-801238-3.99994-X.

PROJECT LEADERS

Fred Vermolen

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Qiyao Peng, Ginger Egberts, Fred Vermolen

COOPERATIONS

-

FUNDED BY

Dutch Burns Foundation, China Scholarship Council

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	50 %

START OF THE PROJECT

2015

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PROJECT LEADERS
Fred Vermolen
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
Menel Rahrah, Luis Antonio Lopez-Pena, Bernard Meulenbroek, Fred Vermolen
COOPERATIONS
-
FUNDED BY
-
FUNDED %

University	-
FOM	-
STW	50 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	50 %

START OF THE PROJECT
2015
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PROJECT AIM

Develop models and computational methods for flow in porous media.

PROGRESS

We are developing network models for the growth of biofilm in porous media. This is done in the framework of microbial enhanced oil recovery. Furthermore, we develop computational methods and uncertainty quantification for poro-elastic models.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. L.A Lopez-Peña, B Meulenbroek, F Vermolen. A network model for the biofilm growth in porous media and its effects on permeability and porosity. Computing and Visualization in Science 21 (1-6), 11-22.
2. M Rahrah, FJ Vermolen, LA Lopez-Peña, BJ Meulenbroek. A poroelastic model using a network-inspired porosity-permeability relation. Progress in Industrial Mathematics at ECMI 2018, 83-88.

Project Aim

Develop models for the simulation of cancer to predict the likelihood of metastasis.

Progress

Agent-based models for the simulation of pancreas cancer are developed. One model incorporating cancer cells, immune cells, and constitutive cells has been developed. Furthermore, a cell-based model for cell deformation and migration has been developed to estimate the probability of metastasis. Finally, we worked on a model for skin cancer. The lastmentioned model is based on a spatial Markov chain model. On all models, uncertainty quantification has been applied.

Dissertations

-

Scientific Publications

1. J Chen, D Weihs, FJ Vermolen Computational modeling of therapy on pancreatic cancer in its early stages Biomechanics and modeling in mechanobiology, 1-18
2. Chen J., Weihs D., Vermolen F.J. (2019) Computational Cell-Based Modeling and Visualization of Cancer Development and Progression. In: Tavares J., Fernandes P. (eds) New Developments on Computational Methods and Imaging in Biomechanics and Biomedical Engineering. Lecture Notes in Computational Vision and Biomechanics, vol 33. Springer, Cham.

Project leaders

Fred Vermolen

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Jiao Chen, Daphne Weihs, Ilkka Polonen, Fred Vermolen

Cooperations

Prof Daphne Weihs, Technion, Haifa, Israel, Dr Ilkka Polonen, University of Jyvaskyla, Finland

Funded by

China Scholarship Council

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	50 %

Start of the project

2015

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Mathematical physics

Prof.dr.ir. AW Heemink

Prof.dr.ir. ELC Deleersnijder

Prof.dr.ir M. Verlaan

The central research direction of the group is the mathematical modeling of physical phenomena using (partial) differential equations. The research is application driven and includes the modeling phase, analysis of the model and the numerical implementation of the model. The focus is now more and more on the research themes:

Inverse modeling and data assimilation

Data assimilation methods are used to combine the results of a large scale numerical model with the measurement information available in order to obtain an optimal reconstruction of the dynamic behavior of the model state. Many data assimilation schemes are based on solving the Euler-Lagrange equations. A recursive algorithm to solve this two-point boundary value problem can be derived and results in the well-known Kalman filtering algorithm. Variational data assimilation is also a powerfull method, but requires the implementation of the adjoint (of the tangent linear approximation) of the numerical model. In a serie of externally funded PhD projects the mathematical algorithms have been developed and applied in a number of real life applications:

- Tidal flow models (funding: Rijkswaterstaat)
- Atmospheric-chemistry modeling (funding: NWO, TNO, RIVM).
- Oil reservoir modeling (Funding: Shell, TNO).

Perturbation methods for partial differential equations

The main focus within this theme is to develop perturbation methods to analyse initial value problems and initial-boundary value problems for partial differential equations. The applications are in a variety of fields, such as: the wind flow (or rain-wind) induced oscillations of bridges, high-rise buildings, or of overhead power transmission lines; the vibrations of conveyor belts; and the morphodynamics in tidal embayments.

High performance computing and parallel algorithms

This research theme aims to design efficient and scalable parallel algorithms and apply high performance computing technology to applications, such as the storm surge forecasting and pollutant transport in North Sea or rivers. Domain decomposition and grid partitioning is an effective approach for parallel simulation of models described by partial differential equations. Sparse matrices typically occur in numerical simulation of problems described by partial differential equations. One of our research focus is on designing parallel algorithms for solving sparse matrix systems. Lagrangian models, often also called particle models, for transport problems in coastal waters, can deal with steep gradients of concentration. Because the movements of the particles are largely independent from each other, so particle models are very suited for parallel and distributed computing. We have developed parallel models for transport problems of the Dutch coastal water (e.g., Wadden sea). Currently, a particle model with adaptive time steps is being developed, besides the derivation of the numerical scheme the additional challenge is to maintain a good load balance in an adaptive scheme. Grid computing is the next step of development in high performance computing.

Project Aim

Large scale numerical models are often used for prediction problems. These models however are however far from perfect. The model predictions can be improved by assimilating measurements into the model. Model Order Reduction is a corner stone in developing new efficient sub-optimal data assimilation scheme's.

Progress

We have developed a model reduction methodology for large scale numerical models in corporation with TNO, Shell and Deltares. New PhD projects around the theme "Inverse modeling of atmospheric transport" have started. In these PhD projects we will develop and apply model reduction and filtering techniques for assimilating data into the EUROS-LOTOS atmospheric transport models. Other application areas are ecological coastal sea models and reservoir models.

Dissertations

1. Dust Emission inversion using data assimilation, Jin.,J., 2019, PhD Thesis, promotor H.X. Lin and A.W. Heemink.

Scientific Publications

1. An Efficient Robust Optimization Workflow using Multiscale Simulation and Stochastic Gradients, Journal of Petroleum Science and Engineering, de Moraes, R.J., Fronseca, R.M., Helici, M.A., Heemink, A.W., Jansen, J.D.,Volume 172, January 2019, Pages 247-258.
2. Adjoint-based adaptive convergence control of the iterative finite volume multiscale method(Conference Paper), de Zeeuw, W, de Moraes, R.J., Heemink, A.W., Jansen, J.D., Society of Petroleum Engineers - SPE Reservoir Simulation Conference 2019, RSC 2019.
3. Dust Emission Inversion Using Himawari-8 AODs Over East Asia: An Extreme Dust Event in May 2017, Jin, J., Segers, A.J., Heemink, A.W., Yoshida, M., Han, W., Lin, H.X., Journal of Advances in Modelling Earth Systems, Volume 11, Issue 2, February 2019, Pages 446-467.
4. Magnetic Susceptibility Estimation for Magnetostatics, Vijn, A., Lepelaars, E., Dubbeldam, J., Van Gijzen, M.B., Heemink, A.W., IEEE Transactions on Magnetics, Volume 55, Issue 3, March 2019.
5. Non-intrusive subdomain POD-TPWL for reservoir history matching, Xiao, C., Leeuwenburgh, O., Lin, H.X., Heemink, A.W., Computational Geosciences, Volume 23, Issue 3, 15 June 2019, Pages 537-565.

Project leaders
A.W. Heemink

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
C. van Velzen, M. Verlaan, A.W. Heemink, G.Y. El-Serafy, Cong Xiao, Jianbing Jin, A. Ziemba, Aad Vijn

Cooperations
Deltares, Statoil, TNO, Vortech

Funded by
Deltares, Shell, TNO, NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	40 %
Industry	-
TNO	30 %
GTI	20 %
EU	-
Scholarships	10 %

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PROJECT LEADERS
A.W. Heemink
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
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COOPERATIONS
-
FUNDED BY
-
FUNDED %

University	60 %
FOM	-
STW	-
NWO Other	10 %
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	20 %

START OF THE PROJECT
2003
INFORMATION
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PROJECT AIM

The main focus within this project is to develop and to apply perturbation methods to analyze initial value problems and (initial)boundary value problems for partial differential equations. The applications are in a variety of fields, such as: the wind or rain-wind induced oscillations of elastics structures (such as bridges, high-rise buildings, and overhead power transmission lines); the vibrations of conveyor belts and elevator cables; the morphodynamic evolution of coastal systems (such as beaches, and estuaries); nonlinear water waves and the dynamics of polymers in shear flow.

PROGRESS

In 2019 the applicability of different types of perturbation and bifurcation methods was investigated. For problems with boundary damping, for nonselfadjoint problems, for weakly nonlinear problems, and for problems with variable coefficients all kinds of computational aspects have been studied by using perturbation methods, methods from dynamical system theory, numerical methods, and stochastic methods.

DISSERTATIONS

1. Regime shifts in sediment concentrations in tide-dominated estuaries, Dijkstra Y.M., 2019, PhD thesis, promotor: H.M. Schuttelaars and Z.B. Wang.

SCIENTIFIC PUBLICATIONS

1. Shallow water models for stratified equatorial flows, Geyer, A. & Quirchmayr, R., 2019. In : Discrete and Continuous Dynamical Systems – Series A 39(8), pp. 4533-4545.
2. Linear instability and uniqueness of the peaked periodic wave in the reduced Ostrovsky equation, Geyer, A., Pelinovsky, D. , 2019. In: SIAM Journal on Mathematical Analysis 51(2), pp 1188-1208.
3. On a simple oscillator problem describing ice-induced vibrations of an offshore structure, Abramian, A.K., Vakulenko, S.A., van Horssen, W.T., 2019. In: Nonlinear Dynamics 98(1), pp 151-166.
4. On boundary damping to reduce the rain-wind oscillations of an inclined cable with small bending stiffness, Akkaya, T., van Horssen, W.T., 2019. In: Nonlinear Dynamics 95(1), 00.783-808.
5. Magnetic Susceptibility Estimation for Magnetostatics, Vijn, A., Lepelaars, E., Dubbeldam, J., van Gijzen, M., Heemink, A., 2019. In: IEEE Transactions on Magnetics 55(3), p. 1-9 8630674.
6. Generalized diffusion-wave equation with memory kernel, Sandev, T., Tomovski, Z., Dubbeldam, J.L.A., Chechkin, A., 2019. In: Journal of Physics A: Mathematical and Theoretical 52(1), p. 1-23 015201.
7. A max-cut approximation using a graph based MBO scheme, Keetch, B., van Gennip, Y., 2019. In: Discrete and Continuous Dynamic Systems – Series B 24(11), pp. 6091-6139.
8. Sensitivity of Tidal Bar Wavelength to Channel Width, Hepkema, T.M., de Swart, H.E. & Schuttelaars, H.M., 2019. In : Journal of Geophysical Research: Earth Surface. 124(10) p. 2417-2436.
9. Can the Scheldt River Estuary become hyperturbid? A model analysis of suspended sediment concentrations and transport in response to channel deepening, Dijkstra, Y.M., Schuttelaars, H.M. & Schramkowski, G.P., 2019. In: Ocean Dynamics. 69(7) p. 809-827.

10. Thickness-weighted averaging in tidal estuaries and the vertical distribution of the eulerian residual transport, Klingbeil, K., Becherer, J., Schulz, E., de Swart, H.E., Schuttelaars, H.M., Valle-Levinson, A. & Burchard, H., 2019. In: Journal of Physical Oceanography. 49(7) p. 1809-1826.
11. A Regime Shift From Low to High Sediment Concentrations in a Tide-Dominated Estuary, Dijkstra, Y.M., Schuttelaars, H.M. & Schramkowski, G.P., 2019. In: Geophysical Research Letters. 46(8) p. 4338-4345.
12. Modeling the Transition to High Sediment Concentrations as a Response to Channel Deepening in the Ems River Estuary, Dijkstra, Y.M., Schuttelaars, H.M., Schramkowski, G.P. & Brouwer, R.L., 2019. In: Journal of Geophysical Research: Oceans. 124(3) p. 1578-1594.
13. Influence of geometrical variations on morphodynamic equilibria in short tidal basins, Meerman, C., Rottschäffer, V. & Schuttelaars, H., 2019. In: Ocean Dynamics. 69(2) p. 221-238.

Project leaders
A.W. Heemink, H.X. Lin
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
H.X. Lin, J.B. Jin, T. Deng
Cooperations
TNO, CMA China, Shandong University, China
Funded by
-
Funded %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	50 %

Start of the project
2015
Information
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Project Aim

The research aims at improving the forecast accuracy of (mainly) PM10 concentrations caused by dust storms.

Progress

The research focuses on modeling the emission and transport process of dust in heavy dessert storms. Measurements data are assimilated to improve model forecast, in particular the unknown spatial varying emission parameters are estimated. We want to predict the dust concentrations in populated cities often far from the dessert. The PM10 observations around the city actually represent a sum of dust and non-dust aerosols, the latter are anthropogenic emissions from factories and vehicles etc. It is impossible to separately measure the two. So, for the dust emission inversion we use machine learning to estimate the PM10 concentrations as a result of anthropogenic emissions and then compute the PM10 concentrations related to the dust storms. Simulation using the chemical transport model (CTM) Lotus-Euros has shown that the combination of data assimilation and machine learning produces far more accurate forecast.

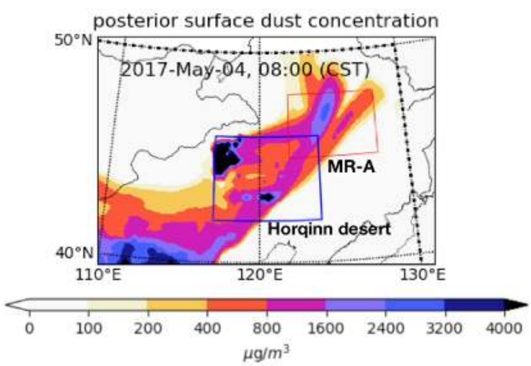
Dissertations

1. J.Jin, Dust Storm Emission Inversion Using Data Assimilation, Promotores: H.X. Lin and A.W. Heemink, TU Delft, December 2019.

Scientific Publications

1. J. Jin, H.X. Lin, A. Segers, Y. Xie, A.W. Heemink (2019), Machine learning for observation bias correction with application to dust storm data assimilation, Atmospheric Chemistry and Physics, Vol.19, pp. 10009—10026.
2. J. Jin, A.W. Heemink, A. Segers, M. Yoshida, W. Han, H.X. Lin (2019), Dust Emission Inversion Using Himawari-8 AODs Over East Asia: an Extreme Dust Event in May 2017, Journal of Advances of Modeling Earth Systems, pp. 446-467.
3. H.X. Lin, J. Jin, H.J. van den Herik (2019), Air Quality Forecast through Integrated Data Assimilation and Machine Learning, in Proc. 11th International Conference on Agents and Artificial Intelligence (ICAART 2019).
4. T. Deng, A. Cheng, W. Han, H.X. Lin (2019), Visibility Forecast for airport operations by LSTM Neural Network, in Proc. 11th International Conference on Agents and Artificial Intelligence (ICAART 2019).

A massive sand stormswept through a village next to Gobi desert (source: Mail online)



Model simulation of a dust storm in China with data assimilation

PROJECT AIM

The aim of this project is to predict the temperature and the radiative heat flux in a rotary kiln used for the production of cement by our industrial partner. The kiln is fired by the non-premixed combustion of gaseous fuel. Information on the heat releasewill allow to further optimize the production process while at the same time meeting ever more stringent conditions on the environmental footprint.

PROGRESS

Progress was made in the modeling of the turbulent non-premixed combustion in three dimensions, including the post-processing for the NOx concentrations.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

D. Lahaye

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Mohamed el Abbassi (PhD student)
C. Vuik

COOPERATIONS

-

FUNDED BY

Almatis B.V. Rotterdam

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2015

INFORMATION

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PROJECT LEADERS
D. Lahaye
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
Prajakta Nakate (PhD student)
C.Vuik
COOPERATIONS
-
FUNDED BY
AluChemie B.V. Rotterdam
FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017
INFORMATION
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PROJECT AIM

Our industrial partner employs furnaces for the baking of anodes for the production of aluminum. These furnaces are fired by the non-premixed combustion of gaseous fuel.The aim of this project is to predict the heat distribution and the pollutant formation in these furnaces. The outcome of the project is expected to allow to further optimize the production process while at the same time meeting ever more stringent conditions on the environmental footprint.

PROGRESS

Progress was made in the modeling of non-premixed turbulent combustion in two dimensions and the modeling of non-reactive flow in three dimensions.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. P. Nakate, D. Lahaye and C. Vuik, “Reactive Turbulent Model of Anode Baking Furnace to Estimate Nox Through Zeldovich Mechanism”, Proceedings of the Fifth World Congress on Mechanical, Chemical and Material Engineering (MCM 2019), Lisbon, Portugal, August 2019, Paper No. HTFF 141, DOI: 10.11159/httf19.141.
2. P. Nakate, D. Lahaye, C. Vuik and M. Talice, “Computational Study of the Anode Baking Industrial Furnace”, Annual Industrial Combustion Symposium of the American Flame Research Committee (AFRC), September, Hawaii, US, 2019.
3. A. Martinez Gonzalez, P. Nakate and D. Lahaye, “Presumed Beta-PDF Models for the Prediction of NOx and CO Emissions in Combustion Chambers“, Comsol Multiphysics Users Meeting, Cambridge, UK, 2019, www.comsol.com/paper/82561.
4. P. Nakate, D. Lahaye, C. Vuik and M. Talice, “Systematic Development and Mesh Sensitivity of a Mathematical Model for an Anode Baking Furnace”, FEDSM2018-83131, V002T09A010; 8 pages https://doi.org/10.1115/FEDSM2018-83131

Dr.ir. M Rohde

Mission

The Reactor Physics and Nuclear Materials department contributes to the development of sustainable nuclear energy such that it can play a major role in the global energy production. To this end, we focus on new and innovative nuclear reactors with improved efficiency, a high degree of safety, flexibility, and with a reduced waste production.

Research

Research in the department can be divided into three categories:

1. Thermal Hydraulics of Nuclear Reactors
    - Heat transfer in supercritical fluids (experimental)
    - Stability of advanced nuclear reactors (experimental, numerical)
    - Rheology of molten fuel salts (experimental, numerical)
    - Heat transfer in molten fuel salts (experimental, numerical)
2. Reactor Physics Analysis of New Reactor Designs
    - VHTR: Design and analysis of a gas-cooled Very High Temperature Reactor for hydrogen production. Focus on core design and safety/transient analysis.
    - GCFR: Design and analysis of a Gas-Cooled Fast Reactor with a self-generating core and reduced waste production.
    - ADS: Dynamics analysis and development of reactivity measuring methods for Accelerator Driven Systems.
    - MSR: Design and Analysis of a Molten Salt Reactor with a high-conversion and/or breeding fuel cycle. Focus on core design, fuel cycle analysis, and dynamics and safety analyses.
    - Exotic designs, like the Fluidized Bed Reactor with a fast neutron spectrum, the CANDLE burnup reactor, and reactors for new applications.
3. Methods and Codes for Reactor Physics and Particle Transport
    - Development and application of electron-photon-neutron particle transport, possibly coupled to other codes like CFD.
    - Development and application of Monte Carlo transport methods possibly coupled to other codes like deterministic transport codes, and CFD.
    - Development and application of new reactor physics methods, like -mode calculations, coupled time-dependent neutronics and thermal-hydraulics, etc.
    - Development of methods to reduce leakage of nuclides from a geological disposal site.

Prof.dr. S Hickel

Prof.dr. F Scarano

The research in the Aerodynamics Group involves fundamentals of Fluid Dynamics and its applications to aerodynamic problems of relevance in Aerospace Engineering systems.

The activities cover boundary layer research in low speed and high-speed flows, including re-entry aero-thermodynamics, complex unsteady flows, fluid-structure interaction problems and aeroacoustics.

The group works in close connection with the Wind Energy section for the investigation of rotor blade aerodynamics. Specific flow control strategies by passive (e.g. vortex generators) and active means (suction, plasma actuators) are explored for their application in flow transition and separation delay.

The experimental research is supported by the Aerodynamics Laboratories, which cover flow simulation range from incompressible to hypersonic regime. Emphasys is given to the development and application of image based advanced flow diagnostic techniques like Tomographic PIV, Background Oriented Schlieren, InfraRed Thermography.

The study of Fluid-Structure interactions and of unsteady flow simulation drive the development of efficient simulation tools for 3D-unsteady viscous flows (e.g. adaptive meshing, mimetic methods, multiscale computation of turbulence). Applications range from flapping wings and micro aerial vehicle aerodynamics to aircraft flutter and unsteady loads on wind turbines. The research on CFD also covers quantification of uncertainties in aerodynamics problems simulation.

PROJECT AIM

The project aims at developing large-scale Particle Image Velocimetry (PIV) for three-dimensional measurements over large scales (several liters, up to the size of the human body). Sub-millimeter helium-filled soap bubbles (HFSB) are used as flow tracers due to their high light scattering efficiency. The project investigates the properties and production of the HFSB, as well as dedicated approaches for the flow measurements based on co-axial arrangement between imaging and illumination, and robotic manipulation of the measurement system. The technique is applied for flow measurements in the field of aeronautics.

PROGRESS

The operating regimes of an orifice-type helium-filled soap bubbles (HFSB) generator have been investigated for several combinations of air, helium and soap flow rates to establish the properties of the production process and the resulting tracers. The geometrical properties of the bubbles, the production regimes and the production rates have been studied with high-speed shadowgraphy. The results show that the bubble volume is directly proportional to the ratio of helium and air volume flow rates, and that the bubble production rate varies approximately linearly with the air flow rate. The use of HFSB for measurements at high Reynolds numbers (up to 3.2 million) in aeronautics has been evaluated. The measurements have been conducted in the Low Speed Tunnel (LST) of the German-Dutch Wind Tunnels (DNW) using a high-lift airfoil in close-to-stall conditions up to 70 m/s. A novel approach has been introduced to enlarge the range of measurable velocities by PTV systems. The approach relies upon the acquisition of two or more sets of double-frame images with increasing pulse separation time Δt.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Faleiros DE, Tuinstra M, van Rooijen BD, Scarano F and Sciacchitano A, Soap bubbles for large-scale PIV in industrial wind tunnels, 13th International Symposium on Particle Image Velocimetry – ISPIV 2019, Munich, Germany, July 22-24, 2019.
2. Faleiros DE, Tuinstra M, Sciacchitano A and Scarano F, Generation and control of helium-filled soap bubbles for PIV, Exp Fluids (2019) 60:40.
3. Saredi E, Sciacchitano A and Scarano F, Multi-Δt 3D-PTV based on Reynolds decomposition, 13th International Symposium on Particle Image Velocimetry – ISPIV 2019, Munich, Germany, July 22-24, 2019.

PROJECT LEADERS

Dr. A. Sciacchitano
Prof. F. Scarano

RESEARCH THEME

Complex structures of fluids

PARTICIPANTS

D. Engler Faleiros, C. Jux, E. Saredi

COOPERATIONS

Dutch Aerospace Center NLR
LaVision GmbH

FUNDED BY

NLR, LaVision GmbH, University

FUNDED %

University	25 %
FOM	-
STW	-
NWO Other	-
Industry	75 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2013

INFORMATION

Andrea Sciacchitano
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www.tudelft.nl/en/ae/organisation/departments/aerodynamics-wind-energy-flight-performance-and-propulsion/aerodynamics/

Project leaders
Dr. A. Sciacchitano
Prof. F. Scarano

Research theme
Complex structures of fluids

Participants
W. Terra, A. Spoelstra

Cooperations
Team Sunweb
TU Delft Sports Engineering Institute

Funded by
ERC Proof of Concept Grant 665477
NWO-TTW OTP Grant 15583

Funded %

University	-
FOM	-
STW	50 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	50 %
Scholarships	-

Start of the project
2015

Information
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www.tudelft.nl/en/ae/organisation/departments/aerodynamics-wind-energy-flight-performance-and-propulsion/aerodynamics/

Project Aim

This project aims at investigating speed sports aerodynamics by quantitative flow visualization. Velocity measurements are conducted via large-scale Particle Image Velocimetry (PIV) both in wind tunnels and on-site during the athletes' training, using the innovative "ring of fire" concept. From the velocity measurements, the pressure field is retrieved via solution of the Poisson equation. The aerodynamic loads are computed based on the conservation of momentum in a control volume. The flow measurements provide information on the areas that are most critical for the generation of drag, thus enabling design optimizations that enhance the athlete's performance.

Progress

The accuracy and drag resolution of the ring of fire system for on-site sports aerodynamic investigation have been assessed via dedicated experiments using a full-scale ring of fire system in both indoor and outdoor configurations. Robotic volumetric PIV measurements in a wind tunnel have been conducted on a full-scale cyclist model at free-stream velocities between 5 m/s and 25 m/s to investigate the drag crisis on the rider's ligaments.

Dissertations

-

Scientific Publications

1. Scarano F, Terra W and Sciacchitano A, Investigation of the drag crisis on the leg of a cycling mannequin by means of robotic volumetric PIV, 15th International Conference on Fluid Control, Measurements and Visualization, 27-30 May, 2019, Italy.
2. Spoelstra A, de Martino Norante L, Terra W, Sciacchitano A and Scarano F, On-site cycling drag analysis with the Ring of Fire, Exp Fluids 2019 60:90.

PROJECT AIM

The project aims at developing a new generation of low-noise flow-permeable trailing edges for aerospace and wind energy applications. Porous materials with random and ordered pore arrangements are tested at the trailing edge of different airfoils to assess their acoustic scattering and aerodynamic performance under different lifting conditions. The project investigates the relationship between noise mitigation, aerodynamic performance and material characteristics.

PROGRESS

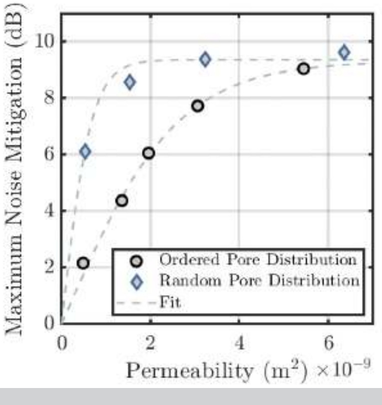
The mechanism of noise generation on permeable trailing edges was initially investigated employing acoustic and aerodynamic measurements on metal foam edges. A decrease of the scattering efficiency of the edge has been reported exclusively for trailing edges with effective permeability, i.e., that communicate suction and sides of the airfoil. To exploit this mechanism, permeable trailing edges with simplified pore geometry have been designed and analyzed. They mimic noise mitigation of trailing edges with a more complex pore arrangement, and the comparison yields an optimal trade-off between noise mitigation and aerodynamic loss with a permeability of 1x10-9 m2 and tortuosity of 1.15.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. A. Rubio Carpio, R. Merino Martinez, F. Avallone, D. Ragni, M. Snellen, S. van der Zwaag; Experimental Characterization of the Turbulent Boundary Layer over a Porous Trailing Edge for Noise Abatement; Journal of Sound & Vibration 443 (2019) 537-558; https://doi.org/10.1016/j.jsv.2018.12.010.
2. A. Rubio Carpio, F. Avallone, D. Ragni, M. Snellen, S. van der Zwaag; 3D-printed Perforated Trailing Edges for Broadband Noise Abatement; 25th AIAA/CEAS Aeroacoustics Conference; AIAA 2019-2458; https://doi.org/10.2514/6.2019-2458.
3. J. Meyer, A. Rubio Carpio, D. Ragni; Temperature-Activated Change of Permeable Material Properties for Low-Noise Trailing Edge Applications; Applied Sciences (2019) 9, 3119; https://doi.org/10.3390/app9153119.
4. A. Rubio Carpio, F. Avallone, D. Ragni, M. Snellen, S. van der Zwaag; Mechanisms of Broadband Noise Generation on Metal Foam Edges; Physics of Fluids (2019) 31, 105110; https://doi.org/10.1063/1.5121248.



PROJECT LEADERS

Dr Daniele Ragni Dr. Francesco Avallone, Prof. Sybrand van der Zwaag

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Francesco Avallone, Mirjam Snellen, Sybrand van der Zwaag, Damiano Casalino

COOPERATIONS

-

FUNDED BY

TNO

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	100 %
EU	-
Scholarships	-

START OF THE PROJECT

2016

INFORMATION

Alejandro Rubio Carpio
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Trailing-edge noise reduction for wind turbine under realistic flow conditions

Project leaders
Prof. Dr. Fulvio Scarano, Dr. Daniele Ragni and Dr. Francesco Avallone

Research theme
Complex structures of fluids

Participants
Lourenco Tercio Lima Pereira

Cooperations
Siemens Gamesa Reneable Energy

Funded by
H2020 SmartAnswer project (Marie Skłodowska-Curie grant agreement No. 722401)

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2019

Information
Daniele Ragni
www.tudelft.nl/lr/organisatie/afdelingen/aerodynamics-wind-energy-flight-performance-and-propulsion/wind-energy/

Project Aim

This project studies the reduction of turbulent boundary layer trailing-edge noise by means of trailing-edge serrations applied to wind turbines. The study will focus on the aerodynamic behavior in the near trailing-edge regions and the relations to the observed far-field noise reduction. Experimental techniques such as 4D-PIV and phased array beamforming are used to provide aerodynamic and acoustic data to support the work. Important aspects of the flow over a wind turbine trailing-edge add-ons are covered, i.e. a realistic add-on geometry, installation and flow conditions, i.e., Reynolds and serration loading. Results will be used to better understand, predict and optimize such devices.

Progress

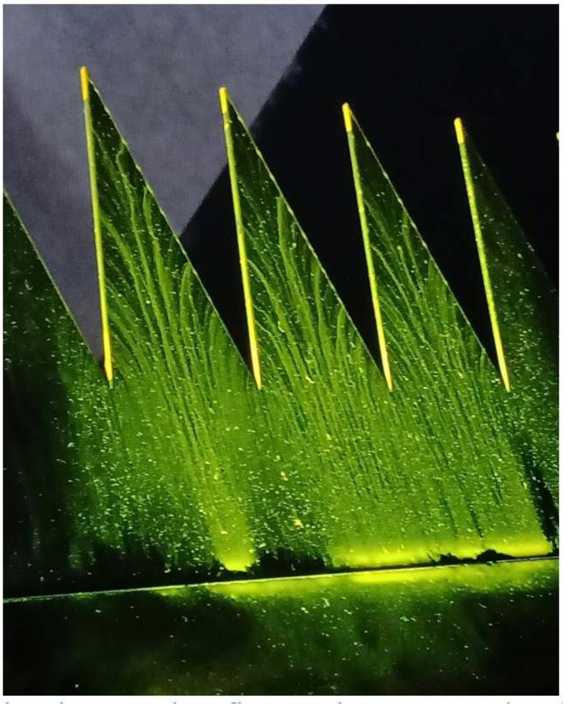
Extended measurement techniques, based on large-scale time resolved PIV, for measurements of the pressure fluctuations near the wall were first explored. The technique was further used, together with acoustic measurements to assess the flow and acoustic properties of a serrated trailing edge at different flow conditions. Results points out to the importance of the trailing edge loading into the noise reduction capabilities of trailing edge serrations. Overall, the tip vortices at the serration edges are seen to significantly increase the produced noise.

Dissertations

-

Scientific Publications

-



Flow visualization illustrating the secondary flow motions generated at the pressure side of a serrated trailing edge.

PIV-based non-intrusive determination of pressure and aerodynamic loads

Project Aim

Novel non-intrusive experimental approaches are developed and applied to determine the flow-field pressure, as well as the integral aerodynamic loads on objects, from flow velocity data measured with particle image velocimetry (PIV). This is achieved by combining the flow field information with basic momentum and control-volume principles. Apart from looking at the fundamental principles (notably 3D flow effects) the project also addresses the development of practical procedures.

Progress

1) Extension of PIV-based determination of (mean) pressure in compressible flows, in particular for transonic base flows with relevance to launcher-afterbody buffeting.

2) Pressure field determination for large-scale flows based on the helium-filled soap bubble PTV technique and its application in aeroelasticity.

3) Surface pressure evaluation on objects of complex shape by means of robotic volumetric PIV.

Dissertations

-

Scientific Publications

1. PL van Gent, Q Payanda, SG Brust, BW van Oudheusden, FFJ Schrijer: Effects of exhaust plume and nozzle length on compressible base flows, AIAA Journal (2019) 57, 1184-1199.
2. BW van Oudheusden, A Flinkerbusch, FFJ Schrijer: Velocity and pressure fields of SWBLIs on porous plates, 13th Int. Symp. on Particle Image Velocimetry – ISPIV 2019, 22-24 July 2019, Munich, Germany.
3. FMA Mitrotta, A Sciacchitano, J Sodja, R De Breuker, BW van Oudheusden: Robotic-PIV measurements of the fluid-structure interaction between a flexible plate and a periodic gust, 13th Int. Symp. on Particle Image Velocimetry – ISPIV 2019, 22-24 July 2019, Munich, Germany.
4. C Jux, A Sciacchitano, F Scarano: Aerodynamic pressure reconstruction on generic surfaces from robotic PIV measurements, 13th Int. Symp. on Particle Image Velocimetry – ISPIV 2019, 22-24 July 2019, Munich, Germany.
5. BW van Oudheusden: Nonintrusive determination of aerodynamic pressure and loads from PIV velocity data (invited), 10th Ankara International Aerospace Conference (AIAC 2019), 18-20 Sept. 2019, Ankara, Turkey, AIAC-2019-003.

Project leaders

Dr. BW van Oudheusden, Prof. F Scarano, Dr. FFJ Schrijer, Dr. A Sciacchitano

Research theme

Complex dynamics of fluids

Participants

G Gonzalez, C Mertens, C Jux

Cooperations

DNW, CNRS, DLR, Uni BW Munich, ONERA, Univ. Southampton, LaVision GmbH

Funded by

EU (H2020-HOMER), LaVision

Funded %

University	20 %
FOM	-
STW	-
NWO Other	-
Industry	20 %
TNO	-
GTI	-
EU	60 %
Scholarships	-

Start of the project

2006

Information

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Project leaders
Dr. F. Avallone and Dr. D. Ragni
Prof. D. Casalino
Research theme
Complex dynamics of fluids
Participants
Christopher Teruna
Cooperations
Siemens-Gamesa Renewable Energy
Funded by
Horizon 2020, Marie S. Curie ITN Fellowship
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2017
Information
Christopher Teruna
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www.h2020-smartanswer.eu/index.php/blog#esr-7-trailing-edge-noise-reduction-by-porous-materials

Project Aim

This project entails the characterization of the properties of metal-foam and the validation of metal foam modelling in computational studies. This will be followed by studies to discover its potential in reducing rotor-stator interaction noise and turbulent-boundary layer trailing-edge noise.

Progress

Using an equivalent fluid modeling approach combined with the Darcy's law, the flow behavior inside the porous medium can be accurately replicated in a lattice-Boltzmann simulation. In a trailing-edge noise study on a NACA 0018 with porous trailing edge, it is found that up to 10 dB noise reduction can be achieved at low frequency. Two noise reduction mechanisms have been identified: 1) the reduced scattering efficiency at the porous trailing edge due to milder impedance jump compared to a solid case, and 2) distributed scattering across the porous medium surface that results in destructive interference between the scattered sound waves.

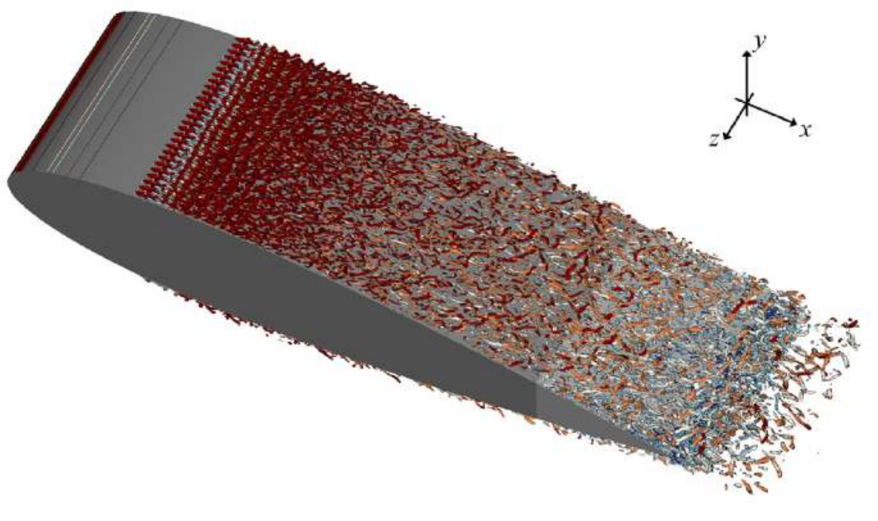
Dissertations

-

Scientific Publications

1. Teruna, C., Manegar, F. A., Avallone, F., Casalino, D., Ragni, D., Rubio Carpio, A., & Carolus, T. Numerical Analysis of Metal-Foam Application for Trailing Edge Noise Reduction. In: 25th AIAA/CEAS Aeroacoustics Conference. 2019. p. 2650.

Instantaneous iso-surface of $\lambda 2=-107$ coloured with the contour of velocity magnitude for the porous trailing edge case. The porous medium is shaded in light grey.



Efficient numerical simulation techniques for wind turbine (wake) simulation and wind farm optimization

Project Aim

This project aims at the reduction of computational time for wind turbine aerodynamics, in particular the wind turbine wake modeling. This results in the detailed analysis of wind turbine – wake interactions, which, in combination with multi-fidelity optimization techniques, results in an improved wind farm layout for maximization of the annual energy production.

Progress

The project that started originally with seven PhD projects, is now almost finished, with one PhD still to defend. Two new PhD projects started, focusing more on the simulation of wind turbine wakes of in particular Vertical Axis Wind Turbines, by using vortex methods or hybrid Eulerian Finite Volume – Lagrangian Vortex Particle methods. These projects connect to the PhD project which provides a multi-fidelity wind farm optimization to obtain a wind farm layout that accounts for rotor-wake interactions to maximize the annual energy production.

Dissertations

-

Scientific Publications

1. Mehta, D., Zhang, Y., Van Zuijlen, A., & Bijl, H. (2019). Large eddy simulation with energy-conserving schemes and the smagorinsky model: A note on accuracy and computational efficiency. Energies, 12(1) doi:10.3390/en12010129.

Project leaders

A.H. van Zuijlen, H. Bijl

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Carlos Baptista, Shaafi Kaja Kamaludeen, Jingna Pan

Cooperations

-

Funded by

FOM, CSC

Funded %

University	33 %
FOM	33 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	33 %

Start of the project

2012

Information

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Efficient adjoint approach to automatic mesh optimization for predictive Large Eddy simulation

Project leaders
Prof. Stefan Hickel, Dr. Steven Hulshoff

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Xiaodong Li, Nils Barfknecht

Cooperations
-

Funded by
CSC

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project
2017

Information
Stefan Hickel
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Project Aim

LES is highly successful in situations where the computational mesh is fine enough to resolve an appropriate range of scales. Currently, only highly experienced engineers are able to generate meshes that ensure the required prediction accuracy at tractable computational cost. The need for manual input are so far preventing the application of LES in automatic design optimization and limiting the practical application of LES for the validation and verification of design decisions. This research project will address the above-mentioned challenges and lead to intervention-free high-fidelity simulation methods for rigorous design assessment and optimization.

Progress

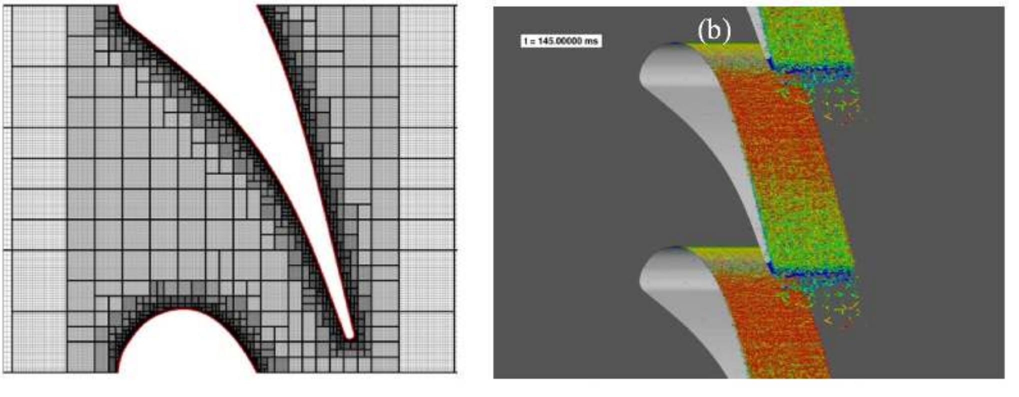
Over the last year we have focused on the representation of the unsteady primal solution within the solution of the adjoint equations. Effective online reduced-order representations have been developed which can be scaled to large problems. Our current test simplified test problems show large increases in efficiency are possible with little effect on adaptive mesh optimization patterns.

Dissertations

-

Scientific Publications

1. Li, Xiaodong, Steven Hulshoff, and Stefan Hickel. “Towards adjoint-based mesh refinement for Large Eddy Simulation using reduced-order primal solutions: Preliminary 1D Burgers study.” Computer Methods in Applied Mechanics and Engineering 379 (2021): 113733.



Adaptive-grid LES of a transonic nozzle cascade: (a) Cartesian AMR grid; (b) Iso-surfaces of lambda 2 criterion visualizing instantaneous coherent structures (Hickel 2017, unpublished).

PROJECT AIM

Novel non-intrusive experimental procedures are developed and applied in the analysis of aeroelastic problems (flutter, buffet). An integrated measurement approach is followed that characterizes fluid-dynamic and structural aspects simultaneously, with a single measurement system. Extensive use is made of Robotic PIV that allows both flow tracers and surface markers to be tracked. This data is subsequently used to establish all forces involved (aerodynamic, elastic and inertial).

PROGRESS

1) Assessment of different experimental configurations (flow over an actuated surface panel, wing-flap in pitching excitation and gust response of a flexible wing). Classic techniques are used for validation.

2) Advancement of data assimilation to improve measurement spatial resolution.

3) Investigation of the instability mechanism and control of transonic buffet.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. FMA Mitrotta, A Sciacchitano, J Sodja, R De Breuker, BW van Oudheusden: Robotic-PIV measurements of the fluid-structure interaction between a flexible plate and a periodic gust, 13th Int. Symp. on Particle Image Velocimetry – ISPIV 2019, 22-24 July 2019, Munich, Germany.
2. A D'Aguanno, FFJ Schrijer, BW van Oudheusden: Transonic buffet control by means of upper Gurney flaps, 54th 3AF International Conference on Applied Aerodynamics, 25-27 March 2019, Paris, France.
3. A D'Aguanno, FFJ Schrijer, BW van Oudheusden: Study of upstream traveling waves in transonic buffet, 13th International Symposium on Particle Image Velocimetry – ISPIV 2019, 22-24 July 2019, Munich, Germany.

PROJECT LEADERS

Dr. BW van Oudheusden, Dr. A Sciacchitano, Prof. F Scarano, Dr. FFJ Schrijer

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

G Gonzalez, C Mertens, A D'Aguanno

COOPERATIONS

DLR, CNRS, Uni BW Munich, ONERA, Univ. Southampton, LaVision GmbH

FUNDED BY

EU (H2020-HOMER)

FUNDED %

University	20 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	80 %
Scholarships	-

START OF THE PROJECT

2018

INFORMATION

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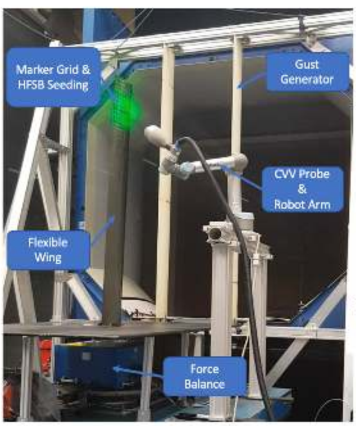

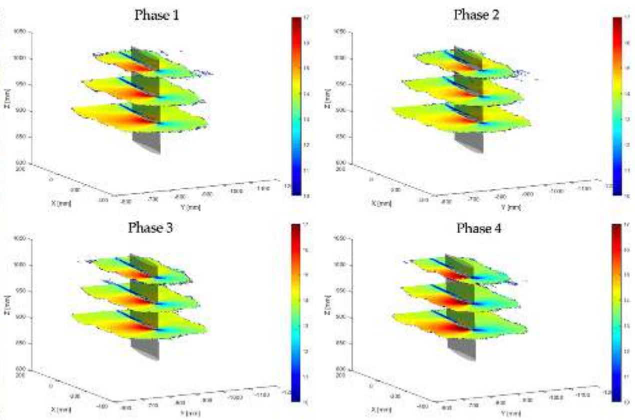

Flapping-flight propulsion

Project leaders
Dr. BW van Oudheusden
Research theme
Complex dynamics of fluids
Participants
M Percin
Cooperations
Middle Eastern Technical University
Funded by
-
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2010
Information
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http://www.tudelft.nl/

Project Aim

The project considers fundamental and applied research on aerodynamic characterization of flapping-wing propulsion for the flight regime of small Micro Aerial Vehicles (Re ~ 10,000). Specific challenges are the occurrence of highly unsteady flow features resulting from massive separation, wing-wing interaction and the high amount of wing flexibility.

Progress

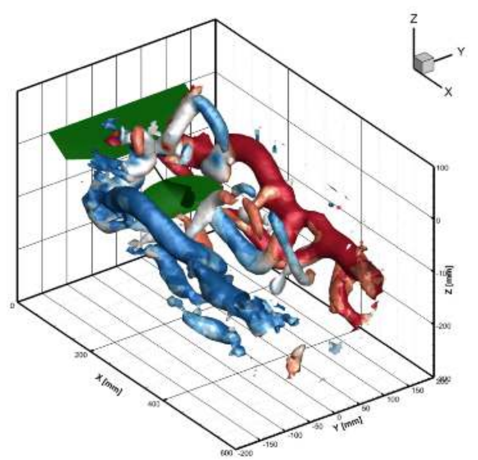
The work has two major fields of attention: 1) the study of generic aeroelastic phenomena relevant to MAV propulsion and 2) a more detailed characterization of the aerodynamic behaviour of the flapping-wing DelFly MAV itself. PIV wind tunnel studies were directed towards the characterization of the DelFly in both near-hover and forward flight configurations. Large-scale and free-flight visualization studies were performed using helium-filled soap bubbles.

Dissertations

-

Scientific Publications

1. DNWM Heitzig, BW van Oudheusden, D Olejnik, M Karasek: Effects of asymmetrical inflow in forward flight on the deformation of interacting flapping-wings, 11th Int. Micro Air Vehicle Comp. and Conf. (IMAV 2019); 30 Sept. – 4 Oct. 2019, Madrid, Spain.
2. D Risseeuw, BW van Oudheusden, AH van Zuijlen, G. Chourdakis: Fluid structure interaction modelling on flapping wings, VIII Int. Conf. on Computational Methods for Coupled Problems in Science and Engineering, 3-5 June 2019, Sitges, Spain, 33-46.
3. M Percin, M Yazdanpanah, HA Hazaveh, R van de Meerendonk, BW van Oudheusden: Flow field characteristics of translating and revolving flexible wings, 13th Int. Symp. on Particle Image Velocimetry – ISPIV 2019, 22-24 July 2019, Munich, Germany.
4. M Yazdanpanah, HA Hazaveh, M Percin, R van de Meerendonk, BW van Oudheusden: Flow field characteristics of translating and revolving flexible wings, 10th Ankara International Aerospace Conference (AIAC 2019), 18-20 Sept. 2019, Ankara, Turkey, AIAC-2019-177.



Large-scale flow visualization of a flapping-wing Micro Air Vehicle (Blanca Martinez Gallar, MSc thesis, 2019)

Advanced flow diagnostics and flow control for swept wing transition

Project Aim

This is a long running project aimed at the investigation of crossflow (CF) instabilities, widely acknowledged as the leading mechanism behind swept wing transition. While extremely important for the efficiency of modern aircraft, several aspects of CF-dominated transition are currently unknown. The project aims at closing this gap through advanced spatio-temporal measurements and BiLocal stability analysis of primary and secondary crossflow instabilities . A second aim is the development of viable active control methods to mitigate the growth of CF instabilities, thus leading to transition delay and drag reduction.

Progress

In 2018 the project's "first generation" of PhD's successfully defended their thesis work, while new partners such as Embraer R&D were involved. The major scientific outcomes in 2018 involved the first successful application of BiLocal stability analysis on experimentally derived baseflows and several insights into the receptivity of CF instabilities. However, the highlight of the year was the first documented delay of CF-dominated transition using plasma actuators. These breakthroughs formed the basis for the ERC Starting Grant proposal GLOWING, which was awarded to Dr. Kotsonis in August 2018 and will form the continuation of this project for the coming years.

Dissertations

-

Scientific Publications

1. Kurelek, J. W., Yarusevych, S., & Kotsonis, M. (2019). Vortex merging in a laminar separation bubble under natural and forced conditions. Physical Review Fluids, 4(6).
2. Tol, H. J., De Visser, C. C., & Kotsonis, M. (2019). Experimental model-based estimation and control of natural Tollmien–Schlichting waves. AIAA Journal, 57(6), 2344-2355.
3. Tol, H. J., de Visser, C. C., & Kotsonis, M. (2019). Model reduction of parabolic PDEs using multivariate splines. International Journal of Control, 92(1), 175-190.
4. Tol, H. J., Kotsonis, M., & De Visser, C. C. (2019). Pressure output feedback control of tollmien-schlichting waves in falkner-skan boundary layers. AIAA Journal, 57(4), 1538-1551.
5. Zong, H., & Kotsonis, M. (2019). Effect of velocity ratio on the interaction between plasma synthetic jets and turbulent cross-flow. Journal of Fluid Mechanics, 865, 928-962.

Project leaders

Marios Kotsonis

Research theme

Complex dynamics of fluids

Participants

Dr. Theo Michelis (promoted 2017)
John Kurelek (defence 2020)
Srikar Yadala Venkata (defence 2020)
Alberto Vidales (defence 2021)
Kaisheng Peng (defence 2023)
Giulia Zoppini (defence 2023)
Jordi Casacuberta (defence 2023)
Sven Westerbeek (defence 2024)
Alessandro Della Pia (defence 2023)

Cooperations

Dr. Serhiy Yarusevych (U.Waterloo)
Dr. Nicolas Benard (U. Poitiers)
Dr. Markus Kloker (U. Stuttgart)
Prof. Kozo Fujii (Tokyo Univ. Science)
Prof. Luigi de Luca (U. Napoli)

Funded by

NWO, Embraer, ERC

Funded %

University	10 %
FOM	-
STW	-
NWO Other	-
Industry	20 %
TNO	-
GTI	-
EU	70 %
Scholarships	-

Start of the project

2013

Information

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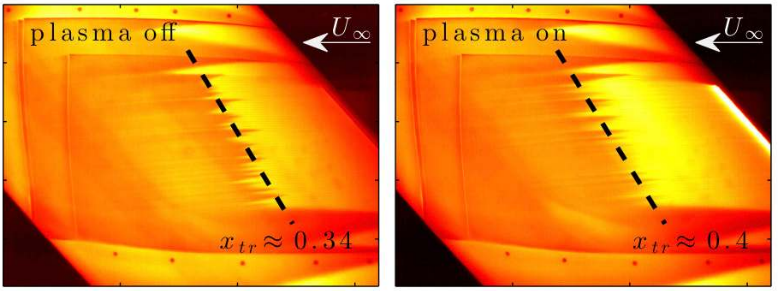
http://tudelft.nl/lr/aerodynamics

Thermal imaging of swept wing transition controlled by plasma actuators (Rec = 2.2 million)



Environmental Fluid Mechanics

Prof.dr.ir. AJHM Reniers

Prof.dr. JD Pietrzak

Prof.dr.ir. WSJ Uijttewaal

The Environmental Fluid Mechanics Group performs fundamental research with a focus on physical understanding of fluid flow problems ranging in scale from turbulence to geophysical fluid dynamics. We also help solve problems of practical relevance in water management, environmental engineering, hydraulic engineering and coastal engineering. We have a strong output of scientific papers and contribute to the numerical modelling community, with models such as SWAN (Simulating Waves Nearshore) and SWASH (Simulating Waves till Shore). Free surface flow models based upon unstructured grids are in preparation and will be released in the near future. Within this philosophy the research program encompasses the following topics:

- Fluid dynamics our areas of research include shallow flows, turbulence and flow structures in rivers and their flood plains, stability and transport under waves and currents of rock elements in cover layers consisting of loose, granular material.
- Physical Oceanography our areas of research include mixing, internal waves, estuarine and coastal processes, large scale dynamics and climate, numerical modelling and field observations.
- Free surface waves our areas of research include the generation and prediction of squall oscillations and harbour seiches, dynamics of surf beat and the wave models SWAN and SWASH.
- Sediment dynamics our areas of research include advanced experimental and numerical work concerning particle-turbulence interaction, as well as flocculation and sedimentation processes.
- Numerical model development our areas of research include development of non-hydrostatic models for the investigation of dam breaks including inundations, short wave problems, tsunamis, near field plume discharges, stratified flows, and local scour near dams, unstructured grids via finite volume methods and finite element methods.

The impact of the local eddy activity on deep convection and sinking processes in the Labrador and Irminger Seas

Project Aim

The aim of this PhD is to investigate the impact of the local eddy activity on deep convection and sinking of dense waters in the Labrador and Irminger Seas. Using a highly idealized regional model (Massachusetts Institute of Technology (MIT) general circulation model –MITgcm) fundamental research will be conducted in order to study the impacts of the local eddy activity on deep convection and sinking of dense waters in the Labrador and Irminger Seas.

Progress

The pathways and the timescales of the water masses exiting the Labrador Sea (LS) via the boundary current have been investigated by Lagrangian particle tracking. This method is applied to the output of an idealized model that is capable of representing the physical processes involved in the cycle of convection in the LS. The trajectories reveal that prior to exiting the domain the water masses follow either a fast route within the boundary current or a slower route that involves boundary-interior exchanges. This study underlines the necessity of resolving the mesoscale features required to capture the interior-boundary exchange in order to correctly represent the export of the LSW.

Dissertations

-

Scientific Publications

1. Georgiou, S., van der Boog, C.G, Brüggemann, N., Ypma, S.L., Pietrzak, J.D. and C.A., Katsman, 2019. On the interplay between downwelling, deep convection and mesoscale eddies in the Labrador Sea, Ocean Modelling, 135, 56-70, https://doi.org/10.1016/j.ocemod.2019.02.004.
2. Georgiou, S., van der Boog, C.G., Brüggemann, N., Ypma, S.L, Pietrzak, J.D., and Katsman, C.A., (2019). On the interplay between downwelling, deep convection and mesoscale eddies in the Labrador Sea. Poster presentation, European Geophysical Union General Assembly, Vienna, Austria.

Project leaders

Dr. C.A. Katsman

Research theme

Complex dynamics of fluids

Participants

Prof. J.D. Pietrzak, Dr. J-M Sayol (post-doc), S. Georgiou (PhD), S.L. Ypma (PhD)

Cooperations

-

Funded by

NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

Sotiria Georgiou
015 278 9340
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Experimental and numerical assessment of near/far-field flow interaction at storm surge barriers with hydro-turbines

Project leaders
Robert Jan Labeur, Wim Uijttewaal
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Merel Verbeek
Cooperations
Deltares, Svasek Hydraulics BV, Witteveen + Bos BV, Tocardo Solutions BV, Dutch Marine Energy Centre, Rijkswaterstaat, European Regional Development Fund (ERDF) 2014-2020
Funded by
NWO
Funded %

University	-
FOM	-
STW	-
NWO Other	90 %
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016
Information
Merel Verbeek
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www.nwo.nl/onderzoek-en-resultaten/programmas/The+New+Delta/Projecten

Project Aim

We develop a calculation tool to quantify the energy production and the hydraulic resistance of free-stream turbines in barriers. The Eastern Scheldt Storm Surge barrier in the Netherlands houses the world's first array of tidal turbines. The hydrodynamics and performance of the location is investigated. The resulting theoretical model is validated using detailed experiments and implemented in a regional numerical model to investigate the far-field response of turbines. In this way, environmentally acceptable levels of tidal energy can be harvested.

Progress

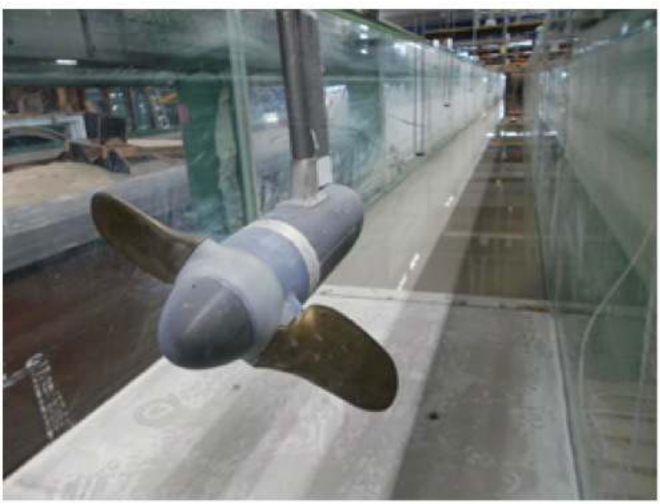
We conducted experiments with a down-scaled tidal turbine in the flume (see figure) and measured performance and wakes. The data prove how more power can be harvested by adjusting turbine position. Furthermore the data validate the theoretical model developed in this project and point at ways to reduce model redundancy.

Dissertations

-

Scientific Publications

1. M. C. Verbeek, R. J. Labeur, and W. S. J. Uijttewaal, 2019, Estimating the stability of a bed protection downstream of a weir-mounted tidal turbine, in: Proc 13th EWTEC, D. Vicinanza, Ed., University of Napels, Italy, 1499(1)-1499(4).
2. Verbeek, M. C., Labeur, R. J., Bijlsma, A. C. and O'Mahoney, T. S. D., 2019, How bathymetric features affect turbine performance: Insights from a cfd model, in 7th Oxford Tidal Energy Workshop 8-9 April 2019, Oxford, UK, pp. 13-14, available online: http://www2.eng.ox.ac.uk/tidal/ote2019-1/proceedings-ote2019.



Project Aim

This project aims to develop a generalized stochastic wave model that allows for statistically heterogeneous and non-Gaussian wave statistics when required, but otherwise reduces to a conventional action balance as used in existing spectral wave models. The proposed approach is to couple a generalized action-balance equation (which transports the full second-order statistics) with an evolution equation for the bi-spectrum. This requires not only further development of the transport equations for the cross-correlations and for the bi-spectrum, but also developing an advanced approximation for the statistical closure.

Progress

We completed the first part of the project which led to the accepted paper (to appear soon in the Journal of Fluid Mechanics) with the title “Modelling statistical wave interferences over shear currents”. This part generalizes the model proposed by Smit and Janssen (2015), which transports the complete second-order statistics of a wave field over variable bathymetry, to cases of wave-current interactions. Therefore, the generalized model, referred to as the “Quasi-Coherent model”, is currently capable to account for the statistical contribution of wave interferences (usually neglected in operational model such as SWAN) generated in areas where currents induced focal zones (see, e.g., the figure below).

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. Reniers, A.J.H.M., Dr.ir. Zijlema, M.

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

G. Akrish

Cooperations

Advisor: Dr. P.B. Smit (Sofar Ocean Technologies)

Funded by

NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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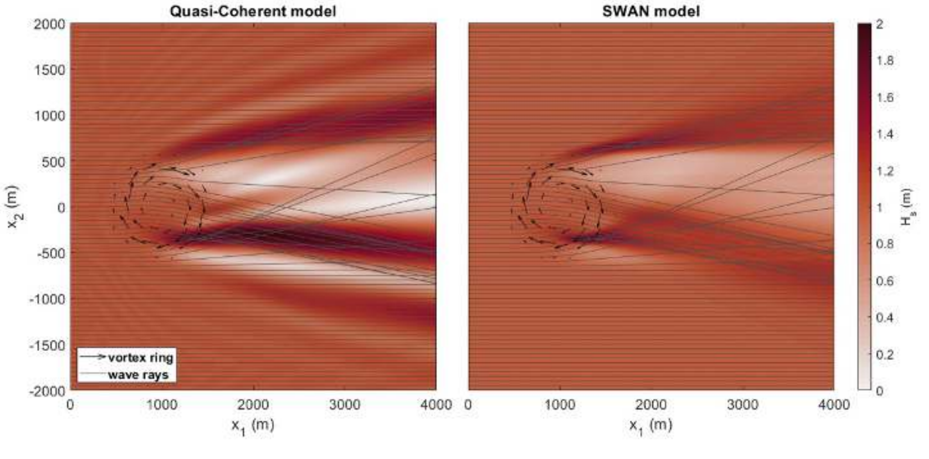

The distribution of the significant wave height due to the interaction between waves and a vortex-ring.

Project leaders
M Zijlema, A Reniers
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
D.P. Rijnsdorp, P.B. Smit, F. de Wit, T. Suzuki, L.K. Phan, Z. Hu, P. Vasarmidis
Cooperations
-
Funded by
TU Delft
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2010
Information
M Zijlema
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http://swash.sf.net

Project Aim

The long term goal is the development of the SWASH (Simulating WAves till SHore) model for model for describing complex changes to rapidly varied flows and wave transformations in coastal waters, ports and harbors.

Progress

Internal wave generation techniques are implemented for accurate generation of regular and irregular long-crested waves in domains of interest. In addition, simulation of a full three-dimensional turbulent, free surface flow with anisotropic Reynolds stresses is made possible in SWASH. SWASH can be downloaded from http://swash.sf.net. There were over 3,600 downloads distributed over 100 countries by the end of 2019 since the launch of SWASH at the website (as of February 9, 2011).

Dissertations

-

Scientific Publications

1. The effects of wave non-linearity on wave attenuation by vegetation, K.L. Phan, M.J.F. Stive, M. Zijlema, H.S. Truong, S.G.J. Aarninkhof, Coastal Engineering, 147, 63-74.
2. Internal wave generation in a non-hydrostatic wave model, P. Vasarmidis, V. Stratigaki, T. Suzuki, M. Zijlema, P. Troch, Water, 11 (5), 986.
3. Non-hydrostatic modeling of drag, inertia and porous effects in wave propagation over dense vegetation fields, T. Suzuki, Z. Hu, K. Kumada, L.K. Phan, M. Zijlema, Coastal Engineering, 149, 49-64.
4. The role of the Rankine-Hugoniot relations in staggered finite difference schemes for the shallow water equations, M. Zijlema, Computers and Fluids, 192, 104274.

Project Aim

To develop a bio-morphodynamic model for mangrove ecosystem restoration in mud coastlines. The model will be based on the analysis of field data, collected by the students in the extremely eroding Demak coastline, Java, Indonesia. Once developed, it will be used to assess the transition from a stable towards an eroding profile, upon which the mangrove-mud coast is not able to restore autonomously from human or natural disturbances. Further, the model will be used to identify the conditions under which restoration of the sediment balance may lead to the restoration of a sustainable mangrove green belt. Generic design rules for coastal restoration will be developed based on the knowledge provided by the model.

Progress

During 2019 Celine published a scientific article, in which she studied the physical factors driving mangrove retreat and expansion. Silke processed field data of Indonesia and has been developing a morphodynamic model for sand lenses, denoted as cheniers, in Delft 3D. She was also awarded a best poster award during NCK days. Alejandra has concluded her first draft and she's currently working on the second, both of them related on defining the drag coefficient of brushwood structures, in order to provide design tools for future restoration efforts.

Dissertations

-

Scientific Publications

1. Van Bijsterveldt et al. 2020. How to restore mangroves for greenbelt creation along eroding coasts with abandoned aquaculture ponds. Estuarine, Coastal and Shelf Science 235.

Project leaders

JC Winterwerp, WSJ Uijttewaal

Research theme

Complex dynamics of fluids

Participants

A Gijón Mancheño, SAJ Tas, C van Bijsterveldt

Cooperations

TU Delft, NIOZ, Diponegoro University (Indonesia)

Funded by

TTW (NWO), Ecoshape, Deltares, Wetlands International, Witteveen+Bos

Funded %

University	-
FOM	-
STW	75 %
NWO Other	-
Industry	25 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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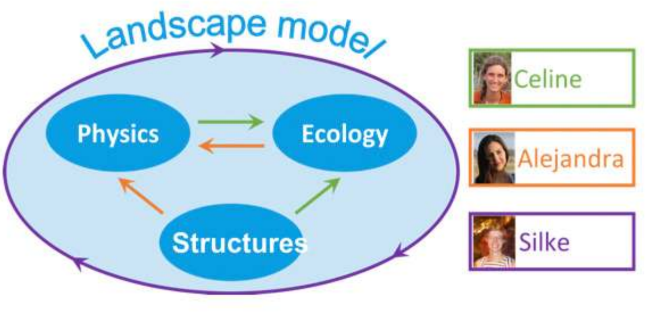
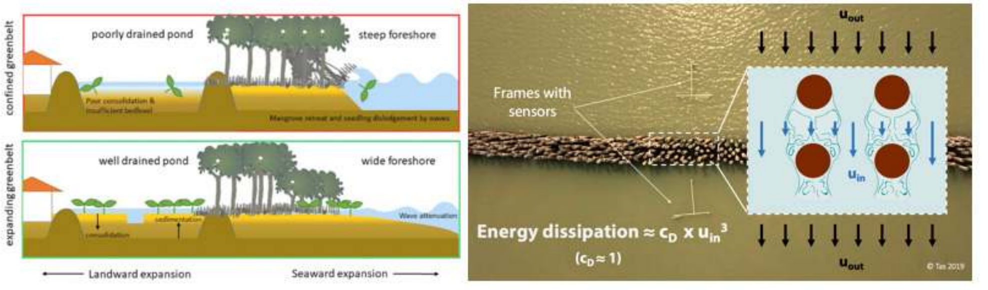
www.biomanco.org



.(left) Diagrams illustrating factors driving mangrove expansion and retreat, by van Bijsterveldt et al. (2020). (right) Diagram illustrating wave dissipation inside bamboo and brushwood structures.



PROJECT LEADERS
C.A. Katsman, J.D Pietrzak, H.A. Dijkstra
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
C.G. van der Boog
COOPERATIONS
Utrecht University
FUNDED BY
Delft University of Technology
FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2016
INFORMATION
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PROJECT AIM

Satellite altimetry shows that the Caribbean Sea is a region rich in eddy activity. Eddies shed from the North Brazil Current (NBC) intermittently enter the region through straits between the chain of islands that separates the Atlantic from the Caribbean. However, not all NBC eddies reach the Caribbean and it is unclear why this is the case. Surprisingly, the altimetry shows that the eddies become stronger over time once they are in the Caribbean region. No satisfactory explanation exists for this phenomenon either. In this study, a regional model of the Caribbean Sea will be developed, in which the lifecycle of ocean eddies can be studied to address these questions.

PROGRESS

- Development of a regional model of the Caribbean Sea and an analysis of the influence of wind stress on the development of Caribbean eddies.
- Development of a high-resolution ocean model of the Caribbean Sea to study the eddy-island interaction.
- Analysis of double-diffusive thermohaline staircase structures in the Caribbean Sea to study water mass transformation in this region.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Van der Boog, C. G., de Jong, M. F., Scheidat, M., Leopold, M. F., Geelhoed, S. C. V., Schulz, K., ... & Katsman, C. A. (2019). Hydrographic and Biological Survey of a Surface-Intensified Anticyclonic Eddy in the Caribbean Sea. Journal of Geophysical Research: Oceans, 124(8), 6235-6251.
2. Van Der Boog, C. G., Pietrzak, J. D., Dijkstra, H. A., Brüggemann, N., Van Westen, R. M., James, R. K., ... & Katsman, C. A. (2019). The impact of upwelling on the intensification of anticyclonic ocean eddies in the Caribbean Sea. Ocean Science, 15(6), 1419-1437.

Project Aim

Breaching is a gradual, retrogressive failure of a steep subaqueous slope, greater than the angle of repose. Breaching flow slides are accompanied by the generation of turbidity currents. This current is driven by excess density versus the ambient fluid; it may increase erosion of the sand surface, picking up more sediment into suspension, thereby increasing speed and erosion potential. The aim of this research is to understand the interaction between the turbidity current and the slope surface.

Progress

Novel large-scale experiments on breaching flow slides were conducted. We obtained direct measurements of breaching-generated turbidity currents illustrating their spatial development and visualizing the structure of their velocity and sediment concentration. The results reveal that breaching-generated turbidity currents are self-accelerating; sediment entrainment and flow velocity enhance each other. Consequently, the erosion rate of the breach face increases in the downstream direction until a certain threshold, possibly due to turbulence damping.

Dissertations

-

Scientific Publications

1. Alhaddad, S., Labeur, R. J., & Uijttewaal, W. (2019). The need for experimental studies on breaching flow slides. MPM (27), 166-172.
2. Alhaddad, S., Labeur, R. J., & Uijttewaal, W. (2019). Large-Scale Experimental Investigation of Breaching Flow Slides. NCK Days Conference, March 21 2019, Enkhuizen, the Netherlands.

Project leaders

Wim Uijttewaal, Robert Jan Labeurl

Research theme

Complex dynamics of fluids

Participants

Said Alhaddad

Cooperations

-

Funded by

The Netherlands Organization for Scientific Research (NWO)

Funded %

University	-
FOM	-
STW	-
NWO Other	53 %
Industry	47 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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The experimental setup

SEAWAD

Project leaders
Prof.dr.ir. Z.B. Wang

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
F.P. de Wit, M.F.S. Tissier, A.J.H.M. Reniers, 3 more PhD's, 7 supervisors and 4 promotors from Delft University of Technology, Utrecht University and University of Twente

Cooperations
Delft University of Technology, Utrecht University and University of Twente

Funded by
STW

Funded %

University	-
FOM	-
STW	67 %
NWO Other	-
Industry	33 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016

Information
Floris de Wit
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www.citg.tudelft.nl/en/research/stories-of-science/hydraulic-engineering/seawad/

Project Aim

Improve understanding and model capabilities of intra-wave sediment transport in environments where waves and strong currents are encountered. The SEAWAD project focusses on the tidal inlet near Ameland, where tidal currents and waves combine and result in sediment transport. Firstly representation of wave nonlinearity (skewness and asymmetry) will be investigated and improved as this is an important driving force for sediment transport. Subsequently, steps will be made towards intra-wave sediment transport.

Progress

A big field campaign was performed in September-October 2017. Five measurement frames measured hydrodynamic and morphodynamic conditions in the vicinity of the Ameland inlet and ebb tidal delta. Most time is spend on analyzing the field data. A paper was written, submitted and accepted with the title: Characterizing wave shape evolution on an ebb-tidal shoal in the Journal of Marine Science and Engineering.

Dissertations

-

Scientific Publications

1. Characterizing wave shape evolution on an ebb-tidal shoal. F de Wit, M Tissier, A Reniers – Journal of Marine Science and Engineering.

Assessing the role of eddies on deep convection and the sinking of dense waters in the Nordic Seas

Project Aim

The research aim is to understand the connection between the ocean dynamics in the Nordic Seas (ocean circulation, deep ocean convection, water mass transformations and properties of the boundary currents) and changes in environmental conditions. For this, a high resolution, idealized, regional ocean model will be developed. Furthermore, pathways of different water masses are studied using high resolution, realistic, global ocean models. This project is part of the NWO-ALW VIDI project "… how ocean eddies govern the response of the Atlantic Meridional Overturning Circulation to high-latitude climate change", granted to C. A. Katsman.

Progress

A conceptual model has been derived for the Nordic Seas to study its sensitivity to changes in atmospheric forcing. This analyses is extended using an idealized model simulations where the buoyancy loss is altered. Furthermore, a Lagrangian study is performed to investigate the connectivity of the Norwegian Atlantic Front Current using observations and models.

Dissertations

-

Scientific Publications

1. Ypma, S. L., Brüggemann, N., Georgiou, S., Spence, P., Dijkstra, H. A., Pietrzak, J. D., & Katsman, C. A. (2019). Pathways and watermass transformation of Atlantic Water entering the Nordic Seas through Denmark Strait in two high resolution ocean models. Deep Sea Research Part I: Oceanographic Research Papers, 145, 59-72.
2. Ypma, S.L., S. Georgiou, J.M. Sayol, J.D. Pietrzak, C.A. Katsman, Heat exchange across the Polar Front, NAC 2019, Utrecht.
3. Ypma, S.L., S. Georgiou, N. Brüggemann, J.M. Sayol, J.D. Pietrzak, C.A. Katsman. Idealized model study of the Polar Front in the Nordic Seas, IUGG 2019, Montreal.

Project leaders

Dr. C.A. Katsman, Prof. dr. J.D. Pietrzakl

Research theme

Complex dynamics of fluids

Participants

Steffie Ypma

Cooperations

University of Bergen (Norway)
Woods Hole Oceanographic Institution (USA)

Funded by

NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

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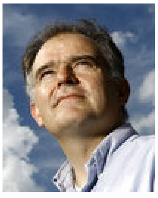
Prof.dr.ir. BJH van de Wiel



Prof.dr.ir. HJJ Jonker

Prof.dr.ir. AP Siebesma

Atmospheric turbulence is profoundly influenced by the thermodynamics through phase transitions of water in the atmosphere in ways that have no counterpart in other manifestations of turbulence. In addition, the influence of radiation on the stability of the atmosphere and the interaction with the underlying surface are extra challenging factors that affect the nature of the turbulent atmosphere.

As part of the Geoscience and Remote Sensing (GRS) section at the faculty of Civil Engineering and Geoscience of the TU Delft, we study the role of atmospheric fluid dynamics to gain a better understanding of these processes in the context of weather and climate and to improve their representation in operational weather and climate models.

A main theme is the turbulent transport of heat, moisture and momentum in the stable and convective clear boundary layer, the cloud topped boundary layer as well as for deep cumulus convection where cloud dynamics strongly influences the transport properties. These topics adress many of the key issues in atmospheric science relevant for weather and climate: Improving our understanding and representation of the stable atmospheric boundary layer, reducing cloud climate feedback, understanding the interaction between wind and cumulus convection, the role of global warming in relation to changing patterns of (extreme) precipitation and the interaction between aerosols, cloud microphysics and cloud dynamics.

In developing new theories, descriptions and parameterisations, a hierarchy of models is used, ranging from Direct Numerical Simulations, Large Eddy Simulations to large scale weather and climate models. These models and theories are critically confronted with observations from the Cabauw Experimental Site for Atmospheric Research (CESAR), as well as with observations from dedicated field campaigns.

Finally, a new exciting development is the shift of operational atmospheric models towards turbulence-permitting resolutions. This positions our group in a ideal situation to explore the possibilities and challenges associated with the operationalisation of this models such as our own modeling flagship, the Dutch Atmospheric Large Eddy Simulation (DALES), for use in short-term prediction of wind and solar power for the renewable energy sector and for hazardous weather prediction (fog, low cloud ceiling, precipitation and wind) over high impact areas such as the Schiphol area and the Rotterdam harbour.

REPORTS OF INDIVIDUAL RESEARCH GROUPS

Technische Universiteit **Eindhoven** University of Technology

Where innovation starts

Applied Physics (AP)

- Fluids and Flows (AP-FF)
- Mesoscopic Transport Phenomema (AP-MST)
- Transport in Porous Media (AP-TPM)
- Plasma Physics (AP-PP)

Mechanical Engineering (ME)

- Energy Technology (ME-ET)
- Power & Flow (ME-PF)
- Microsystems (ME-MS)

Chemical Engineering and Technology (CET)

- Multi-scale Modelling of Multiphase Flows (CET-MMM)
- Chemical Process Intensification (CET-CPI)
- Interfaces with mass transfer (CET-SIM)

Mathematics and Computer Science (MCS)

- Centre for Analysis, Scientific Computing and Applications (MCS-CASA)

Civil Engineering / Built Environment (CEBE)

- Urban Physics and Wind Engineering (CEBE-UPWE)

Biomedical Engineering (BE)

- Cardiovascular Biomechanics (BE-BVM)

Fluids and Flows

Prof.dr. HJH Clercx

Prof.dr.ir. GJF van Heijst

Prof.dr. F Toschi

Prof.dr.ir. AA Darhuber

The research in this section addresses fundamental questions in fluid dynamics through statistical fluid mechanics, large-scale computations and dedicated laboratory experiments with modern optical diagnostics for detailed flow measurements. Our motivation is the desire to unravel the fundamental properties of these phenomena and systems and use that knowledge to help solve challenges.

Our tools effectively expose the intricate fundamentals of turbulence to our curiosity, allowing us to answer many intriguing questions. How do buoyancy and rotation affect the statistical properties of turbulence? What can – and should – we do to shape turbulence to our needs? These questions are also extended to environmental applications. How is particulate matter such as sediment or droplets transported in turbulent flows?

Within the exciting field of multiphase and complex fluids, we study the role of mesoscale physics on the macroscopic dynamics of such systems. For example: how drastically do fluid-fluid interfaces, bubbles, particles or polymers affect macroscopic properties? We also study the fluid physics at even smaller scales where capillary and even molecular-length scales are relevant, and where surface and interfacial effects dominate the behavior. Examples include Marangoni flows, interfacial instabilities and (de)wetting phenomena.

Our main research themes are turbulence, environmental fluid mechanics, multiphase and complex fluids, and nano- and microhydrodynamics.

TROCONVEX: Turbulent rotating convection to the extreme

Project Aim

Many geophysical and astrophysical systems are driven by buoyancy and affected by rotation. The flow behavior in these large-scale systems shows remarkable differences with the small-scale geometries usually studied in laboratory or simulation settings, making extrapolations from current scaling models impossible. In recent years evidence of a new scaling regime has been observed. This so-called geostrophic regime is expected to be relevant to these large-scale flows. Heat transfer models are an essential part of studying their energy balance, however strong thermal forcing and rapid rotation make difficult to replicate in numerical computations. In this project we aim to model the heat transfer by carrying out parallel numerical simulations capable to cover an unprecedented part of this new regime and to compare whenever possible with experimental results from the companion experimental investigations in this project. The outcome is crucial for the understanding of rotating convection in geo/astrophysics.

Progress

We study rotating Rayleigh-Bénard convection of different fluids at extreme parameter values relevant to geo-/astrophysical settings. We characterize the flow via heat transport efficiency, mean temperature distribution and flow statistics. We distinguish several flow regimes, in particular, one of large-scale vortices (LSVs; see Fig.1) for fluids with low- and moderate-viscosity at high rotation rates. These large-scale flows resemble those in the atmosphere, in the oceans and in the interior of planets as in the Earth's outer core. Multiple articles are in preparation for submission early 2020.

Dissertations

-

Scientific Publications

-

Project leaders

RPJ Kunnen, HJH Clercx

Research theme

Complex dynamics of fluids

Participants

AJ Aguirre Guzman, M Madonia, JS Cheng, HJH Clercx, RPJ Kunnen

Cooperations

-

Funded by

ERC

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2016

Information

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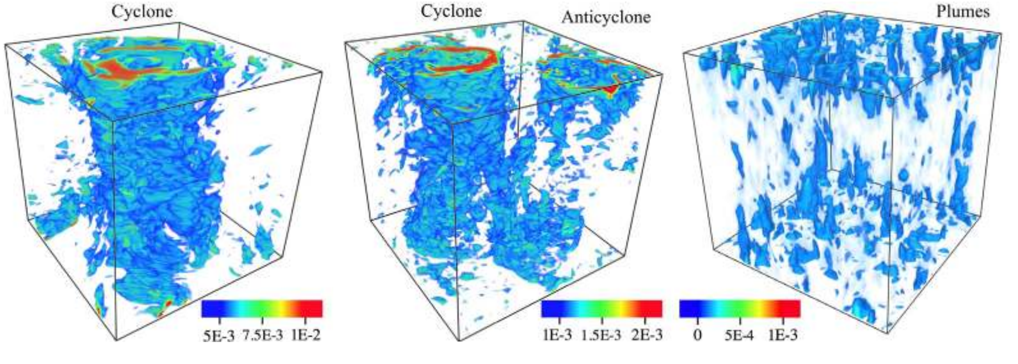

Project leaders
F Toschi, HJH Clercx
Research theme
Complex dynamics of fluids
Participants
KMJ Alards, HJH Clercx, F Toschi, RPJ Kunnen, PR Joshi, H Rajaei
Cooperations
D Lohse, R Stevens (UTwente)
Funded by
FOM
Funded %

University	-
FOM	100 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2014
Information
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Project Aim

In this project the dynamics of inertial and buoyant particles in Rayleigh-Bénard convection is investigated numerically. Both passive tracers and (thermally) inertial particles are implemented in a Rayleigh-Bénard cell and the effect of these particle properties on the thermal convection and on the transition between turbulent states explored. First, typical flow structures are characterized by collecting statistics of the velocity and acceleration of the tracer particles and by focusing on the geometry of the trajectories itself. Second, we study the effect of feedback of thermally inertial particles on the heat transfer and the possible modification of interaction between bulk and boundary layer. We use a finite-difference code for exploring a cylindrical and horizontally unbounded setup.

Progress

This project has been finished with the thesis of K.M.J. Alards (2018).

Dissertations

-

Scientific Publications

1. Alards, K.M.J., Kunnen, R.P.J.; Clercx, H.J.H. & Toschi, F. - Statistical properties of thermally expandable particles in soft-turbulence Rayleigh-Bénard convection. 2019, Eur. Phys. J. E 42, 129 (12 p).
2. Alards, K., Kunnen, R., Stevens, R. J. A. M., Lohse, D., Toschi, F. & Clercx, H., - Sharp transitions in rotating turbulent convection: Lagrangian acceleration statistics reveal a second critical Rossby number3 Jul 2019, In : Physical Review Fluids. 4, 7, p. 1-19 19 p., 074601.

PROJECT AIM

For Magnetic Density Separation (MDS) the behavior of particles in a low turbulence channel flow is relevant. Particles are involved in a neutral buoyancy sedimentation field and it is important that particles with different densities can be separated. In this study the so called particle-fluid-particle interaction is studied under various circumstances in order to know how a stable stratification of particles will take place in a neutral buoyancy field. The investigations are carried out experimentally as well as via numerical methods by two PhD students.

PROGRESS

Inside the tank which has an effective mass density gradient a lot of experiments have been carried out with particle tracking velocimetry (PTV). This effective mass density gradient has been created with a MnCl2 solution together with a strong Halbach array magnet. The experiments both used single particles as multiple particles that could also collide. Where the particles could be spherical as ellipsoid in shape. The results of this research have been presented at 10th International Conference on Multiphase Flow 2019 and Physics@Veldhoven 2019.

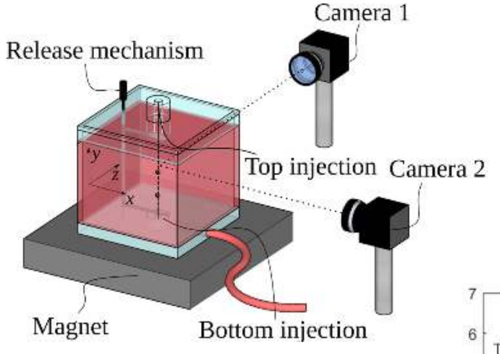
DISSERTATIONS

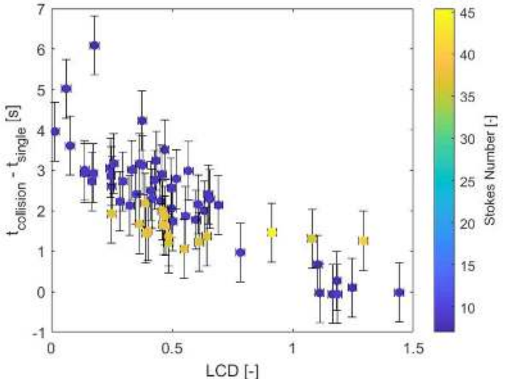
-

SCIENTIFIC PUBLICATIONS

-

Tank used for PTV setup with magnet and MnCl2 solution.





Experimental results of PTV measurements.

PROJECT LEADERS

JCH Zeegers, JGM Kuerten, AA Darhuber

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

R Dellaert, S Tajfirooz, J van der Veen and projectleaders

COOPERATIONS

TU Delft, UTwente, UU, Radboud University, and several companies, part of Perspectief programme STW

FUNDED BY

STW, Umincorp, Sumitomo, Syngenta, Dimaen, FNLI, AEB,

FUNDED %

University	-
FOM	-
STW	70 %
NWO Other	-
Industry	30 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2016

INFORMATION

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Ultra low turbulence ducts for magnetic density separation. Project 2.1 Perspectief MDS

Project leaders
JCH Zeegers, JGM Kuerten, AA Darhuber

Research theme
Complex dynamics of fluids

Participants
R Dellaert, S Tajfirooz, J van der Veen and projectleaders

Cooperations
TU Delft, UTwente, UU, Radboud University, and several companies, part of Perspectief programme STW

Funded by
STW, Umincorp, Sumitomo, Syngenta, Dimaen, FNLI, AEB,

Funded %

University	-
FOM	-
STW	70 %
NWO Other	-
Industry	30 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016

Information
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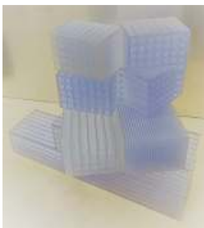
Project Aim
For Magnetic Density Separation (MDS) development of a low turbulence channel flow is important. This has to be achieved through honeycomb pipe bundles alone as filter screens cannot be used due to fouling. Experimental and numerical investigations will be carried out to study under which conditions the downstream flow field of a honeycomb system has lowest turbulence level. This is needed to achieve best separation quality downstream of the honeycomb. The study is carried out by two PhD students.

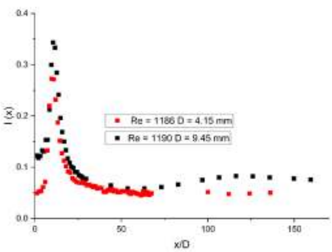
Progress
Currently a lot of measurement data have been gathered from the laser Doppler velocimetry (LDV) wind tunnel. The understanding of these results will be fit with a turbulence decay power law and put into a paper. Parallel to the LDV wind tunnel also a lot of experiments have been carried out in the particle image velocimetry (PIV) wind tunnel. These results are also being fit in a turbulence decay power law and are then compared with the LDV turbulence decay power law. The plan is to publish a paper about these results as well. Already some results have been presented at Physics@Veldhoven 2020.

Dissertations
-

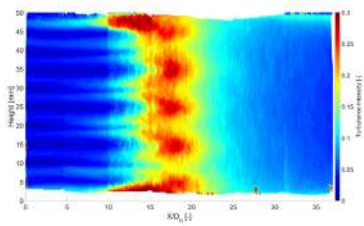
Scientific Publications
-

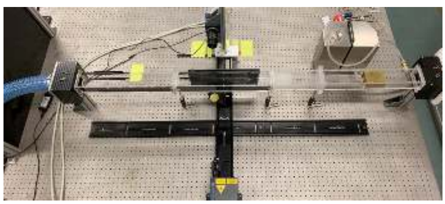

Various honeycombs that can be installed in both wind tunnels.

Experimental results of LDV setup.



Experimental results of PIV setup.




Wind tunnel for PIV setup.


Wind tunnel for LDV setup.

Project Aim

The goal of the project is to elucidate the origin of and physical mechanism behind so-called watermark defects in immersion lithography. When photoresist-covered wafers come into contact with water droplets, the photoresist structures can be adversely affected after development, pointing towards a lower solubility of the resist. The generic suspicion is that the leaching of photoresist chemicals by the water droplets is responsible for the defect formation.

Progress

Several manuscripts have been finalized and published in 2019 containing experimental results and numerical/theoretical models. The main insight was that water droplets remove ionic material from the surface region of the photoresist, which induces deliquescence, i.e. a reduction in vapor pressure and a corresponding slow down of the droplet evaporation rate. Moreover, it was discovered that residues that were deposited after complete evaporation could not completely be removed by rinsing with water (which is standard procedure in the industrial process), despite that the residue is thought to be composed of small molecular species.

Dissertations

-

Scientific Publications

1. He, B. & Darhuber, A.A. Electrical surface charge patterns induced by droplets sliding over polymer and photoresist surfaces. J. Micromech. Microeng. 29 105002 (2019).
2. Heijden, A.W.G. van der, Darhuber, A.A. & Schoot, P.P.A.M. van der. Compound redistribution due to droplet evaporation on a thin polymeric film: Theory Journal of Applied Physics 126, 065303 (2019).
3. He, B. & Darhuber, A.A. Evaporation of water droplets on photoresist surfaces – An experimental study of contact line pinning and evaporation residues Colloids and Surfaces A: Physicochemical and Engineering Aspects 583, 123912 (2019).

Project leaders

AA Darhuber, PPAM van de Schoot, JDR Harting

Research theme

Complex dynamics of fluids

Participants

B He, TGW van der Heijden, AA Darhuber, PPAM van der Schoot, JDR Harting

Cooperations

ASML

Funded by

STW, ASML

Funded %

University	-
FOM	-
STW	70 %
NWO Other	-
Industry	30 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

AA Darhuber
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Non-linear response in sediment transport: linking the small and the large scales

Project leaders
M Duran Matute, HJH Clercx
Research theme
Complex dynamics of fluids
Participants
TJJM van Overveld, M Duran Matute, HJH Clercx
Cooperations
W-P Breugem (TUD)
Funded by
University
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019
Information
M Duran Matute
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Project Aim

The objective of this project is to characterize the non-linear interactions between sediment particles and an oscillating fluid, which result in the emergence of large-scale patterns in the form of particle chains or ripples. This project focuses on the dynamics of sediment under a symmetrically oscillating flow, for which non-linear effects are directly visible. Different flow conditions will be related to both the statistical response of individual sediment grains and the macroscopic patterns. Non-linear effects will be studied by changing the flow conditions in a complex manner. The problem will be studied using fully resolved simulations and verified using experiments.

Progress

Experimental and numerical results from literature (for particle chains and ripples) were collected and compared in order to define relevant regimes. Using these parameters, exploratory experiments on particle chains under a free surface with gravity waves have been done. Data analysis tools were developed to obtain particle positions, trajectories and 2D density correlation function from these experiments. For future experiments a setup without a free surface was designed. For the numerical simulations, a finite volume code with immersed boundary method has been adapted.

Dissertations

-

Scientific Publications

1. Duran-Matute, M., van Gorp, M. D., & van Heijst, G. J. F. (2019). Wavelength selection of vortex ripples in an oscillating cylinder: The effect of curvature and background rotation. Physical Review E, 99(3), 033105.

ACCESS – Active Contamination Control for Equipment and SubstrateS particle contamination transport

Project Aim

Obtain fundamental understanding of the transportation of small contamination particles at finite Knudsen numbers. In this rarefied regime non-equilibrium effects take place for which continuum approach modelling is inaccurate. Direct simulation Monte Carlo (DSMC) will therefore be used to investigate the complicating effects like velocity slip and thermophoretic forcing. The numerical modelling will be verified with experiments. The obtained knowledge will be used to develop a simplified model for the behavior of these particles in rarefied conditions which can be used in engineering focused simulation software.

.

Progress

Familiarize with the world of rarefied gases and the inhouse developed DSMC code. Implemented wall boundary condition based on the CLL-scattering kernel and the adiabatic-scattering kernel. Working on the implementation of a particle inside the DSMC simulation procedure. Setting up the requirements for the validation experiment which will then be incorporated into the design of apparatus staged at VDL ETG.

Dissertations

-

Scientific Publications

-

Project leaders

HJH Clercx, F Toschi

Research theme

Complex dynamics of fluids

Participants

RRL Reinartz, HJH Clercx, F Toschi, RPJ Kunnen

Cooperations

DA Shestakov (VDL ETG)

Funded by

VDL ETG, Rijksdienst voor Ondernemend Nederland, TU/e

Funded %

University	10 %
FOM	-
STW	-
NWO Other	-
Industry	57 %
TNO	-
GTI	-
EU	-
Scholarships	38 %

Start of the project

2019

Information

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PROJECT LEADERS
R Benzi, F Toschi
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
G Guccione, R Benzi, F Toschi A Plummer D Nelson
COOPERATIONS
University of Rome, Tor Vergata, HPC-LEAP Program
FUNDED BY
HPC-LEAP (Marie Curie Fellowship)
FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	50 %
Scholarships	-

START OF THE PROJECT
2017
INFORMATION
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PROJECT AIM

This project focuses on the enhancement or suppression of selective advantage in population dynamics subject to advection of two dimensional compressible turbulence. We implement a two dimensional code particularly suited to investigating a large number of particles.

PROGRESS

Many interesting studies can follow up on our work. One of those we are here moving into is to analyze the dynamic and the genetic of marine phytoplankton in the presence of a turbulent flow and we develop a new theory to understand how the eddy diffusivity is involved on the fixation time of beneficial allele.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Guccione, Giorgia, et al. Discrete Eulerian model for population genetics and dynamics under flow. Physical Review E, 2019, 100.6: 062105.

Left side: Shape of the asymptotic fraction $f_{\infty} = \lim_{t\rightarrow\infty}$ over its initial fraction f(0). Populations starting close to the source become increasingly grown compared with their initial position. Right side: 1D section plot of the plot on the left. Comparison between numerical simulation $P_{fix}/f(0)$ (purple dots) and deterministic line $f_{\infty}/f(0)$ (continuous black line).

The effects of barotropic vortices on sediment transport: an experimental and numerical study

Project Aim

Understand the underlying physics and improve the modeling of how barotropic vortices and sediment interact.

Progress

Our research on the sediment transport capabilities of translating monopolar vortices has concluded with a publication currently under review. Additionally, we made an in-depth analysis of the photogrammetric technique used to measure the deformation of a submerged sediment bed. Currently, we are studying the transport of sediment by large-scale, tidal dipolar vortices by means of numerical simulations. The hydrodynamics are solved using a coastal three-dimensional model that solves the equations of motion with the use of a turbulence closure model. The interaction with the sediment bed is modelled using a zeroth order Partheniades-Krone resuspension formulation. Furthermore, the importance of the vertical velocities on the sediment transport capacity of the dipolar vortex is determined by comparing simulations with and without the vertical advection of sediment.

Dissertations

-

Scientific Publications

-

Project leaders

GJF van Heijst, M Duran Matute

Research theme

Complex dynamics of fluids

Participants

AS Gonzalez Vera, M Duran Matute

Cooperations

-

Funded by

CONACYT (Mexico)

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project

2015

Information

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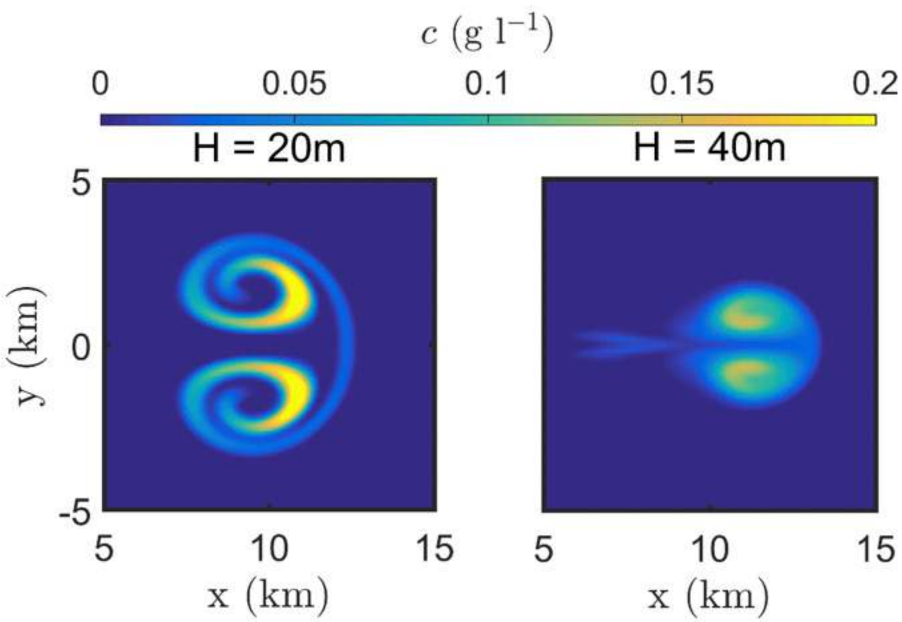

Study of non-isothermal rarefied gas flows with hybrid DSMC-LBM simulations

Project leaders
HJH Clercx, F Toschi
Research theme
Complex dynamics of fluids
Participants
B Goshayeshi, G Di Staso, HJH Clercx, F Toschi
Cooperations
-
Funded by
TU/e
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
Information
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Project Aim

This project will contribute to the development of a hybrid computational tool combining Direct Simulation Monte Carlo (DSMC) and Lattice Boltzmann Method (LBM) for the simulation of rarefied gasses. This hybrid DSMC-LBM algorithm allows to switch efficiently between DSMC and LBM depending on the local value of the Knudsen number quantifying the rarefaction of the flow. Within this project the hybrid DSMC-LBM algorithm will be extended to include thermal effects. The goal in the end is to measure, model and understand heat fluxes and fluid-wall interactions on surfaces over which a rarefied gas flow is forced.

Progress

Physics of thermal transfer problem in a 2D rarefied Rayleigh-Bénard system at the slip flow regime for $0.015<Kn<0.03$ is numerically investigated, using high-performance DSMC simulations. Heat transfer was evaluated (in the form of a Nusselt number) under different rarefactions and gravitational accelerations. At each rarefaction degree, three behaviors were observed as the gravitational acceleration increases: (i) onset of convection, (ii) maximum of convection, (iii) extinction of convection (presumably due to the stratification).

It was observed that the onset of convection can be approximated at a constant modified Rayleigh number. At the maximum convection state, rarefaction affects the Nusselt number to have a linear behavior with respect to the rarefaction degree (Kn). Finally, the extinction of convection at high Rayleigh numbers found to be under the effect of two factors of stratification and rarefaction.

Dissertations

-

Scientific Publications

-

High-efficiency organic solar cells by controlling microstructure through processing

Project Aim

The aim is to study the basic fluid dynamics physics of multi-component phase separation and solidification of suspensions under steady evaporation. This will contribute to a better understanding on the dynamics of the morphology formed during the processing of organic solar cells and may contribute in increasing the power conversion efficiency.

Progress

Demixing dynamics near the substrate: Comparison of the Lattice Boltzmann results and the diffusion-dominated phase field theory to understand the impact of hydrodynamics during the demixing process of a binary blend near a preferentially wetting substrate. Percolation characteristics of demixing morphologies: Study the evolution of the extend of percolating domains in demixing morphologies especially in contact with a preferentially wetting substrate, particularly important in the context of organic solar cells for effective charge transport.

Dissertations

-

Scientific Publications

-

Project leaders

F Toschi, PPAM van der Schoot

Research theme

Complex dynamics of fluids

Participants

A Goyal, F Toschi, PPAM van der Schoot, RAJ Janssen

Cooperations

-

Funded by

Shell-NWO/FOM

Funded %

University	-
FOM	100 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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Capacitive tomography of water saturation distributions in thin porous media

Project leaders
AA Darhuber, LPJ Kamp
Research theme
Complex dynamics of fluids
Participants
S Wang, AA Darhuber, LPJ Kamp
Cooperations
Canon
Funded by
NWO, Canon, TU/e, UT
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019
Information
AA Darhuber
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Project Aim

The goal of the project is to develop an experimental technique for measuring the distribution of water in paper with high spatial and temporal resolution based on capacitance tomography and to validate it using experiments and numerical simulations.

Progress

Shuo Wang has followed an introduction into micro-/nanofluidics and electrokinetics and has commenced experiments at Canon using an existing setup for 1D monitoring of the imbibition dynamics of water into paper based on impedance spectroscopy. The design of a setup providing 3D resolution is underway.

Dissertations

-

Scientific Publications

-

Project Aim

Develop a system to visualize and analyze the flow around a human swimmer and extract information from resolved flow field of interest for trainers, coaches and sports scientists. Visualization will be done by means of a bubble system and PIV routine. Furthermore the influence of different and new kinds of feedback to swimmers will be tested on a group of swimmers. In the end the goal is to contribute to improved performance of Dutch elite swimmers.

Progress

This project has been finished with the thesis of J. van Houwelingen (2018).

Dissertations

-

Scientific Publications

1. van Houwelingen, J., Kunnen, R. P. J., van de Water, W., Holten, A. P. C., van Heijst, G. J. F. & Clercx, H. J. H.- Flow visualisation in swimming practice using small air bubbles. 2019, Sports Engineering. 22, 2, 8 p., 13.

Project leaders
HJH Clercx

Research theme
Complex dynamics of fluids

Participants
J van Houwelingen, PJ Beek,
HJH Clercx, GJF van Heijst,
RPJ Kunnen, W van de Water

Cooperations
R Verzicco (Roma, Italy),
PJ Beek (VU), J Westerweel (TUD),
InnoSportlab de Tongelreep

Funded by
STW

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2013

Information
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RARETRANS: TRANSPORT IN RAREFIED GASES IN NEXT GENERATION PHOTOLITOGRAPHY MACHINES

PROJECT LEADERS
F Toschi, HJH Clercx

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
C Livi, G Di Staso, F Toschi, HJH Clercx

COOPERATIONS
HC van Brummelen, ASML

FUNDED BY
STW

FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2018

INFORMATION
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PROJECT AIM

The RareTrans project focuses on the development of computational techniques to predict heat and mass transfer in rarefied gas flows, as occurring in Extreme-Ultra-Violet (EUV) machines. Gas flows in EUV machines are extremely complicated, on account of the wide range of Knudsen numbers (viz, the ratio of the mean free path between gas molecules and the device scale) that occur in EUV machines. Conventional Navier-Stokes continuum models are invalid in the rarefied regime, so the RareTrans project addresses the development of computational techniques to overcome this barrier by solving the more fundamental Boltzmann equation.

PROGRESS

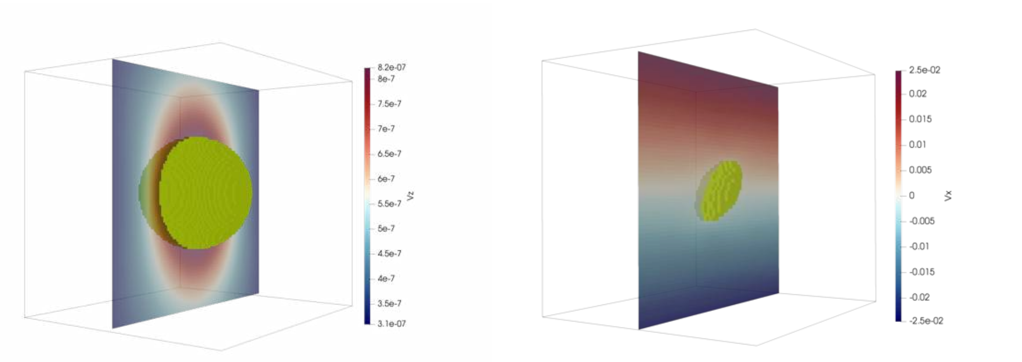
We performed a systematic error analysis of finite-size particle dynamics using the Hermite regularized Lattice Boltzmann method, for different particles resolution, addressing translational and rotational systems separately. The motivation is the understanding of the degree of accuracy provided by different boundary condition models at the fluid-solid interface, with a focus on cases where particles are discretized using few lattice grid points. An improved version of the interpolation scheme for curved boundaries is developed in order to compute particle boundary position also when the particle is crossing a link between two fluid nodes, showing that the capability to resolve non-spherical particles is further enhanced.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Snapshots of LBM 3D simulations. On the left the settling of a spherical particle in the Stokes regime is used to investigate translational dynamics accuracy. On the right the rotation of an ellipsoid in a shear flow is used to address rotational dynamics accuracy.

PROJECT AIM

The aim of the project is to understand and control the absorption and imbibition of solutions and suspensions (e.g. inkjet ink) in porous media, such as paper.

PROGRESS

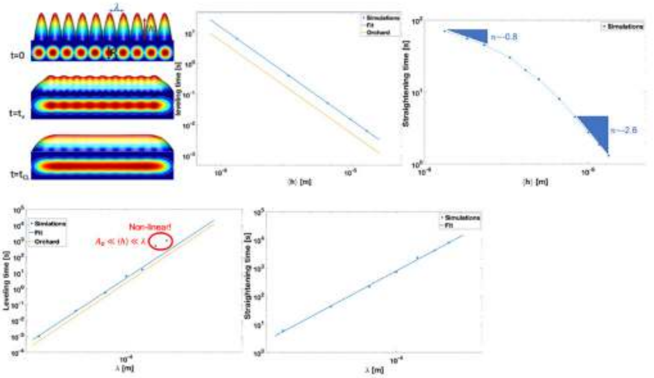
We studied the process of leveling1 and straightening2 for an infinite array of small overlapping droplets. We compare the leveling time with the Orchard time (leveling time for lines). We developed a model that include contact angle heterogeneities without phenomelogical relationship, but based on thin film approach. We tested and proved that this model has more than one equilibrium contact angle and the advancing contact angle is different from the receding one. We modelized the deposition process as a smooth process, it can be however generalized to instantaneous/sharp deposition paying in computational work. We finally use all the features developed to study the formation of primary head on both the horizontal (contact line) plane and vertical (thickness) plane.

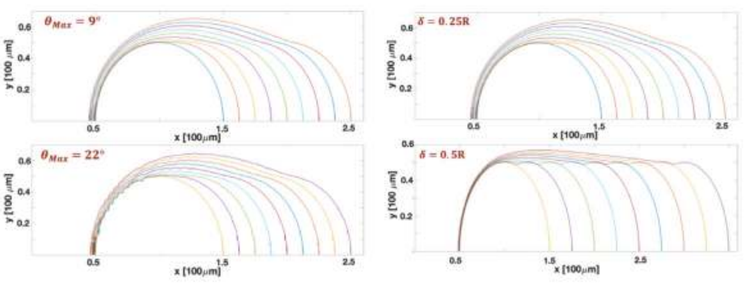
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-





PROJECT LEADERS

AA Darhuber, J Harting

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

G Venditti, AA Darhuber, J Harting

COOPERATIONS

S Luding (UT), Océ

FUNDED BY

NWO/STW

FUNDED %

University	-
FOM	-
STW	75 %
NWO Other	-
Industry	25 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2016

INFORMATION

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Project leaders
MFM Speetjens, F Toschi
Research theme
Complex dynamics of fluids
Participants
S Varghese, RR Trieling
Cooperations
Collaborative project of TU/e-ET and TU/e-F&F
Funded by
NWO (CSER programme)
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2014
Information
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Project Aim

The study investigates scalar transport in enhanced subsurface flows driven by injection and production wells for 3 generic transport problems: (i) rapid scalar extraction; (ii) confinement of a scalar quantity for in situ processing; (iii) targeted delivery of a scalar quantity to a designated subsurface region. The generic transport problems are investigated by analyses of transport in a 2D circular reservoir with a Darcy-type flow driven by injection and production wells positioned on its perimeter. Considered are steady flow due to static injector-producer pair ("base flow") and time-periodic flows due to systematic reorientation of base flow by reoriented well pairs ("RPM flow").

Progress

This project has been finished with the thesis of S. Varghese (2019).

Dissertations

1. Varghese, S. (2019). Scalar transport in enhanced subsurface flows .Eindhoven: Technische Universiteit Eindhoven. ((Co-)promot.: Toschi, F., M.F.M. Speetjens, Trieling, R.R.).

Scientific Publications

1. Speetjens, M., Varghese, S. & Trieling, R.. Lagrangian approach to analysis and engineering of two generic transport problems in enhanced subsurface flows. 2019. Journal of Contaminant Hydrology. 224, 22 p., 103482.

Project Aim

The aim of the project is to use DNS (Direct Numerical Simulation) and LES (Large Eddy Simulations) to explore the role of tidal straining on the mixing-stratifying competition. It is also an objective to improve turbulent closures for application in Delft3D (Deltares) using simulation results and field data (made available by the Port of Rotterdam), which specifically take into account anisotropy due to inhomogeneous horizontal and vertical conditions.

Progress

This year has exclusively been spent on writing the thesis and work is still in progress.

Dissertations

-

Scientific Publications

1. Kaptein, S.J., Duran-Matute, M., Roman, F., Vincenzo Armenio, F. & Clercx H.J.H. (2019). Existence and properties of the logarithmic layer in oscillating flows. Journal of Hydraulic Research.
2. Kaptein, S.J., Duran-Matute, M., Roman, F., Armenio, V. & Clercx, H.J.H. (2019). Effect of the water depth on oscillatory flows over a flat plate: from the intermittent towards the fully turbulent regime. Environmental Fluid Mechanics.19, 5 p. 1167-1184 p.

Project leaders
HJH Clercx

Research theme
Complex dynamics of fluids

Participants
SJ Kaptein, M Duran Matute, HJH Clercx

Cooperations
M Blaas (Deltares, Utrecht),
J Pietrzak (TU Delft),
V Armenio (University of Trieste)

Funded by
NWO-TTW

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2014

Information

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Sensing and controlling resin-layer thickness in additive manufacturing processes

Project leaders
HJH Clercx, RPJ Kunnen
Research theme
Complex dynamics of fluids
Participants
A Kozhevnikov, RPJ Kunnen, HJH Clercx
Cooperations
TNO
Funded by
TKI
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
Information
HJH Clercx
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Project Aim

The project focuses on the improvement of technologies in industrial additive manufacturing and particularly in ceramic vat photopolymerization that aims in decreasing of the building time and increasing quality and accuracy of the final products. The project will contribute to the development of a tool for the resin layer thickness measurements after the recoating process. The study will also include an investigation of recoating parameters and their influence on the free-surface deformations with different geometries.

Progress

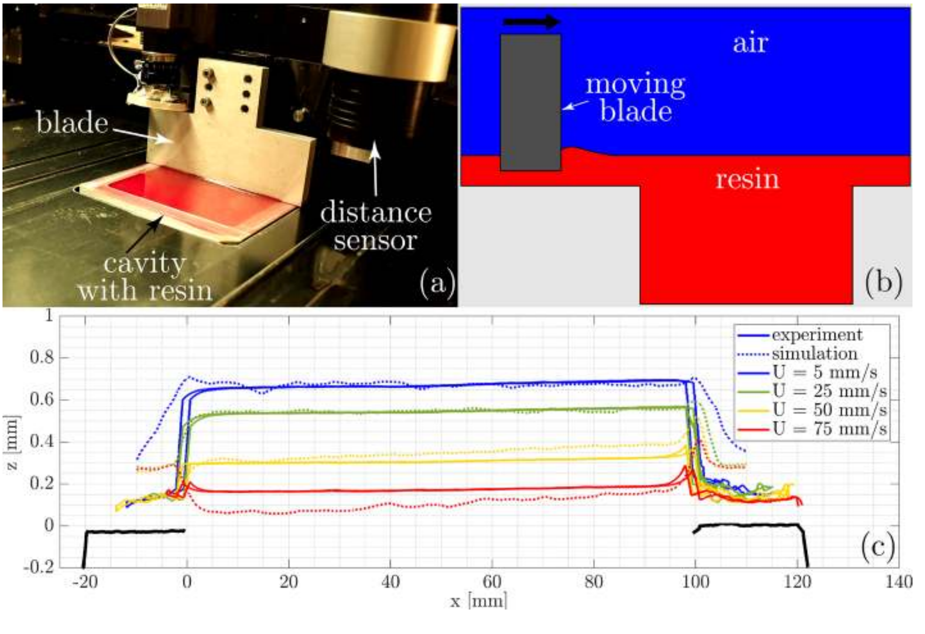
Experimental and numerical study of the recoating process in additive manufacturing have been continued in 2019 year. A liquid layer deposition over a rectangular-shaped topography was explored. It has been found that the resin surface level over the cavity can be successfully controlled by changing the recoater speed. Simple analytical expression has been obtained to qualitatively predict the liquid surface topography. Numerical and analytical results showed a good agreement with the experiment.

Dissertations

-

Scientific Publications

-



The experimental setup (a) and sketch of the 2D CFD model (b) (not to scale). The comparison of resin surface topography (c) after recoating at different speeds (solid lines are for the experiments, dashed lines are for the CFD simulations).

Evaporation of "living liquid" drops

Project Aim

1) Study on the formation of the coffee-ring effect for evaporation drops of living liquids. Identify the basic mechanisms that control cell-pattern formation and the differences in (collective) dynamics of E-coli bacteria inside the drop and near the contact line.

(2) Study on the deposition patterns of collagen in evaporating collagen solution drops and the response of mammalian cells to these patterns. Construct a morphology map for different collagen pattern structures in function of collagen concentration of the solution and the evaporation rate.

(3) Study on the peeling and re-peeling mechanism of an adhesive tape under tension.

Progress

(1) Construct and test setup; humidity control, side view recording and fluorescence microscopy of the bacteria.

(2) Using the setup of (1) we record the contact line motion and contact angle. With polarized light microscopy (PLM) we measure the profile of the collagen stain, shown in figure 1. Cells are found to strongly respond to the patterns formed. Collaboration with BioMedical Engineering (TU/e)

(3) Formulating theoretical model to discribe the (re-) peeling mechanisms of an adhesive tape loop. Model is in good comparison to experimental data. Collaboration with University of Twente (UT).

Dissertations

-

Scientific Publications

-

Project leaders
H Gelderblom

Research theme
Complex dynamics of fluids

Participants
T Wilting, H Gelderblom

Cooperations
AA Darhuber (TU/e), J Foolen (TU/e), A Marin (UT), J Snoeijer (UT)

Funded by
Veni (NWO), TU/e

Funded %

University	50 %
FOM	-
STW	-
NWO Other	50 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2018

Information
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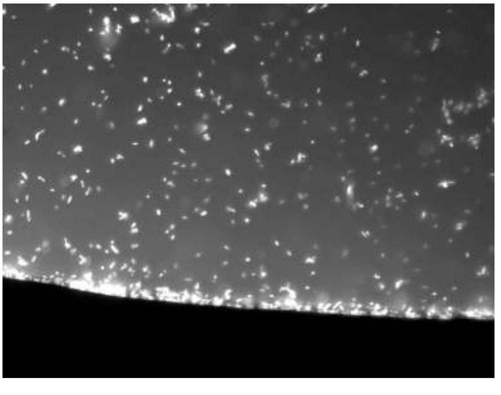

Bacteria at the contact line of a drying drop

PLM image of a collagen stain

PROJECT LEADERS
F Toschi, HJH Clercx

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
H Li, F Toschi, HJH Clercx

COOPERATIONS
-

FUNDED BY
China Scholarship Council

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT
2017

INFORMATION
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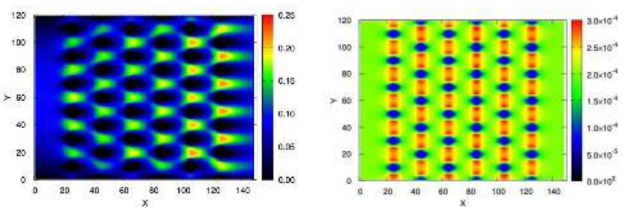
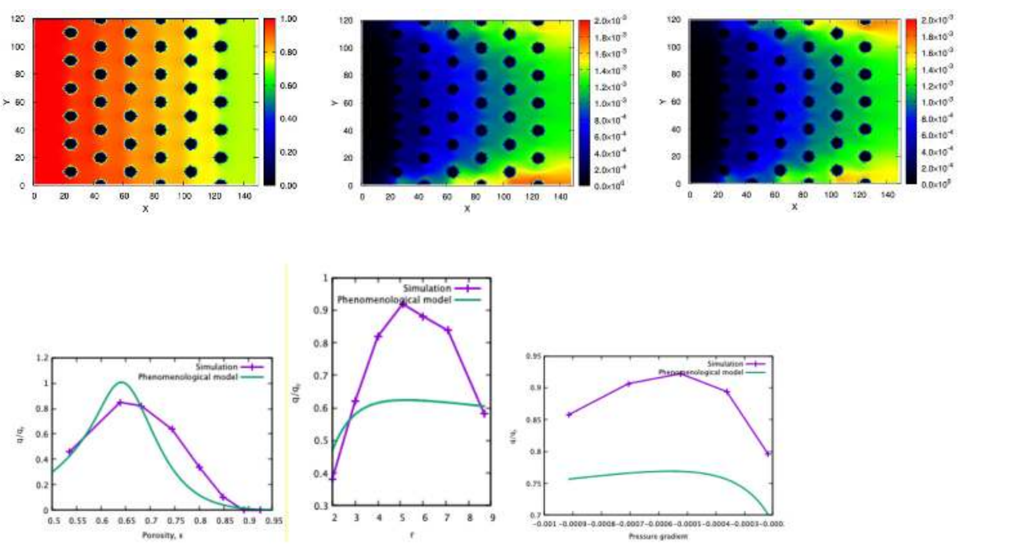
PROJECT AIM
The conversion of CO_2 into methanol using energy that is not produced from fossil fuels has been suggested to be one of the best ways of storing energy as well as for CO_2 recycling. Plasma assisted catalytic conversion may help achieving this goal. To gain insights and optimize the conversion proceedure, numerical models based on the Lattice Boltzmann methods and zero dimensional simulations will be employed. The goal is to achieve an efficient conversion way.

PROGRESS
A 2D Lattice Boltzmann (LB) model is developed for plasma/flow problems. Simulations of simplified plasma fluid with electric breakdown reaction in a homogenous packed spheres bed are studied. And a phenomenological model is developed based on the simulations to help optimize the control perimeters of the test.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-





Simplified plasma fluid with electric breakdown reaction in a homogenous packed spheres bed. A fluid with only neutral species A flows through a regularly packed spheres bed. A pair of electrodes is placed at the top and at the bottom of the bed. The reaction is A □ B+ + C- with rate k, and k is a function of the electric field. A constant pressure drop is applied in the X direction and bounce back conditions are applied in the Y direction.

TROCONVEX: Turbulent rotating convection to the extreme

Project Aim

Many geophysical and astrophysical systems are driven by buoyancy and affected by rotation. The flow behavior in these large-scale systems shows remarkable differences with the small-scale regimes usually studied, making extrapolations from current scaling models impossible. In recent years evidence of a new scaling regime has been observed. This so-called geostrophic regime is expected to be relevant to these large-scale flows. TROconvex is an experimental setup that is able to reach new extreme parameters through a 4 m high rotating tank, allowing us to have an unprecedented insight into these flows.

Progress

Completed collection of heat transfer data, also from 4 m tank, covering three different Ekman numbers. Calculation of heat transfer efficiency at different regimes, with temperature profile analysis. Visualization of the different flow regimes in the experimental setup. Analysis and characterization of the different flow regimes in Rotating Convection. Major operations of maintenance and repair of the setup, in order to solve major technical issues. Calculation of heat loss of the setup. Design and realization of a new transparent segment to perform Stereo PIV, including a calibration grid system and illumination.

Dissertations

-

Scientific Publications

-

Project leaders

RPJ Kunnen, HJH Clercx

Research theme

Complex dynamics of fluids

Participants

M Madonia, AJ Aguirre Guzman, JS Cheng, HJH Clercx, RPJ Kunnen

Cooperations

-

Funded by

ERC

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2016

Information

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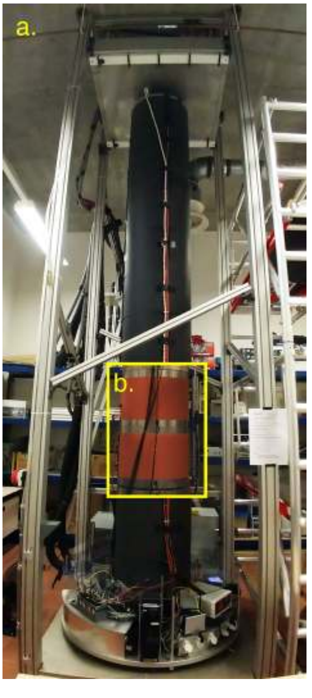
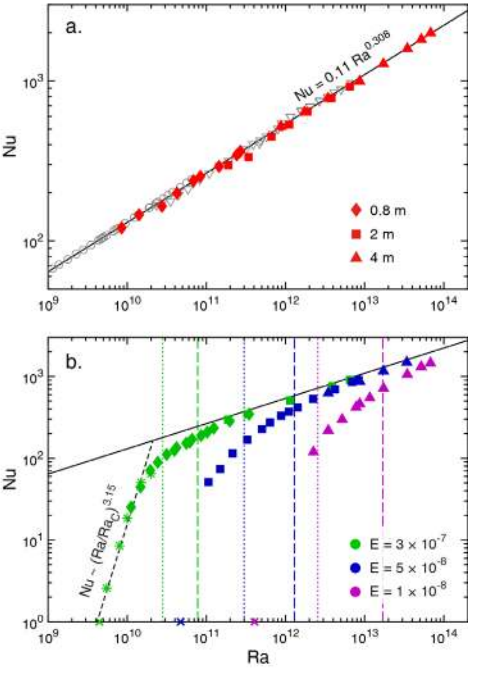


TROCONVEX 4m tank



Algorithms for Eulerian-Lagrangian approaches in turbulence, micro- and nano-fluidics

Project leaders
F Toschi

Research theme
Complex dynamics of fluids

Participants
FMN Milan, L Biferale (Rome), M Sbragaglia (Rome), F. Toschi

Cooperations
University of Rome, Tor Vergata, HPC-LEAP Program, Univ. of Wuppertal (Germany)

Funded by
HPC-LEAP (Marie Curie Fellowship) Horizon 2020

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2015

Information
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Project Aim

Developing new algorithms to describe finite-size particles (with internal dynamics) in turbulent flows.

Progress

This project has been finished with the thesis of F.M.N. Milan.

Dissertations

1. Milan, F.M.N. (2019). Multiscale Lattice Boltzmann simulations of droplet dynamics in time-dependent and turbulent flows. Eindhoven: Technische Universiteit Eindhoven. ((Co-) promot.: Toschi, F., L. Biferale & M. Sbragalia).

Scientific Publications

-

Spreading and imbibition of water-based printing inks in porous media - experiments

Project Aim

Aqueous inkjet printing performs superbly on expensive paper coated with microporous layers, but the print quality on uncoated, recycled copier paper is generally less optimal. Fundamental understanding of the underlying processes is mandatory to improve water-based printing. In collaboration with Océ, we will investigate the complex multiscale and multiphase ink-substrate interactions. This will allow answering challenging questions such as: What is the role of surfactants in the imbibition dynamics? How does the nanostructure of the medium affect absorption/swelling, and how can one account for it at larger scales?.

Progress

Systematic experiments concerning the water imbibition dynamics in paper substrates were conducted using infrared thermography. A corresponding model was developed based on unsaturated flow coupled with heat and mass phenomena in the adjacent gas phase. The numerical simulations reproduce the experimental findings well. A paper has been accepted for publication in 2020.

Dissertations

-

Scientific Publications

-

Project leaders

AA Darhuber, JCH Zeegers

Research theme

Complex dynamics of fluids

Participants

V Murali. AA Darhuber, JCH Zeegers

Cooperations

N Tomozeiu (Océ), H Wijshoff (Océ), J Harting, S Luding (UTwente)

Funded by

STW + Océ

Funded %

University	-
FOM	-
STW	70 %
NWO Other	-
Industry	30 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

AA Darhuber
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True Solvent Free: Towards the next generation waterborne coatings

Project leaders
J Harting
Research theme
Complex dynamics of fluids
Participants
MPJ Wouters, J Harting, HP Huinink, SJF Erich, OCG Adan, P Venema, J Keddie, B Voogt
Cooperations
DSM Coating Resins, AkzoNobel, Océ, Drywood, TNO, NVVT, SHR
Funded by
STW
Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2014
Information
MPJ Wouters
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Project Aim

The scientific aim is to understand film formation of new coatings consisting of polymer particles (acrylate based) that can be plasticized by water. The project aims to develop a simulation model that connects film drying with the chemistry of the polymer particles and the environmental conditions to enable a targeted design of waterborne coatings. Furthermore, it tries to identify handles for designing fully waterborne coatings with improved performance.

Progress

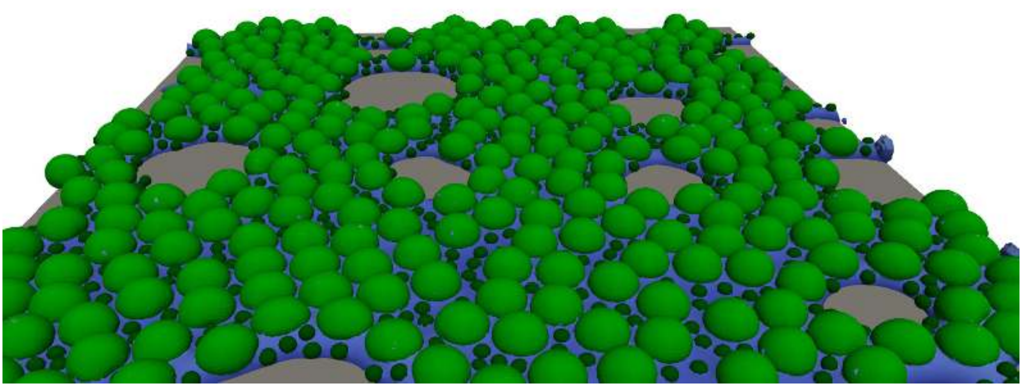
Our developed simulation method has been shown able to accurately model soft capsules in an evaporating fluid. We applied this method to study the capillary interactions between soft particles protruding through a thin fluid film on top of a substrate. Furthermore, we investigated the relaxation of a single layer of soft particles, which is initialized out of equilibrium to better understand the final properties of dried suspensions of soft particles.

Dissertations

-

Scientific Publications

1. Wouters, M., Aouane, O., Kruger, T., Harting, J. Mesoscale simulation of soft particles with tunable contact angle in multi-component fluids, Physical Review E 100(3) 033309, 2019



Project Aim

The main scientific goal of the "Fundamental Fluid Dynamics Challenges in Inkjet Printing (FIP)" programme is to obtain insight into unresolved issues in the current inkjet process and to improve and extend the functionality of inkjet printing to meet future requirements. The current project aims at a mesoscale model describing the deposition and imbibition of droplets of ink in paper.

Progress

1. We investigated numerically the coalescence of liquid droplets on a thick film with a multi-component lattice Boltzmann method. The growth of the bridge height follows h ~ t2/3. The bridge profiles and horizontal velocity profiles show self-similar dynamics. The simulation results are in agreement with experimental results and the theoretical prediction. Moreover, the effect of the droplet contact angle on the dynamics of coalescence were studied.

2. We investigated numerically the capillary interactions of liquid droplets on a thin film. The capillary force increases with decreasing the thickness of the liquid film.

Dissertations

-

Scientific Publications

1. Xie, Q. & Harting, J. The effect of the liquid layer thickness on the dissolution of immersed surface droplets. Soft Matter 15, 6461-6468 (2019).
2. Sukhov, A., Ziegler, S., Xie, Q., Trosman,O., Pande,J.,Grosjean, G., Hubert, M.,Vandewalle,N., Smith, A-S., & Harting, J. Optimal motion of triangular magnetocapillary swimmers. Journal of Chemical Physics 151, 124707 (2019).

Project leaders

J Harting, S Luding, WK den Otter

Research theme

Complex dynamics of fluids

Participants

Q Xie

Cooperations

The project is part of the programme "Fundamental Fluid Dynamics Challenges in Inkjet Printing (FIP)"

Funded by

Océ, UT, TUE, and FOM/NWO

Funded %

University	24,90 %
FOM	19.54 %
STW	-
NWO Other	11,11 %
Industry	44,44 $
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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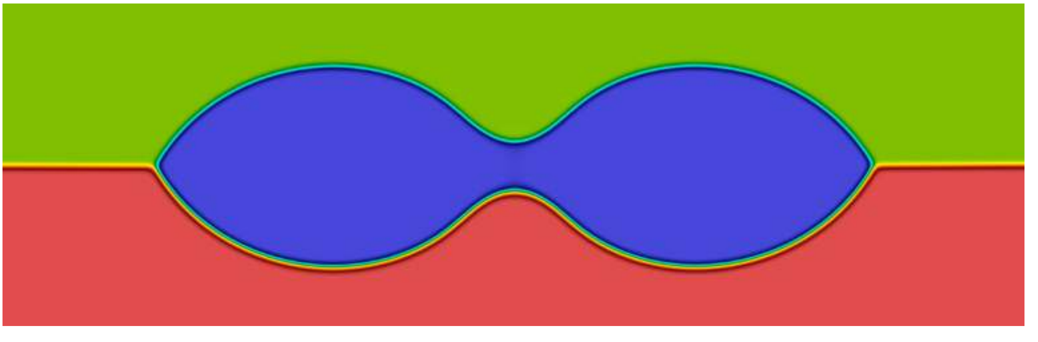

Project leaders
F Toschi
Research theme
Complex dynamics of fluids
Participants
X Xue, F Toschi, M Sbragaglia (Rome), L. Biferale (Rome)
Cooperations
University of Rome, Tor Vergata, HPC-LEAP Program, Eurotech (changed to Nvidia)
Funded by
HPC-LEAP (Marie Curie Fellowhsip), Horizon 2020
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2015
Information
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Project Aim

Implementation of novel algorithms and/or optimization of existing fully parallel and scalable algorithms to study thermal flows at macro-scales and/or fluctuating hydrodynamics at micro and nano-scales. If the opportunity arises, exploration of the coupling with finite size particles (with and/or without internal dynamics).

Progress

This project has been finished with the thesis of X. Xiao (2019).

Dissertations

1. Xuo, X. (2019). Fluctating multicomponent hydrodynamics via the lattice Boltzmann models. Eindhoven: Eindhoven University of Technology. ((Co-) promot.: Toschi, F., L. Biferale & M. Sbragaglia).

Scientific Publications

1. Xue, X., Biferale, L., Sbragaglia, M. & Toschi, F., 25 Aug 2019. Particle settling in a fluctuating multicomponent fluid under confinement, in : arXiv. 13 p., 1909.01092v1.

PROJECT AIM

The aim of the project is to study the physics of fluid jetting, as inspired by inkjet printing applications, mostly by means of numerical modelling and simulations. The focus of the project is on full 3D instabilities that, due to a number of physical causes, can lead to droplets being generated at an angle with respect to the symmetry axis.

PROGRESS

The color-gradient (CG) multi-phase Lattice Boltzmann model is used to investigate jetting of microdroplets and the effects of wetting on the jetting process. Comparison to other numerical approaches (FEM and VOF) is currently underway. The CG approach has been further validated through a droplet oscillation testcase where the simulated oscillation frequency matches the analytic prediction with an error less than 5% for a coarse mesh and less than 1% for a more refined mesh, see Fig. 1. Furthermore, a Rayleigh-Plateau test case has confirmed proper ligament breakup behavior when compared to other numerical approaches and experimental data.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

F Toschi

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

K Datadien, F Toschi, H Wijshoff

COOPERATIONS

L Lohse (UTwente)

FUNDED BY

STW

FUNDED %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2014

INFORMATION

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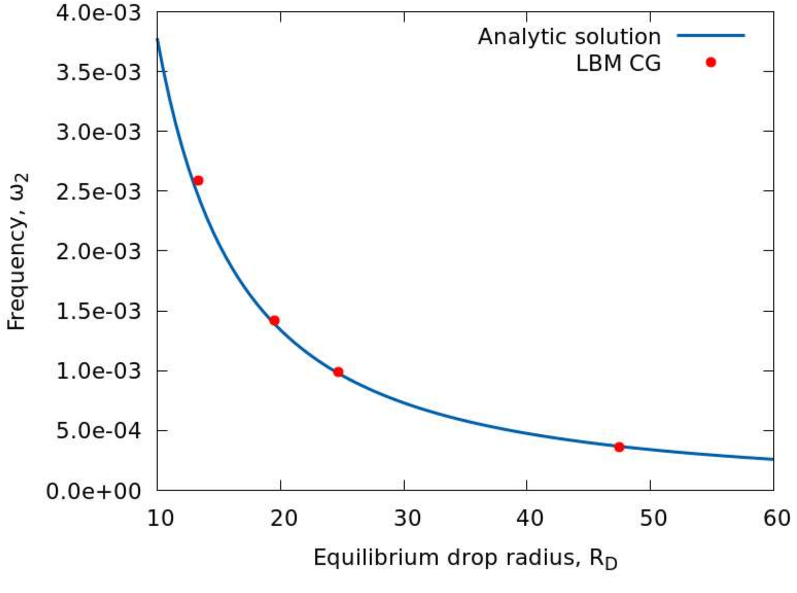

Results of an oscillating droplet testcase showing good agreement between simulated (red) and analytic (blue) oscillation frequency

Project leaders
AA Darhuber, J Snoeijer

Research theme
Complex dynamics of fluids

Participants
M Chudak, J Snoeijer , AA Darhuber

Cooperations
WU, CNRS, BASF, IPF, INM, Cambridge University

Funded by
EU H2020

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2015

Information
A. A. Darhuber
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Project Aim

The aim of this project is to elucidate the role of water in inhibiting proper adhesive contact between an adhesive label and a target surface. The goal is both to achieve fundamental understanding as well as to evaluate engineering solutions to remove the water. We will study aspects such as the wetting and dewetting dynamics, the transport of water along and through patterned and/or porous layers.

Progress

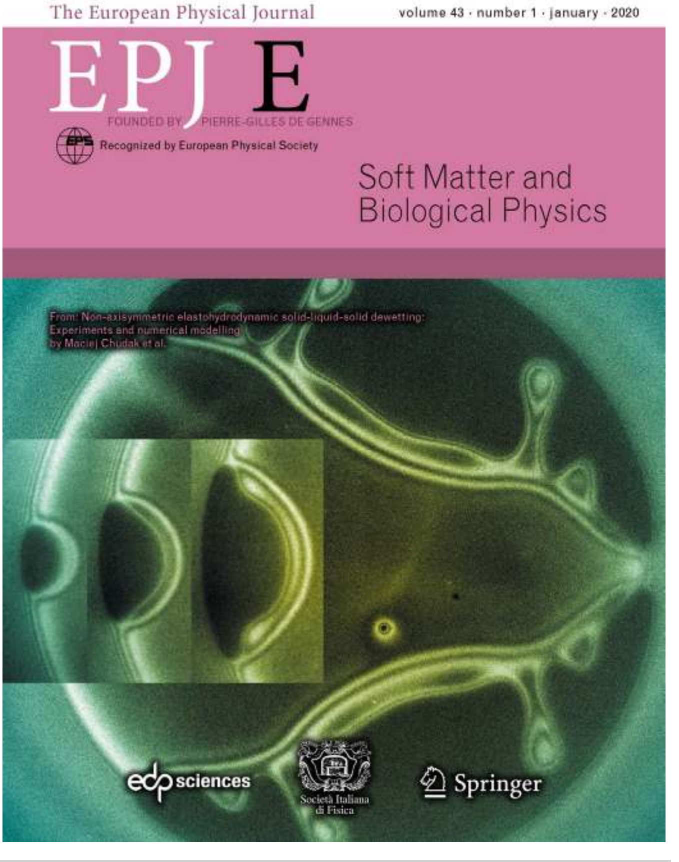
Two manuscripts on solid-liquid-solid dewetting and the dynamics of expulsion of droplets from the contact zone of two solids that are pressed together have been submitted and accepted for publication. The writing of a third manuscript on electrically enhanced adhesion has commenced.

Dissertations

-

Scientific Publications

-



Project Aim

The project aims to investigate the dynamics and development of (directional) instabilities during droplet formation in the process of inkjet printing. The project also focuses on how the presence of particulates near the nozzle boundary influences the physics of droplet formation. Lattice Boltzmann Method with high-density ratio schemes for multiphase flows will be used for generating the droplets and Immersed Boundary Methods will be applied for simulating solid-fluid interactions to study the presence of the particulates in the ink, in the hopes of understanding these processes and increase the reliability and performance of inkjet printers.

Progress

Started focusing on learning the Lattice Boltzmann method (LBM) and Shan-Chen multiphase method for simulating the droplet formation and multiphase flows, Implemented a basic Direct-forcing Immersed Boundary Method (IBM) in 3D in the inhouse LBM code for simulating fluid-solid interactions, validated the DF-IBM implementation with experimental results for a sedimentation of sphere under gravity, made a proof of concept simulation of a liquid droplet interacting with a solid surface (in 2D) with the Shan-Chen and DFIBM implementation.

Dissertations

-

Scientific Publications

-

Project leaders

F Toschi, HMA Wijshoff

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

A Ghosh, F Toschi, HMA Wijshoff

Cooperations

-

Funded by

STW

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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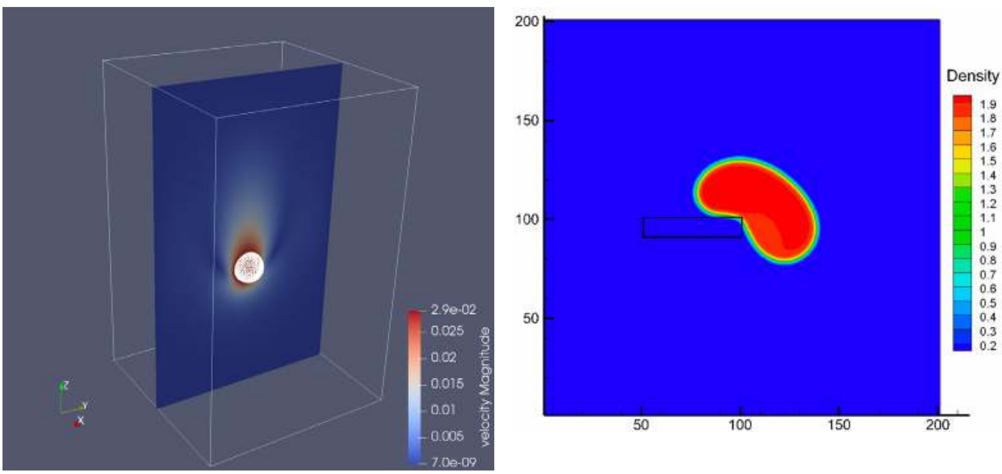
(a) Sedimentation of a sphere under gravity, (b) Interaction of a falling droplet with an Immersed Boundary



PROJECT LEADERS
HJH Clercx, M Duran Matute
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
LM Flores Ramirez, M Duran Matute, HJH Clercx
COOPERATIONS
GH Keetels (TUD)
FUNDED BY
CONACYT (Mexico)
FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT
2019
INFORMATION
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PROJECT AIM

We propose to investigate the Lagrangian statistics of a forced, quasi-two-dimensional turbulent flow bounded by rigid walls through numerical simulations, laboratory experiments and analytical considerations. The purpose is to determine how particle dispersion differs from its typical evolution in the unbounded 2D case as a consequence of the flow confinement by rigid lateral walls and the 3D effects caused by a finite fluid-layer thickness.

PROGRESS

A spectral code for numerical simulations of two-dimensional flows has been tested and an additional module for Lagrangian particle tracking is being implemented. On the other hand, laboratory experiments of a shallow single layer of fluid driven by electromagnetic forcing are being conducted under different conditions (forcing levels, layer depths). Surface velocity fields and particle tracks have been obtained. Additionally, the velocity fields have been employed to reconstruct virtual particle trajectories. Lagrangian statistics will be calculated based on the information of the particle trajectories.

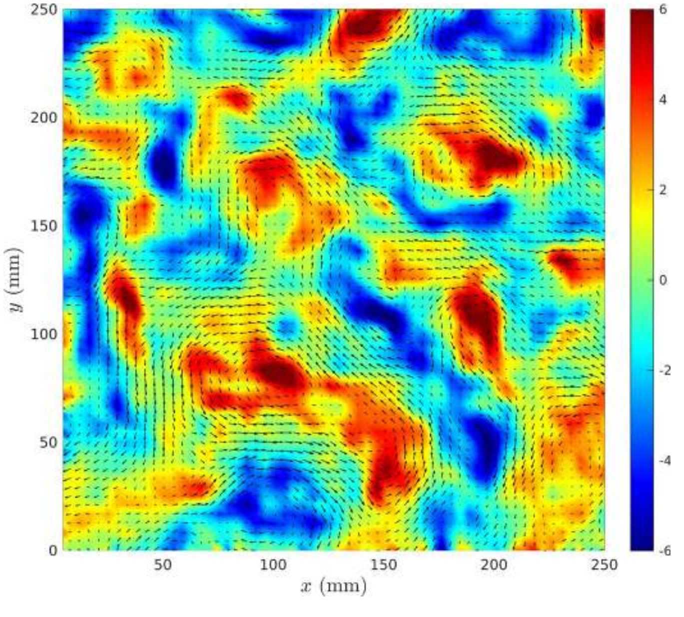
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Vorticity and velocity fields of a typical experiment. Vectors represent the horizontal velocity components and colors denote the vertical component of the vorticity.



PROJECT AIM

The project develops in the broader context of pedestrian dynamics, whose scope is to understand the stochastic and complex dynamics of human crowds in relation with fluid and physics models and with applications to serviceability of civil infrastructures. Pedestrian dynamics is a multidisciplinary field involving statistical physics, mathematical modeling and computer vision, but also civil engineering and social sciences. In this project we consider the pedestrian dynamics of visitors in public infrastructures, museums, outdoor alleys and exhibits. Targeting a major step forward in their fundamental understanding, we develop tools for quantitative monitoring, analysis and crowd control.

PROGRESS

The first year of this VENI project addressed the development of techniques for fine-scale measurement and trajectory-based modeling of pedestrian dynamics. By leveraging on physics-informed machine learning we obtained the first-highly accurate body orientation measurement tool working in real-life and real-time. This tool, thanks to which we modeled quantitatively the connections between individual velocity and orientation, unlocks analyses of nematic ordering in dense crowds. We developed, in parallel, path-integral based tools for modeling the statistics of pedestrian trajectories in complex environments where multiple usage patterns co-exhist.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. E. Ronchi, A. Corbetta, E. Galea, M. Kinateder, E. Kuligowski, D. McGrath, A. Pel, Y. Shiban, P. Thompson, F. Toschi. New approaches to evacuation modelling for fire safety engineering applications. Fire Saf. J. 106, 197-209, 2019.
2. M. Haghani, N. Bode, M. Boltes, E. Cristiani, A. Corbetta. Panic, irrationality, herding: Three ambiguous terms in evacuation dynamics research. J. Adv. Transport., 9267643, 58pp, 2019.
3. A. Corbetta, F. Toschi. Path-integral representation of diluted pedestrian dynamics. in 'Complexity Science. An introduction'. 329-345. Eds. M. Peletier, R. Van Santen, E. Steur. World Scientific., 2019.
4. J. Adrian, N. Bode, M. Amos, M. Baratchi, M. Beermann, M. Boltes, A. Corbetta, G. Dezecache, J. Drury , Z. Fu, R. Geraerts, S. Gwynne, G. Hofinger, A. Hunt, T. Kanters, A. Kneidl, K. Konya, G. Köster, M. Küpper, G. Michalareas, F. Neville, E. Ntontis, S. Reicher, E. Ronchi, A. Schadschneider, A. Seyfried, A. Shipman, A. Sieben, M. Spearpoint, G. Sullivan, A. Templeton, F. Toschi, Z. Yücel, F. Zanlungo, I. Zuriguel, N. van der Wal, F. van Schadewijk, C. von Krüchten, N. Wijermans. A Glossary for Research on Human Crowd Dynamics. Collective Dynamics, 4, 1-13, 2019.
5. M. Haghani, N. Bode, M. Boltes, A. Corbetta, E. Cristiani. Empirical Research on Pedestrians' Behavior and Crowd Dynamics (Editorial). J. Adv. Transport., 3457370, 2p, 2019.

PROJECT LEADERS
A Corbetta

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
A Corbetta, F Toschi

COOPERATIONS
CNR-IAC, Rome, IT, Eindhoven Municipality, Amsterdam Municipality, ProRail BV, Glow Eindhoven, Naturalis Center, Leiden, Signify BV

FUNDED BY
NWO

FUNDED %

University	-
FOM	-
STW	-
NWO Other	90 %
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019

INFORMATION
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Transport in porous media

Prof.dr.ir. OCG Adan

In the group Transport in Permeable Media, TPM, of the department of Applied Physics at the Eindhoven University of Technology research is performed on transport and phase changes in permeable media. Our mission is to advance materials technology through an in-depth understanding of transport physics in permeable media, in support of various technology domains, such as high tech materials, petro physics and thermal energy storage. The interaction between transport of fluids and solutes, phase changes and material response on different scale levels -typically in the micrometer to millimetre range- forms the core of our research activities. Inherently, interdisciplinarity is in TPMs genes, encompassing transport physics, materials science, chemistry and biology. The experiment is at the heart of the group, which is due to the unique opportunities of our MRI Infrastructure, consisting of nine home-built or -modified scanners operating at fields ranging from 0.7-4.7 T. TPMs research profile is based on use-inspired basic research. Consequently, interaction with industrial players forms a cornerstone in our approach. For this reason, fruitful partnerships exist with TNO, AkzoNobel and Oce. The work is mainly funded by the Dutch Technology Foundation (STW), Materials Innovation Institute (M2I).

PROJECT AIM

Developing a thermochemical heat battery on the basis of salt hydration requires a profound understanding of the thermochemical material and its interaction with the absorbing vapor. The aim of this work is to translate the fundamental properties of the salt hydrate into a compact and stable thermochemical material.

PROGRESS

In this study, the water vapor pressure - temperature (p-T) phase diagram of K2CO3, a promising compound for thermochemical heat storage, is studied in detail. We have shown that the phase diagram involves a metastable zone of circa 10 K and the induction times preceding hydration are well-described by classical homogeneous nucleation theory. We conclude that the hydration proceeds as a solid-solid phase transition, where nucleation and growth of the new phase takes place in a wetting layer. Practical aspects like the output temperature of the salt are defined by its metastable zone width (hatched in the figure) rather than its equilibrium phase diagram.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. L. C. Sögütoglu, M. Steiger, J. Houben, D. Biemans, H. R. Fischer, P. A. J. Donkers, H. P. Huinink, O. C. G. Adan. Understanding the hydration process of salts: The impact of a nucleation barrier. Crystal Growth and Design, 19(4), 2279-2288 2019.

PROJECT LEADERS

H.P Huinink

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Dr.ir. H.P. Huinink, Prof.dr. O.C.G. Adan

COOPERATIONS

DOW, CALDIC

FUNDED BY

EU

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

START OF THE PROJECT

2015

INFORMATION

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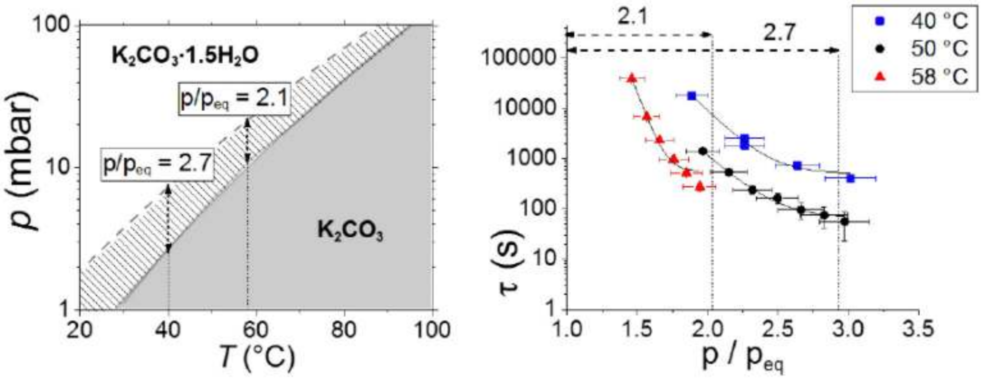
Left: phase diagram of K2CO3. Right: induction times against the overpressure p/peq



Elementary Processes in Gas Discharges

Prof.dr.ir. GWM Kroesen

Prof.dr.ir. U Ebert

Our mission is to study the elementary processes in gas discharges by a mix of theory, modelling, and diagnostics.

A thorough understanding of the intensity and effectivity of elementary processes like ionization, recombination, transport, radiation, excitation, de-excitation, chemical reactions and surface processes enables the group to develop predictive models of a large range of plasmas. The understanding is obtained by a strong interleaved integration of state-of-the art plasma diagnostics with advanced plasma models. Those models then in turn enable users of the plasmas to optimize the plasma source for their specific application. Over the years, the range of applications the group has worked on has shifted continuously: from plasma etching via lighting to medical applications and many other areas. However, the scientific scope of the group have not shifted: continuously the focus has been with the elementary processes in and the physics of plasmas.

Some applications fade and other applications lure, but plasma physics remains our core.

If you are not familiar with plasma and gas discharge physics, you may wish to consult the Wikipedia page about plasma physics. Alternatively, the applications and techniques sections of this site provide an explanation of the plasma sources and measurement and modelling techniques that are used in our group. If nothing else, the pictures shown there may convince you of the visual beauty of the topic of our research!

Passing XSAMS

Project Aim

Expand Giovangigl's current discretization strategy by taking into account the structure of chemical source terms in the numerical method. Applying chemical reduction (model reduction) methods to plasma simulations to reduce computational cost, access more information on plasma chemistry and improve numerical stability. Provide an is an open source implementation of an iterative solver that extends the well-known BiCGStab iterative solver for the Eigen library. Creating web-based methods for managing, distributing, and validating chemical/atomic data sets. Similar to XSAMS, however with a showcase application; MagnumPI.

Progress

Regarding the MagnumPI solver for the dissemination of input-data, there has been work on improving integration strategies. The web interface and data exchange format of this solver have been extensively discussed. Chemical reduction techniques have so far been studied in an explorative manner. Furthermore the work of Rehman on ILDM, has been extended with proof of concept codes. The main findings from the work of the iterative linear solver were the systematic study of the convergence behavior of the BiCGStab, BiCGStab (l), and IDR(S)Stab(L) algorithms. Utilizing the structure of the source term in the discretization strategy shows (preliminarly) that the new method is more effective in guaranteeing charge and mass conservation in numerical simulations.

Dissertations

-

Scientific Publications

-

Project leaders

J. v. Dijk

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

C.E.M. Schoutrop

Cooperations

Plasma Matters B.V., eScience center.

Funded by

NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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PROJECT LEADERS
Sander Nijdam (EPG), Jeroen van Oijen (P&F), Nico Dam (P&F), Jan van Dijk (EPG)

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Thijs Hazenberg, Ravi Patel

COOPERATIONS
NWO, Bosch Thermotechniek, Bekaert Combustion Technology, Micro Turbine Technology, Plasma Pendix

FUNDED BY
NWO, Bosch Thermotechniek, Bekaert Combustion Technology, Micro Turbine Technology

FUNDED %

University	-
FOM	-
STW	83 %
NWO Other	-
Industry	17 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019

INFORMATION
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PROJECT AIM

Plasma-assisted combustion is a promising method to enhance flame-stability in low-temperature flames. The reduction of flame temperature is important for reducing NOx emissions. However, control over the combustion process via the creation of radicals using plasma is not well understood. The goal is to gain an understanding of the plasma activation of combustion via both numerical and experimental works. The hope is that optimal plasma type and plasma parameters can be found which achieve maximum stabilization of the combustion processes in low-temperature regime.

PROGRESS

A new experimental setup aiming low-temperature combustion activation studies for various plasma parameters has been designed. During initial experiments, methane ignition in lean conditions is observed in streamer like plasma mode. ICCD imaging is used for plasma and ignition characterization. Along with new setup characterization, Raman spectroscopy for temperature and major species measurements is being developed for non-equilibrium conditions and results are expected soon. A numerical study of thermoacoustic mitigation using plasma has been initiated. Concurrently, an air plasma chemistry mechanism is being developed and simulated in 0D. Initial results for thermoacoustic mitigation and plasma chemistry simulations are expected soon.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Energy Technology and Fluid Dynamics

Prof.dr.ir. DMJ Smeulders

Prof.dr. HA Zondag

Prof.dr.ir. EH van Brummelen

Research in the field of Energy Technology at a Mechanical Engineering Department requires the combination of fundamental research and the study of engineering systems and devices. The fundamental research is in the field of Heat Transfer, and the engineering system focuses on small-scale Energy Systems with a strong emphasis on sustainability.

The approach is to combine advanced experimental, analytical and numerical techniques to investigate fundamental topics in heat transfer, and to design, construct and test real energy conversion systems. In this way, the research also contributes to the engineering and research training of the mechanical engineering students. The research is concentrated on three topics:

a. Heat transfer and transitional flows.

The research in this area is aimed at a better understanding of the fundamental characteristics of transitional flows in general. Flow cases that are studied are bypass transition along a flat plate (related to turbine blade cooling), laminar thermal transport in compact systems and boiling process control (for heat removal and thermal homogenisation in, for example, lithographic systems). Another research line concentrates on non-equilibrium phase transitions in gas-vapor mixtures.

b. Micro-scale heat transfer and flow phenomena

The aim of this research line is to achieve a better understanding of the heat and mass transfer processes at the small scales. The focus is on evaporative cooling of electronic components, on multi-scale analysis for compact heat storage materials and permeable geothermal reservoirs, and the dynamics of integrated fluid drivers in micro systems. On the smallest scales the physical processes are studied by coupling Molecular Dynamics analysis with a Direct Simulation Monte Carlo model.

c. Heat transfer engineering

The research activities in this area focus more on the system level rather than on the phenomenological level. Main research projects are fouling of heat exchangers used in waste- incinerators and biomass gasifiers, the design of a humidity harvesting device, and heat transfer models in the built environment. Another research line concentrates on biomass reactors for thermo-chemical applications.

More information about the research activities in these areas can be found on our website: www.energy.tue.nl

RARETRANS: Transport in rarefied gases in next generation photo-lithography machines

Project Aim

Investigation of gas/solid interactions for rarefied gases in simplified but representative geometries inspired by EUV PLM applications. Study of the fundamental transport physics of irregularly shaped particles in rarefied flows in the transitional regime. Investigation of the dynamic flow patterns and heat transport in the complete exposure chamber, including the interactions with contiguous solid walls.

Progress

The polyatomic ES-BGK model is verified against multiple test cases. An axisymmetric formulation is derived, which allows to reduce the degrees of freedom. The model can perform full 3D simulations.

Dissertations

-

Scientific Publications

-

Project leaders

E.H. van Brummelen

Research theme

Complex dynamics of fluids

Participants

E.H. van Brummelen, F. Toschi, A.J.H. Frijns, C. Livi, S. Mohammad Nejad, D.A.M. van der Woude, M.R.A. Abdelmalik

Cooperations

ASML

Funded by

ASML, NWO

Funded %

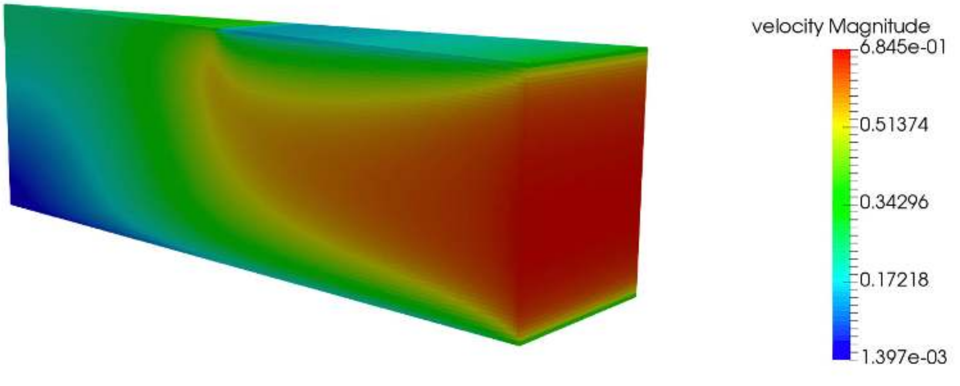
University	-
FOM	-
STW	65 %
NWO Other	-
Industry	35 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

-



Project leaders
E.H. van Brummelen, H.M.A. Wijshoff
Research theme
Complex dynamics of fluids
Participants
T.H.B. Demont
Cooperations
Canon Production Printing
University of Twente
Eindhoven University of Technology
Funded by
Canon Production Printing, NWO
Funded %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
Information
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research.tue.nl/en/persons/tristan-hb-demont

Project Aim

The objective of this project is to develop novel mathematical models and corresponding numerical simulation techniques to investigate dynamic wetting of binary (liquid-vapor) fluids with surfactants. The envisaged modeling paradigm comprises a diffuse-interface model for the binary fluid, based on the recently proposed Navier-Stokes-Cahn-Hilliard (NSCH) model, in combination with separate transport equations for the surfactant in the liquid bulk and surface transport equations for the surfactant on the diffuse liquid-vapor and sharp liquid-solid interfaces.

Progress

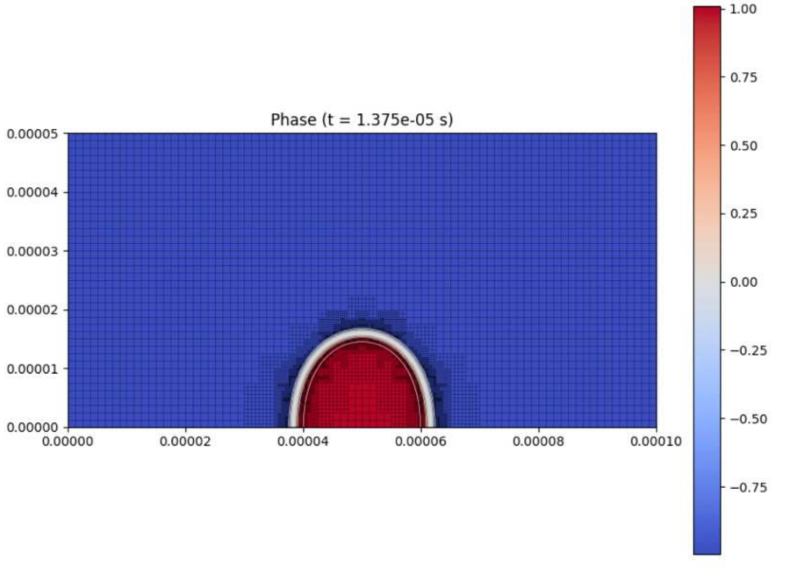
A change in the modeling choice, namely switching to a divergence free velocity field, allows for phase conserving behavior for non-matching densities, and allows us to rewrite the advective term in the Cahn-Hilliard equations, aiding convergence. Additionally, epsilon continuation has been added, allowing for smaller interfaces and larger time steps. First numerical simulations on oscillating droplets have been performed. For small values of epsilon, lower robustness in the simulations has been observed. See the figure below. Lower bounds on the condition numbers of the linear systems are being estimated.

Dissertations

-

Scientific Publications

-



PROJECT AIM

By multi-model coupling, we refer to the surface coupling of a high-fidelity model to a low-fidelity model in a single simulation resulting in a spatial model adaptivity. Using the high-fidelity model for the complete simulation is computationally too expensive, while the low-fidelity model is not accurate enough. The fundamental challenge in multi-model coupling is, that the models are in many cases disparate and live on different scales. The aim of this project is to develop generally applicable methods for multi-scale multi-model coupling and to provide them in a usable and scalable form in the coupling library preCICE.

PROGRESS

We developed a preCICE adapter for the FEM code Nutils and applied it to CHT, fluid-fluid, and FSI problems. We, furthermore, sketched first 1D-3D data mapping concepts together with a prototype implementation in preCICE. We tested the 1D-3D concepts simulating water hammer in a hydraulic pipe coupling Nutils to OpenFOAM. For multi-scale problems in time, we implemented a prototype waveform relaxation layer on top of preCICE and applied it successfully to fluid-structure interaction. Last, preCICE made a big step towards sustainability by becoming a member of the Extreme-scale Scientific Software Development Kit.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. H.-J. Bungartz, G. Chourdakis, F. Lindner, M. Mehl, B. Rüth, D. Sashko, F. Simonis, and B. Uekermann. preCICE: A Dependable Open-Source Coupling Library for Partitioned Multi-Physics Simulations. NL-RSE19.
2. G. Chourdakis, B. Uekermann, G. van Zwieten, and H. van Brummelen. Coupling Open-FOAM to different Solvers, Physics, Models, and Dimensions using preCICE. Proceedings of 14th OpenFOAM Workshop.

PROJECT LEADERS

Benjamin Uekermann
Harald van Brummelen

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Benjamin Uekermann

COOPERATIONS

Hans-Joachim Bungartz, Technical University of Munich

FUNDED BY

European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 754462

FUNDED %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	50 %
Scholarships	-

START OF THE PROJECT

2019

INFORMATION

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Preconditioned iterative solution techniques for immersed finite element methods - with applications in immersed isogeometric analysis for solid and fluid mechanics

Project leaders
Harald van Brummelen and Clemens Verhoosel

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Frits de Prenter

Cooperations
-

Funded by
NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

Information
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Project Aim

The project aims to contribute to the development of robust immersed computational methods. Meshing complicated (such as scan-based) domains can be a laborious task, taking up most of the computational effort and manual labor required for the numerical solution of a problem. Immersed methods bypass this meshing procedure, but suffer from other difficulties, one of which conditioning problems. The objective of this project is to develop effective and efficient solution strategies for linear systems derived from immersed finite element methods.

Progress

De Prenter successfully defended his PhD thesis on 27 June, 2019. He received his doctorate with the predicate cum laude. He was awarded the Biezeno award of the Engineering Mechanics research school, and the ECCOMAS PhD award for his thesis. Two journal publications appeared in 2019, and another one early in 2020, based on the collaboration with the Technical University of Munich on robust solvers for the hp-adaptive finite cell method and with the University of Colorado Boulder on multigrid preconditioners for immersed finite element methods.

Dissertations

1. F. de Prenter. Preconditioned iterative solution techniques for immersed finite element methods. PhD thesis, Eindhoven University of Technology, 2019.

Scientific Publications

1. J. N. Jomo, F. de Prenter, M. Elhaddad, D. D'Angella, C. V. Verhoosel, S. Kollmannsberger, J. S. Kirschke, V. Nu ̈bel, E. H. van Brummelen, and E. Rank. Robust and parallel scalable iterative solutions for large-scale finite cell analyses. Finite Elements in Analysis and Design, 163:14–30, 2019.
2. F. de Prenter, C. V. Verhoosel, and E. H. van Brummelen. Preconditioning immersed isogeo- metric finite element methods with application to flow problems. Comput. Methods Appl. Mech. Engrg., 348:604–631, 2019.

Power & Flow

Prof.dr.ir. NG Deen

Prof.dr.ir. LPH de Goey

Prof.dr. JGM Kuerten

Prof.dr.ir. AW Vreman

Prof.dr. DJEM Roekaerts

Prof.dr. M Golombok

In view of the continuous increase in world energy demand, our vision is that combustion will remain a very important energy conversion process, even in the far future when fossil fuels are depleted, since heavy transport by road, air and water needs dense energy carriers, in other words liquid or solid fuels. An important issue in today's combustion is the shift to ultra-clean and highly efficient 'low-temperature' combustion methods. The second important issue is related to the fuel aspects: we will see increased use of biofuels, and in the longer term the emergence of fuels derived from sustainable sources like solar and metal fuels. Either way, it remains of utmost importance to optimize combustion devices, now in combination with different fuel formulations to minimize undesired emissions and maximize thermal efficiency. With the current level of development of practical combustion systems, further improvements will depend on details of the combustion-system and fuel-composition combination. More accurate and efficient validated models are required to describe the complex interplay between multiphase and/or reactive flows. All these topics fall within the broader theme of process technology, which combines complex flow phenomena with physical and chemical conversions.

The mission of the group is to provide education and to perform world-class scientific research on multiphase and reactive flows in the area of energy conversion and process technology, building a knowledge chain consisting of:

1) development of fundamental models based on first principles
2) experimental validation of these models
3) application and lab-scale demonstration of (reactive) multiphase contact equipment
4) development of predictive tools for practical and industrial applications, derived from the fundamental models based on first principles and experiment

Research themes

The research of the group is concentrated around three main research topics:

1. Combustion systems and their fuels

This research topic is connected to the development of smart injection and combustion strategies of future ultra-clean and efficient combustion systems as well as with the after treatment, with a focus on future diesel engines. With respect to fuels we focus on three main activities: i) enhanced oil recovery, ii) use of bio-based fuels based on biomass components such as lignin, and iii) using micro-structuring gas-liquid bubbly flow processes to intensify biogas-to-liquid conversion.

2. Metal fuels as dense CO2-free energy carriers

This research topic is concerned with a novel type of fuels, i.e. metal powders that have a tremendously high energy density and can act as a major CO2-free energy carrier for the long term. Within the group we develop the combustion technology of metal powder, solid handling including separation and regeneration through chemical reduction.

3. Complex multiphase flows

This research topic is related to various applications in the field of process technology, all involving complex multiphase flow phenomena. This includes equipment with phase transitions, such as evaporation of sessile multi-component ink droplets, cooling of steel by water jets and water-steam flow in evaporator tubes.

PROJECT AIM

The aim of this research is to generalize an existing model for the evolution of a sessile ink droplet subject to evaporation and absorption into a porous substrate by three further aspects:

- the model will be extended to incorporate the presence and influence of surfactants;
- to investigate the impact of neighboring droplets, a generalization to three dimensions is proposed;
- the absorption into the porous substrate will be extended to comprise more general types of porous substrates.

PROGRESS

The model has been expanded to incorporate moving contact lines. Previously, this was done with a precursor film and now it can be done with a slipping contact line as well. Furthermore, the precursor film model has been extended. Also, the soluble surfactant model has been improved to be more accurate and manageable. Lastly, a model involving salts in solution has been implemented.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

PROJECT LEADERS

J.G.M. Kuerten

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

RT van Gaalen, C Diddens, HMA Wijshoff

COOPERATIONS

Océ

FUNDED BY

NWO, Océ

FUNDED %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2014

INFORMATION

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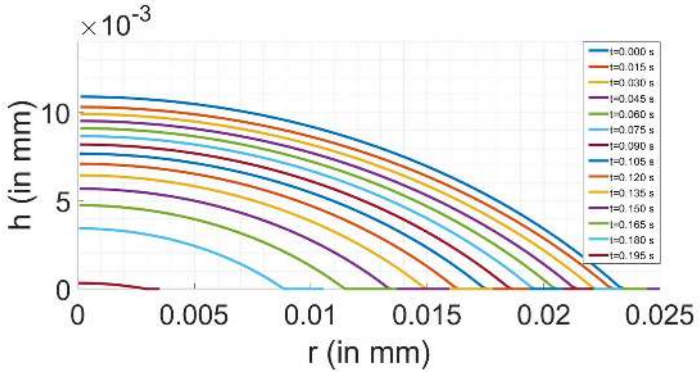

Profile of an evaporating droplet with slipping contact line

Effect of rotor-stator interaction on rotating stall of water pump

Project leaders
BPM Esch

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Changliang Ye

Cooperations
-

Funded by
China Scholarship Council

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project
2018

Information
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Project Aim
(1) Develop a high-precision numerical method suitable for the analysis of pump rotating stall. Focusing on solving the problem that the existing boundary layer transition model relies too much on the plate test results to reflect the large curvature effect of blade leading edge.

(2) Establish a combined hydrofoil with centrifugal pump geometric characteristics. Reveal how the rotor-stator interaction influences the hydrofoil stall by investigating the relationship between the characteristics of hydrofoil boundary layer transition.

(3) Reveal how the rotor-stator interaction influences the water pump rotating stall by investigating the pressure fluctuation characteristics of the flow field at different flow conditions.

Progress
1. The transition model SSTCC γ-Reθt considering curvature correction improves the prediction in the near wall region, the flow fields calculated by different correction coefficient are quite different. In this case, when the scaling coefficient Cscale is 100, the prediction in the near wall region and the wake region has achieved good results.

2. Modified Reθt is got by adjust the original Reθt for consistent with the LES results. The correlation function between Reθt and curvature is obtained by defining the curvature of hydrofoil. The SST γ-Reθt model is modified by applying the new empirical correlations to the original transition model. And the new model works well by verifications.

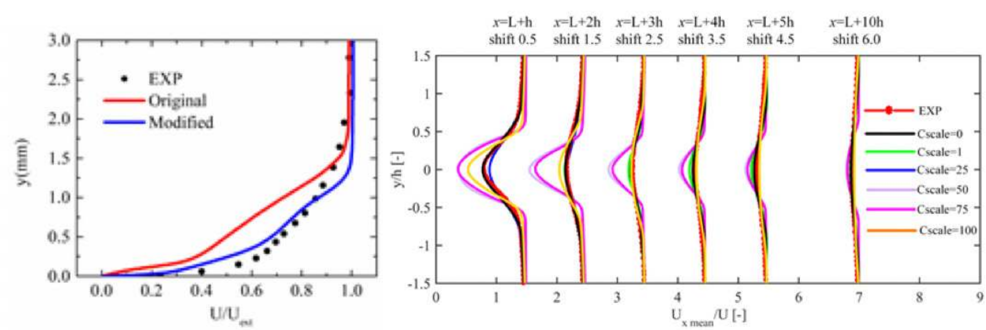
3. The unsteady flow field is divided by DMD method the characteristic frequency of the flow field and the corresponding flow mode are obtained, which can reduce the order of the actual flow.

Dissertations
-

Scientific Publications

1. Ye, C.L. and van Esch, B.P.M., 2019, December. Study of hydrofoil boundary laliur transition using different turbulence models. In IOP Conference Series: Earth and Environmental Science (Vol. 405,No. 1, p. 012025). IOP Publishing.

Figure (a): Time average velocity distribution in X direction of wake area(considering curvature effect)
Figure (b) Velocity profiles at chord locations of NACA 66(mod)-312 hydrofoil (calculated by modified model)



PROJECT AIM

The aim of the project is to study the breakdown and reappearance of aromatics in vaporized liquid fuel non-premixed flames, using aliphatic fuels doped with aromatics. The focus lies on the development and application of (laser) optical detection techniques for intermediate species, found in the flame between the fuel pyrolysis zone and PAH formation zone, in order to gain a more detailed understanding of the found relation between aromatic fuel content and soot emission of combustion engines.

PROGRESS

The existing Raman setup has been expanded with a 266 nm PLIF setup to study the non-premixed combustion of benzene and toluene. These aromatic fuels are vaporized and mixed in low quantities with hydrogen. The rapid outward diffusion and subsequent combustion of hydrogen creates high-temperature low-oxygen boundary conditions for the heavy dopants, while causing minimal interference in the optical experiments. Measurement results have been compared with numerical simulations and reasonable agreement is found (Figure 1). Decreasing fluorescence signal of toluene with height in the flame is purely a result of strong temperature increase, not due to thermal dissociation of toluene. The optical setup has also been used to study contaminants in n-dodecane fuel, and also to characterize the oscillating density field in an acoustic levitator.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

N.J. Dam, N.G. Deen

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

R. Doddema

COOPERATIONS

-

FUNDED BY

TU/e

FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2015

INFORMATION

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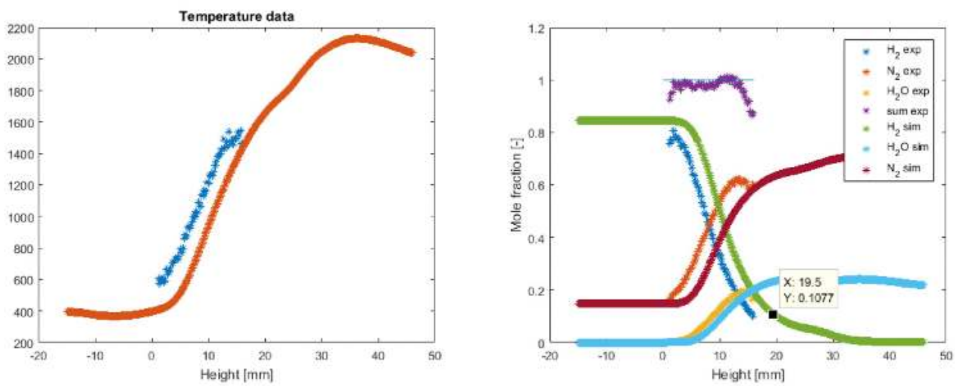
(left) Temperature derived from Raman scattering data in comparison to numerical calculations, (right), major species mole fractions from experiment and simulation



PROJECT LEADERS
N.J. Dam, L.M.T. Somers, N.G. Deen
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
N.C.J. Maes
COOPERATIONS
Fiat Powertrain Technologies
FUNDED BY
Industry, Fiat Powertrain Technologies
FUNDED %

University	67 %
FOM	-
STW	-
NWO Other	-
Industry	33 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2014
INFORMATION
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PROJECT AIM

In a collaboration with Fiat Powertrain Technologies, heavy-duty Diesel sprays and the effect of flame-wall interaction are studied in detail using optical diagnostic techniques and temperature measurements in a constant volume vessel. The higher goal is to design a completely new, heavy duty engine based on optimization through modelling. In order to achieve reliable and predictive models, it is essential to perform fundamental and reproducible experiments at relevant conditions.

PROGRESS

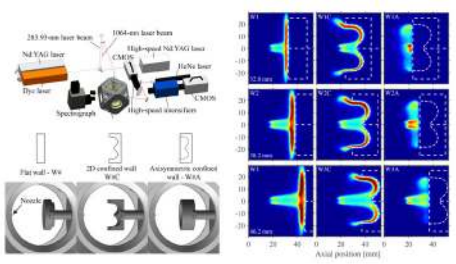
To isolate the effect of flame-wall interaction from representative operating conditions of an internal combustion engine, experiments were performed in a constant-volume pre-burn vessel. Three different wall geometries were studied at distances of 32.8, 38.2, and 46.2 mm from a single-hole 0.09-mm orifice diameter fuel injector. A flat wall provides a simplified case of flame-wall interaction. To mimic the division of a jet into two regions by the piston bowl-rim in an engine, a 2D confined wall is used. A third, axisymmetric confined wall geometry allows a second simplified comparison to numerical simulations in a Reynolds-averaged Navier-Stokes framework. As a limiting situation for a free jet, the distance from the injector orifice to the end wall of the chamber is 95 mm. Thermocouples installed in the end-wall provided insights in local heat-losses for reference cases without a wall insert. The test conditions were according to the Engine Combustion Network Spray A guidelines with an ambient temperature of 900 K, and an ambient density of 22.8 kg/m3 with 15% O2. Flame structures were studied using high-speed OH* chemiluminescence with integrated single-shot OH PLIF, and combined with pressure-based apparent heat-release data to infer combustion progress and spray behavior. Soot was studied in a qualitative manner using high-speed natural luminosity imaging with integrated high-speed laser induced incandescence. Overall, increased mixing upon interaction with the surfaces is observed to increase early heat-release rate and to significantly reduce soot, with the nearest wall distance showing most effect. The flat wall gives rise to the most significant effects in all cases.

DISSERTATIONS

1. Maes, N., "The Life of a Spray," Eindhoven University of Technology, 2019, ISBN 978-90-386-4755-5.

SCIENTIFIC PUBLICATIONS

1. Maes, N., Hooglugt, M., Dam, N., Somers, B., Hardy, G., "On the influence of wall distance and geometry for high-pressure n-dodecane spray flames in a constant-volume chamber," International Journal of Engine Research, 2019, https://doi.org/10.1177/1468087419875242.



Left top: schematic overview of the constant volume combustion vessel with simultaneous high speed OH* chemiluminescence, high-speed LII, OH PLIF, and spectral imaging. Left-bottom: illustration of the three different wall shapes studied in this work. Right: ensemble averaged high-speed OH* stills of the different wall shapes and wall distances that were studied.

Project Aim

This research targets a premixed combustion concept called reactivity controlled compression ignition (RCCI), which potentially facilitates high gross indicated efficiency (GIE) and low levels of nitrogen oxides (NOx) and soot emissions.

Progress

Results of gasoline-diesel RCCI operation on the XEC platform have been published and presented at the ASME ICEF2019 in Chicago in October 2019. RCCI mode was compared to CDC in energy distribution diagrams and specific emissions. Key outcome is that RCCI outperforms CDC only at elevated boost pressures, as heat transfer losses are then strongly suppressed. NOx emissions are extremely low, especially at high boost due to lean mixtures, which readily prevents local high-temperature combustion. By detailed analysis of heat release a new metric is proposed that sheds light on heat release rate shape. The burn ratio (BR) is defined as (CA90-CA50)/(CA50-CA10). BR seems to predict the rate of heat release shape well, which displays a two-phase combustion for high burn ratios and transitions into a single-phase regime for lower values. The mixing time of fuel and air is indicative for the BR. Peak GIE is reached at lowest values of BR, giving the best tradeoff between thermal and combustion efficiency.

Dissertations

-

Scientific Publications

1. Willems, RC, Willems, FPT, Deen, NG, and Somers, LMT. “A Comparison of Low-Load Efficiency Optimization on a Heavy-Duty Engine Operated With Gasoline-Diesel RCCI and CDC.” Proceedings of the ASME 2019 ICEF2019. Chicago, Illinois, USA. October 20–23, 2019. https://doi.org/10.1115/ICEF2019-7149.
2. Willems RC, Bakker PC, Dam NJ. “Laser-induced incandescence versus photo-acoustics: implications for qualitative soot size diagnostics.” Applied Physics B 125:138 (2019). https://doi.org/10.1007/s00340-019-7248-2.
3. Xia L, Willems R, de Jager, B, Willems F. “Constrained Optimization of Fuel Efficiency for RCCI Engines”. IFAC PapersOnLine 52-5 (2019) 648-653. https://doi.org/10.1016/j.ifacol.2019.09.103

Project leaders

L.M.T. Somers, F.P.T. Willems

Research theme

Complex dynamics of fluids

Participants

RC Willems, LMT Somers, FPT Willems, NG Deen

Cooperations

DAF Trucks, TNO, Shell Global Solutions, Delphi Technologies, Sensata, AVL Dacolt

Funded by

TTW, DAF Trucks, TNO

Funded %

University	-
FOM	-
STW	70 %
NWO Other	-
Industry	30 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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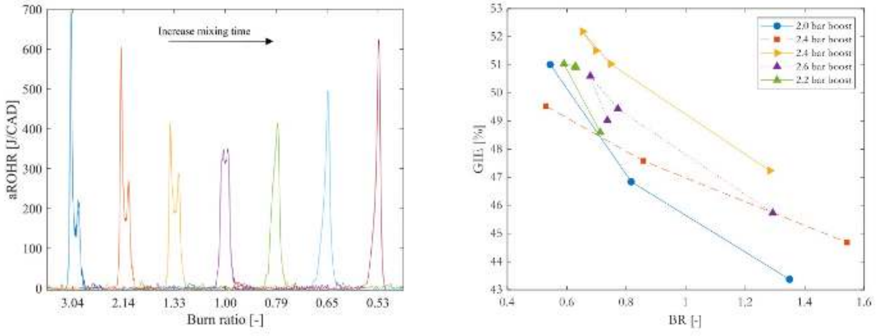
Burn ratio predicts the heat release shape and peak GIE well.



PROJECT LEADERS
J.G.M. Kuerten, C.W.M. van der Geld
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
E.J. Gelissen
COOPERATIONS
-
FUNDED BY
NWO/TTW
FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2016
INFORMATION
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PROJECT AIM

Studying phase-transitional flows through numerical simulations using a Diffuse Interface Model (DIM). The Diffuse interface Model is based on the Navier-Stokes-Korteweg equations and uses the Van der Waals equation as the equation of state.

PROGRESS

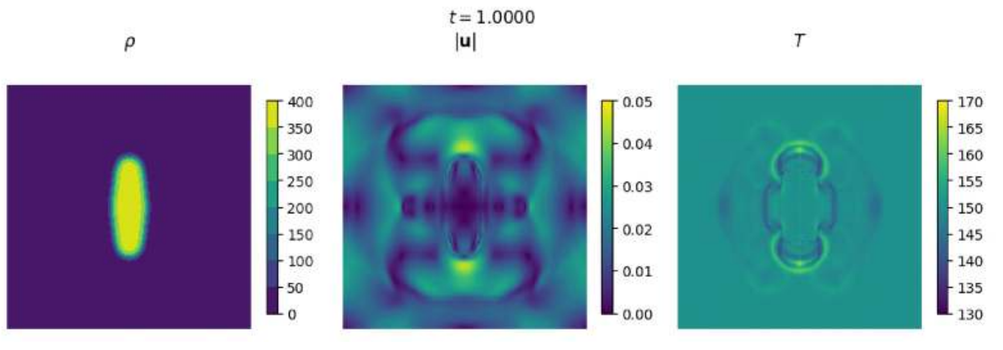
DIM is used to perform simulations of droplet collisions in three spatial dimensions under non-isothermal conditions. DIM is compared with a different method often used for multiphase flows: the Local Front Reconstruction Method (LFRM). Results for fully three-dimensional simulations of droplet collisions at relatively high Weber number are presented and compared. DIM is used to perform simulations of droplet impacts on a heated solid surface, using an especially constructed solid wall boundary condition which enables simulations with different wetting conditions. The model is also extended to include the effects of surface roughness on the behavior of the contact line dynamics.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Explaining boiling beyond boiling temperature: Quench cooling of hot steel plates

Project Aim

During its production, steel is quenched with water jets in the so called Run Out Table (ROT). During quenching of steel at high temperature (900 °C), the boiling process has quite extraordinary features. Rewetting, i.e. contact with the surface, occurs at temperatures far beyond the boiling temperature. The first goal is to get proper understanding on the rewetting phenomena, based on direct observations of the stagnation zone during quenching. The second goal is to develop heat transfer coefficients correlations to implement in the process control system of the ROT.

Progress

The addition of a linear unit to the original setup allows quenching of moving steel surfaces, at speeds up to 9 m/s (Figure 1). This speed range is comparable to industrial conditions and higher than ever reported in lab studies. The updated setup was validated showing very satisfactory reproducibility. The high speed recordings show that, as expected, the surface speed affects the boiling regimes occurring during quenching. At initial temperatures around 550 C, we observe explosive boiling at speeds between 0.5 and 6.5 m/s. At speeds higher than 6.5 m/s, the surface motion allows the formation of a vapor film, leading to film boiling. The presence of film boiling at this conditions is well known in industry. As expected, the surface speed also shows an effect on the heat flux estimations. The experimental results show that higher surface speeds lead to overall lower heat fluxes (Figure 2). The high temperature side of the boiling curve seems to be more affected, showing a change of trend as well. As a result of the intermittent and gentler cooling, high speeds also lead to lower temperature gradients along the plate thickness (Figure 2). The more homogeneous cooling is expected to reflect on more homogeneous mechanical properties.

Project leaders

B.P.M. van Esch, C.W.M. van der Geld, JGM Kuerten

Research theme

Complex dynamics of fluids

Participants

C.F. Gomez

Cooperations

TATA Steel R&D Ijmuiden, M2i

Funded by

NWO-I, TATA Steel R&D IJmuiden

Funded %

University	-
FOM	50 %
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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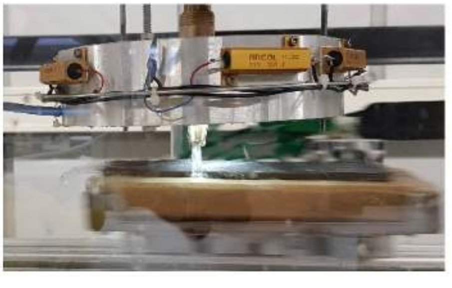
Dissertations

-

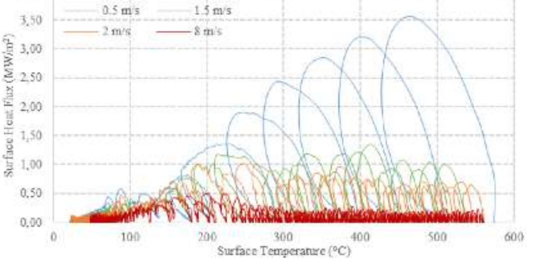
Scientific Publications

1. The nature of boiling during rewetting of surfaces at temperatures exceeding the thermodynamic limit for water superheat. C.F. Gomez, C.W.M. van der Geld, J.G.M. Kuerten, R. Liew, M. Bsibsi and B.P.M. van Esch. Journal of Fluid Mechanics. Submitted September 2019.



Quenching of moving plates setup

Effect of surface speed on the boiling curve. Sandblasted surface and water jet at 25 C.



PROJECT LEADERS
F.P.T. Willems, L.M.T. Somers

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
B. Akkurt, X. Luo, N.G. Deen, M. Steinbuch

COOPERATIONS
TTW, TNO, Sensata, DAF, Delphi

FUNDED BY
TTW, TNO, Sensata, DAF, Delphi

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	80.5 %
TNO	19.5 %
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2014

INFORMATION
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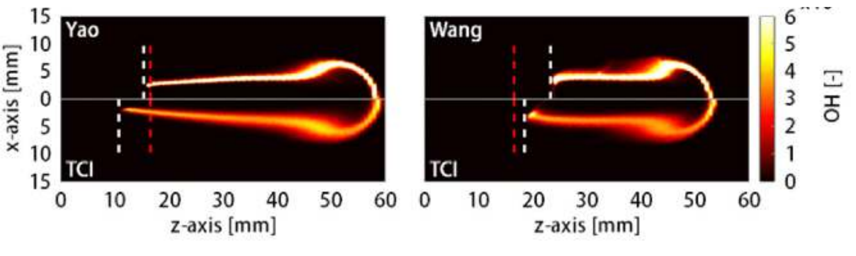
PROJECT AIM
This research project focuses on the development of new modeling technique for high EGR diesel combustion concepts with multiple injection fueling systems, which is seen as an essential step towards future RCCI concepts. The CFD-FGM model, which will be extended for multi-pulse injection strategies, will be extensively validated with experimental data.

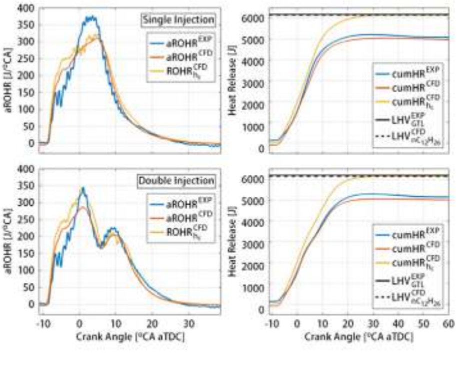
PROGRESS
The combustion modelling part of the project is continued with model validation. Prior to engine simulations and analysis of the results, Turbulence-Chemistry interaction (TCI) is studied with the constant volume application. In this manner, Spray-A simulations are repeated with the FGM tables that considered TCI. In addition to that, the FGM-CFD model is validated with the Cyclops engine experimental data at various operating points, at which the engine speed and the load are varied (i.e. A30, B30 and B50 operating conditions), with motorized cycles (cycles without fuel injection) and single and double injection strategies. The experimental data is obtained with the CYCLOPS engine, which is a test rig based on DAF XE 355 C straight 6-cylinder heavy duty direct injection diesel engine. Also, the model validation is extended for NOx emission.

DISSERTATIONS
1. Akkurt, B.., "Modelling multi-pulse diesel injection with flamelet generated manifolds," Eindhoven University of Technology, 2019, ISBN 978-90-386-4666-4.

SCIENTIFIC PUBLICATIONS
-



Comparison of lift-off lengths (red dashed line for the experiment and white dashed line for the simulations) and OH species mass fraction at the quasi-steady state, t=1.3 [ms], with and without TCI is considered at the nominal Spray-A condition



Comparisons of the aROHR (left-column) and the cumulative heat release (right-column) between the CFD and experiments at B50 with single (top-row) and double (bottom-row) injections

PROJECT AIM

1. The development of a versatile, accurate and efficient numerical simulation method for the flow and heat transfer in heat pipes.

2. The development of a physical model for the mass transfer over the interface that can be coupled to Volume-of-Fluid method.

PROGRESS

1. A Piecewise-Linear Interface Calculation (PLIC) which is able to calculate the interface position of two phase flow on both a Cartesian mesh and a non-orthogonal mesh is proposed and implemented in OpenFOAM.

2. A procedure to smoothen the liquid volume fraction is implemented in order to obtain a more accurate curvature field in the Continuum Surface Force (CSF) model.

3. The height function method is implemented to calculate the curvature field.

4. A heat balance phase transition model based on the sharp interface calculated by the PLIC method is implemented.

The black line segments indicates the sharp interface resolved by PLIC.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

J.G.M. Kuerten, B.P.M. van Esch

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

H. Wang

COOPERATIONS

-

FUNDED BY

China Scholarship Council

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT

2015

INFORMATION

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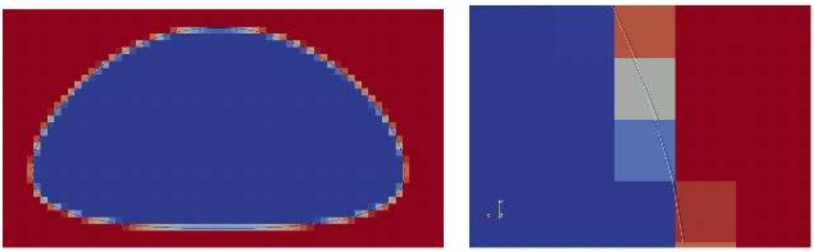
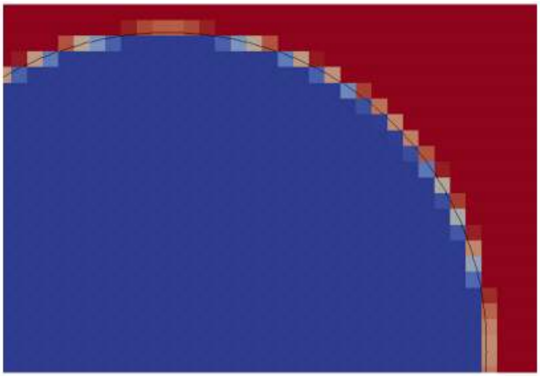
Rising bubble in ellipsoidal regime, Re=35, Eo=10.





Rising bubble in spherical regime, Re=1, Eo=0.25

Project leaders
JCH Zeegers, JGM Kuerten, AA Darhuber

Research theme
Complex dynamics of fluids

Participants
R Dellaert, S Tajfirooz, JCH Zeegers, JGM Kuerten

Cooperations
TU Delft, UTwente, UU, Radboud University, and several companies, part of Perspectief programme TTW

Funded by
TTW, Umincorp, Sumitomo, Syngenta, Dimaen, FNLI, AEB

Funded %

University	-
FOM	-
STW	-
NWO Other	70 %
Industry	30 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016

Information
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Project Aim

The project consists of two sub-projects. The aim of the first sub-project is to investigate the temporal and spatial characteristics of turbulence behind a honeycomb structure. The goal is to minimize the turbulence level behind the flow straightener used in the MDS setup. The second sub-project aims at investigation of particle-fluid-particle interactions in an MDS setup. A combination of experimental and numerical studies are carried out. And the combined research outcomes of the two sub-projects will be used for optimizing the magnetic density separation technology.

Progress

- Direct numerical simulations are carried out to investigate the production and decay behavior of flow instabilities behind a honeycomb structure.

- A point-particle Euler-Lagrange approach is applied to investigate the dynamical motion of spherical particle(s) in paramagnetic and superparamagnetic liquids subject to external magnetic field gradients. Numerical results of particle dynamics in single- and two-particle systems are validated against experimental observations. An excellent agreement is observed between the numerical and experimental results.

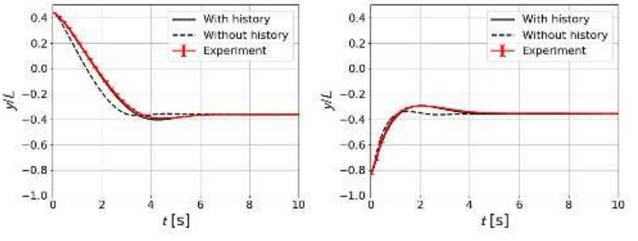
- Magnetic density separation of spherical particles in many-particle systems consisting of up to 0.5 million particles are studied numerically.

Dissertations

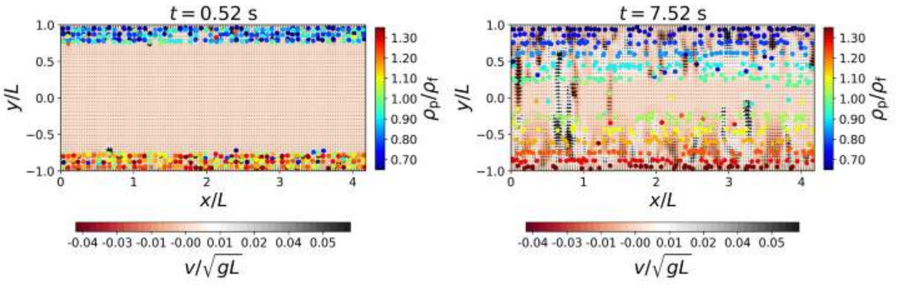
-

Scientific Publications

-



Effect of history force on levitation dynamics of a falling (left) and a rising (right) 5-mm spherical particle in a paramagnetic liquid



Magnetic density separation of 4-mm spherical particles in a paramagnetic liquid. Particles are colored based on their mass densities. The horizontal color bar corresponds to the vertical component of fluid velocity.

Development of reliable emission and atomization models for combustor design

Project Aim

The aim of this project is to develop an accurate and reliable computational tool for prediction of emissions in lean-burn combustion systems for civil aerospace applications. Within this project, the research carried out by TU/e will concentrate on the chemistry reduction method Flamelet-Generated Manifold (FGM), which is intended to reduce the computational cost of the complex chemistry models for application in CFD codes. Improved flamelet tabulation techniques are to be developed focusing on accurate prediction of CO, UHC, NOx and soot emissions from gas turbine combustors.

Progress

An FGM with one extra chemically reactive dimension has been developed for laminar premixed flame simulations involving flame/wall interactions. Including a second reactive degree of freedom in this so-called QFM method resulted in tremendously improved accuracy for prediction of CO concentrations near the wall.

Dissertations

1. D. Efimov, "Taking Flamelet Generated Manifolds to a higher dimension: Reduced combustion modelling with multiple reactive time-scales"; Eindhoven University of Technology.

Scientific Publications

-

Project leaders

J.A. van Oijen

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

D.V. Efimov

Cooperations

Rolls-Royce Deutschland
Rheinisch-Westfälische Technische Hochschule Aachen
Karlsruher Institut für Technologie
Imperial College of Science, Technology and Medicine.

Funded by

EU, University

Funded %

University	25 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	75 %
Scholarships	-

Start of the project

2013

Information

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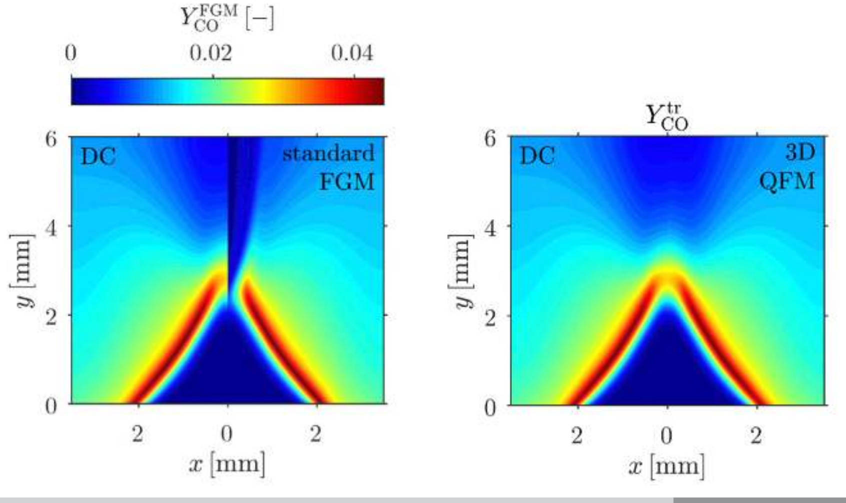
Side wall quenching simulation results for CO mass fraction found with the standard FGM and the FGM based on quenching flamelets (QFM) compared to the detailed chemistry (DC) solution. In each subplot the DC results are shown at the left side (mirrored), while the FGM results are shown at the right. The cold wall (Twall=300 K) is located vertically at x=0 cm.



Modelling advanced engine combustion concepts with FGM in a LES framework

Project leaders
LMT Somers

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
H Bao

Cooperations
-

Funded by
China Scholarship Council

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project
2017

Information
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Project Aim

Reactivity Controlled Compression Ignition (RCCI) engines realize low emissions as well as high efficiency. By blending the port-injected low reactivity fuel with the high reactivity fuel in cylinder, the fuel reactivity is tuned and the combustion phasing is thus controlled. The project aims to provide better understand on the spray and interaction with the chemistry by numerical modelling. Code implementation and model development for RCCI engines are expected.

Progress

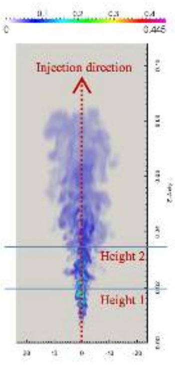
The turbulence model has been improved and validated by ECN (Engine Combustion Network) Spray A non-reacting case, penetration and fuel mixing can be well captured. The inclusion of strain rate effect in FGM is implemented and shows good agreement with the experiment. The new model can be further applied in simulating dual fuel cases.

Dissertations

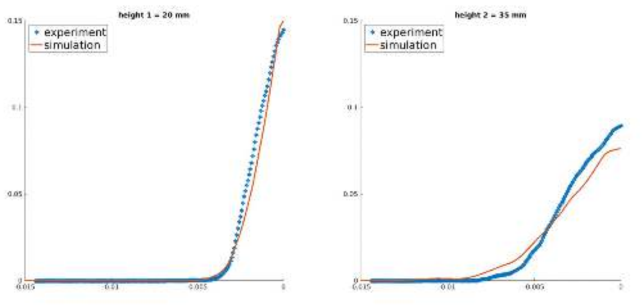
-

Scientific Publications

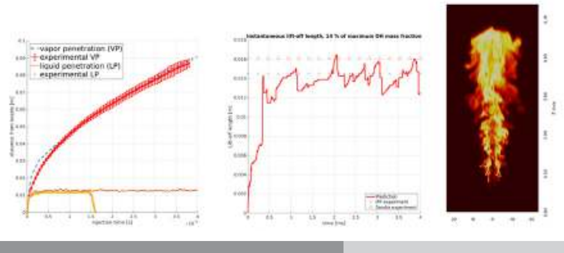
-



Mass fraction of injected fuel (n-Dodecane)



Comparison of predicted radial mixture fraction (using the time-average from 1,2 ms to 5 ms) and experiment.



Left : Prediction of penetration
Middle : Prediction of flame lift-off
Right : Snapshot of temperature at 4 ms

Studies on direct combustion of iron powder as a carbon-free energy carrier

Project Aim

Iron powder was thought as the primary metal fuel whose combustion product is porous solid oxide that can be easily captured. Meanwhile, it is readily recycled with well-established technology. For the successful application of the iron as a renewable carbon-free fuel, some unique combustion properties of the iron powder, compared to our traditional gaseous and liquid hydrocarbon fuels, must be considered in any combustor design for future iron-fueled engine technologies. Therefore, this project will focus on the fundamental characteristics of iron powder combustion and single iron particle burning. These research data will be very useful for the design of future iron-fueled combustors.

Progress

Burn time of micro-sized iron particle in two size ranges burning in different O2 concentration has been measured. The measured burn time changes linearly with O2 concentration.

Dissertations

-

Scientific Publications

-

Project leaders

L.P.H. de Goey

Research theme

Complex dynamics of fluids

Participants

D Ning, Y Shoshin, JA van Oijen

Cooperations

-

Funded by

Chinese Scholarship council

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project

2018

Information

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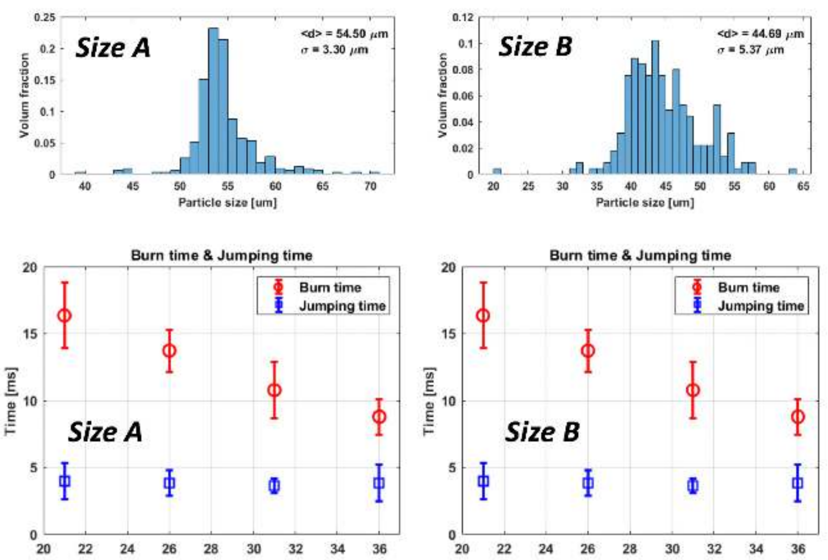
Measured burn time and corresponding particle size distribution



Project leaders
LPH de Goey, I Lopez Arteaga, V Kornilov
Research theme
Complex dynamics of fluids
Participants
M Kojourimanesh
Cooperations
NWO (TTW), ATAG, Remeha, Honeywell, Bekaert
Funded by
NWO (TTW)
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2018
Information
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Project Aim

The goal of this project is to introduce and develop a system level approach to address the challenge of thermo-acoustic design and control of acoustic instability in combustion appliances. This system level approach enables unique new modeling and experimental identification strategies to describe the thermos-acoustic response of flames/burners.

Progress

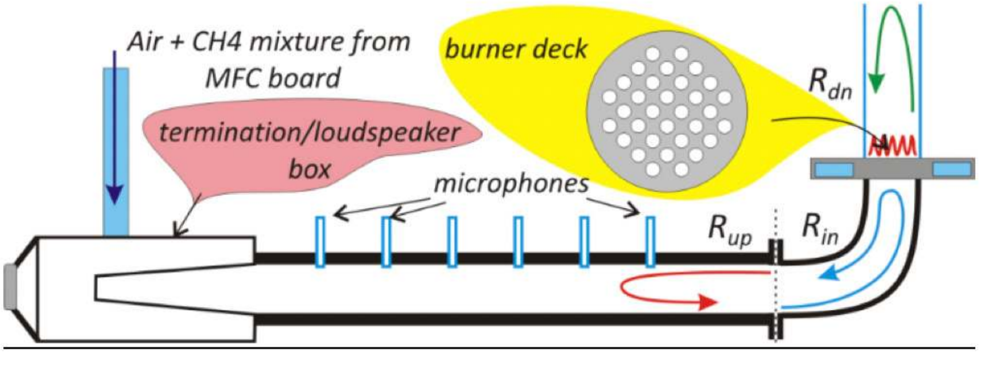
Internal linear thermo-acoustic properties of flames are fully described by the transfer function, temperature and flow area jumps. In order to compose a model to predict the onset of thermo-acoustic instability of combustion, one has to characterize the thermo-acoustic properties of the flame and also components of upstream and downstream sides of the burner. This kind of modelling strategy usually faces practical problems related to the measurement of the reflection coefficient at the hot downstream part of the system, Rdn. However, a novel method is presented to assess thermo-acoustic instabilities based on reflection coefficients measured only from the cold (upstream) side of the burner. Both reflection coefficients at the cold side, Rin and Rup, can be readily measured using standard acoustic techniques, like using the impedance tube shown in Fig. 1. The proposed method is experimentally validated for burners with premixed burner-stabilized Bunsen-type flames.

Dissertations

-

Scientific Publications

-



Experimental setup of impedance tube and combustor.

PROJECT AIM

The understanding of the reduction mechanisms of iron oxide particles is important for the entire recycle process of iron fuels. In this project, experimental and numerical study on the reduction of iron oxides using methanol at low temperatures will be carried out. The aim is to get a detailed understanding of the reduction mechanism of iron oxide particles, and further provide guidance for the practical application of the project.

PROGRESS

Thermogravimetric analysis (TGA) of the reduction of lab-made iron oxides in a continuous stream of syngas or methanol was conducted at temperatures ranging from 350 to 450 °C. The effect of reducing atmosphere and temperature on the reduction behavior of iron oxide particles was investigated. Results showed that for methanol reduction, the optimal reduction temperature is 350 °C, and the initial conversion rate increases rapidly when the reaction temperature increases from 350 °C to 400 °C. In addition, it is easy to form carbon deposits for all test temperatures. In our current experiments, we tested the reduction performance when using the same amount of methanol and syngas. It can be seen that using syngas as reducing agent can get higher conversion degree of iron oxides, whereas atmosphere involving methanol can accelerate the rate of reduction in the initial phase of the reduction period.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

Y Tang, NG Deen

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

X Liu

COOPERATIONS

-

FUNDED BY

China Scholarship Council (CSC)

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT

2018

INFORMATION

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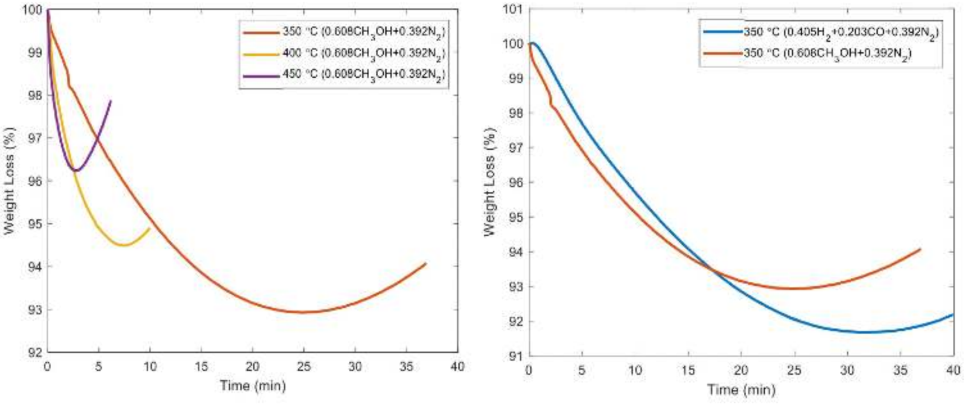

Left : Weight loss curve under different temperature - Right : Weight loss curve under different reducing agents

PROJECT LEADERS
J. A. van Oijen

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
S. Karaca

COOPERATIONS
MariGreen, TUBITAK

FUNDED BY
MariGreen, TUBITAK

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2016

INFORMATION
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www.tue.nl/power-flow

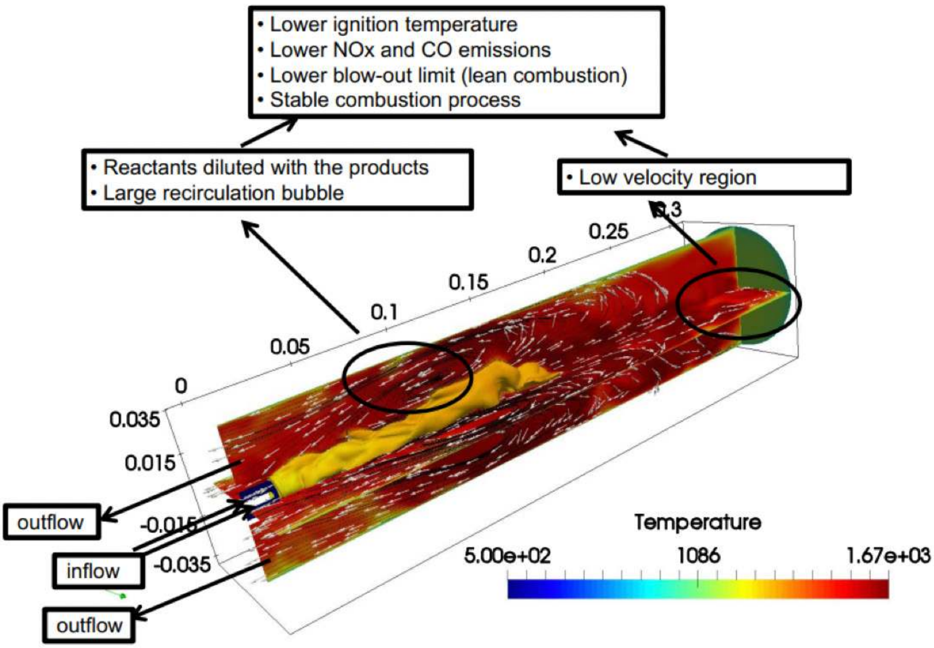
PROJECT AIM
Stabilization of flame is a crucial issue in combustors. In literature there are many ways to stabilize the flame such as swirl, bluff body and reversed flows. In this project very lean aero-engine burners with reversed flow configuration will be investigated by using chemistry reduction method – FGM. The aim is to understand flow and chemistry part of the reversed flow configuration and develop accurate numerical tools to predict emissions like CO and NOx.

PROGRESS
A model to predict emissions like CO is constructed to the OpenFOAM solver. Heat loss effects are investigated by using different wall temperatures. Effects of turbulence momentum closure models for LES also investigated in this burner.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-

Stagnation Point Reverse Flow combustor configuration



Computational fluid dynamics simulations of flows in alkaline water electrolyzers (Alkaliflex)

Project Aim

Research on bubbly flows in electrolyzers is performed with the aim to understand and relieve limitations of alkaline water electrolysis.

Progress

Bubbly flows of high gas volume fraction in electrolyzers have been simulated using the Ansys Fluent solver. More specifically, the Euler-Euler approach has been used to simulate the multiphase flow in the hydrogen compartment of an electrolyzer and the effect of various outflow boundary conditions has been investigated.

Dissertations

-

Scientific Publications

-

Project leaders

AW Vreman, NG Deen

Research theme

Complex dynamics of fluids

Participants

A Zarghami, TAM Homan

Cooperations

MT de Groot (Nouryon)

J van der Schaaf (Chem. Eng.)

Funded by

RVO, Nouryon

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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www.tue.nl/power-flow

PROJECT LEADERS
TAM Homan, Y Tang, NG Deen
RESEARCH THEME
Complex structures of fluids
PARTICIPANTS
CJM Hessels
COOPERATIONS
-
FUNDED BY
TU/e
FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2018
INFORMATION
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PROJECT AIM

To maintain a stable energy grid, it is important to look for ways to store and transport renewable energy in large amounts and at high energy density. We can envision a "metal fuel cycle" in which metal powder is combusted in slightly altered coal power plants and the produced metal-oxides are reduced back to metal powder using renewable energy. The research focusses on the reduction of combusted iron particles using environment-friendly produced hydrogen in a fluidized bed reactor. Both numerical (CFD-DEM) and experimental techniques will be used.

PROGRESS

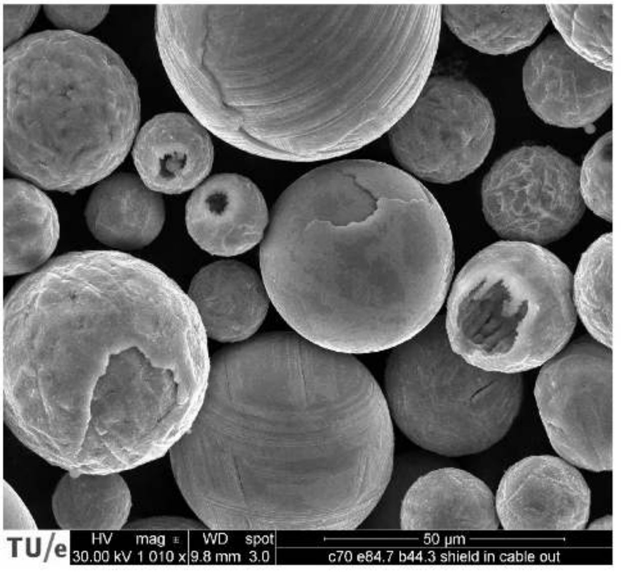
The focus of the first year lays on determining the reaction kinetics of a single iron oxide particle. On the numerical side a 1D single particle reduction model is being developed, based on the shrinking core model. An analytical solution is derived and the influence of hydrogen on fluid properties is analyzed. Experimentally, particle analysis on combusted iron is performed using scanning electron microscopy (SEM) and quantitative x-ray powder diffraction (Q-XRD). Initial results show hollow spherical particles, completely oxidized to a ratio of hematite and magnetite.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



SEM image of combusted iron particles (~20 µm). Some particles appear to be hollow, which might be caused by impurities turning into gas during combustion

INVESTIGATION ON THE INSTABILITY OF TIP LEAKAGE VORTEX CAVITATION AND INDUCED SUCTION-SIDE-PERPENDICULAR CAVITATING VORTICES IN AN AXIAL-FLOW PUMP

PROJECT AIM

(1) Elucidating the coherent mechanism of SSPCV induced by TLV and sheet cavitation. Studying the turbulence characteristics in the tip region to reveal the mechanism of PCV inception.

(2) Analyzing the position of the PCV inception and the orientation of vortex vectors, to reveal the evolution of PCV, in terms of its generation, development and collapse.

(3) Investigating the interference of PCV and adjacent blade in different operating conditions with high-speed photography and numerical simulation. The flow passage jamming, sudden drop of the blade load and flow instability will be discussed.

PROGRESS

(1) The hydrofoil 'Delft Twist 11'is utilized to verify the applicability of numerical simulation of cavitating flow. The transient process of sheet cavitation on the surface of hydrofoil, including inception, development and collapse, will be simulated and compared with the experiments.

(2) The hexahedral structured grids are used with thirty-five mesh nodes in the tip gap. The grid quality will be discussed to meet the requirements of large eddy simulation.

(3) The three-dimensional structure and evolution of SSPCVs in an axial flow pump will be studied with unsteady calculations. The effects of TLV, lateral jet and pressure oscillation on the SSPCVs will be discussed, as well as the characteristics of velocity field, pressure field, vorticity field and turbulent kinetic energy and its generation. The high speed photography and pressure fluctuation measurements are used to study the evolution of SSPCVs.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Shen Xi, Zhang Desheng*, Xu Bin, Zhao Ruijie, Jin Yongxin, Chen Jian, Shi Weidong. Numerical and experimental investigations of pressure fluctuation in a mixed-flow pump under low flow conditions(2020). Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 234(1), 46–57.
2. Xi Shen, Desheng Zhang*, Bin Xu, Yongxin Jin, Xiongfa Gao. Experimental and numerical investigation of pressure fluctuation and tip leakage vortex cavitation of the impeller in an axial flow pump. ASME-JSME-KSME Jiont Fluids Engineering conference, 2019-5161.

PROJECT LEADERS
BPM Esch

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
X Shen

COOPERATIONS
-

FUNDED BY
China Scholarship Council

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT
2019

INFORMATION

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06 84974156
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Project leaders
AW Vreman, JGM Kuerten
Research theme
Complex dynamics of fluids
Participants
-
Cooperations
-
Funded by
-
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
Information
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www.tue.nl/power-flow

Project Aim

More understanding of the fluid mechanics in and improved modeling of turbulent flows that contain spherical particles. The working horse is a staggered overset grid method developed for body-fitted simulation of flows with moving spherical objects.

Progress

Several immersed boundary methods have been implemented and compared with the overset grid method.

Dissertations

-

Scientific Publications

-

Alkaliboost

Project Aim

The objective of the Alkaliboost project is to investigate alkaline water-electrolysis that operates at high current densities and pressures so that the product capacity of the electrolytic cells can be increased. The project is divided into two components: an electrolytic cell for operation at high pressure operation is built and numerical simulations of the bubbly flow in an electrolytic cell are performed and compared to the experimental measurements. Electrolytic cell design can be a costly and time-consuming and optical access is limited, but the multi-phase simulations give additional insight and reduce the number of cell prototypes to be tested in the lab.

Progress

The Alkaliboost project has started off at 1 October 2019. The first few months have been filled with learning and reading literature on electrolysis. A bachelor project has been started on the rise velocity and coalescence of bubbles that should provide closure relationships for the Euler-Lagrangian model to be built in the form of an in-house code. At the moment, Comsol is used to study mass transfer, heat transfer and Marangoni flow in the vicinity of a single bubble attached to a gas evolving electrode is being performed. These results give a better understanding of the flow and transport phenomena relevant for bubbles at the electrode and this could also lead to improved closures in the Euler-Lagrangian model.

Dissertations

-

Scientific Publications

-

Project leaders
MT de Groot, AW Vreman

Research theme
Complex dynamics of fluids

Participants
AM Meulenbroek, AW Vreman, NG Deen, R Lira-Garcia-Barros, MT de Groot, J van der Schaaf

Cooperations
Chemical Reactor Engineering, Department of Chemical engineering

Funded by
Rijksdienst voor ondernemend Nederland (RVO), Nouryon

Funded %

University	-
FOM	-
STW	-
NWO Other	85 %
Industry	15 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019

Information
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PROJECT LEADERS
NG Deen, Y Tang

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
R Subburaj

COOPERATIONS
MCEC, P Bruijnincx (UU)

FUNDED BY
MCEC

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT
2019

INFORMATION
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PROJECT AIM

We will investigate a micro-structured slurry bubble column reactor as the preferred process for Methanol production. In slurry bubble columns the reactant gases are bubbled through an inert liquid that is used to carry the catalyst and to act as a heat sink. Wire meshes are used to cut the bubbles We will first compare the slurry bubble column process with conventional reactor types using simple empirical reactor models.

PROGRESS

The process at hand is modelled using a CFD-DEM approach. That is, the liquid is described as a continuous phase, whereas the bubbles are modelled in a Lagrangian manner. The motion of the free surface is modelled with a VOF description. The preliminary simulations were performed using the software OpenFOAM. An illustration of the domain and the average liquid velocity (compared with experiments) is shown in figure 1.

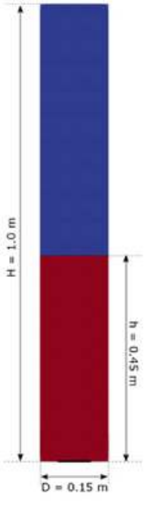
DISSERTATIONS

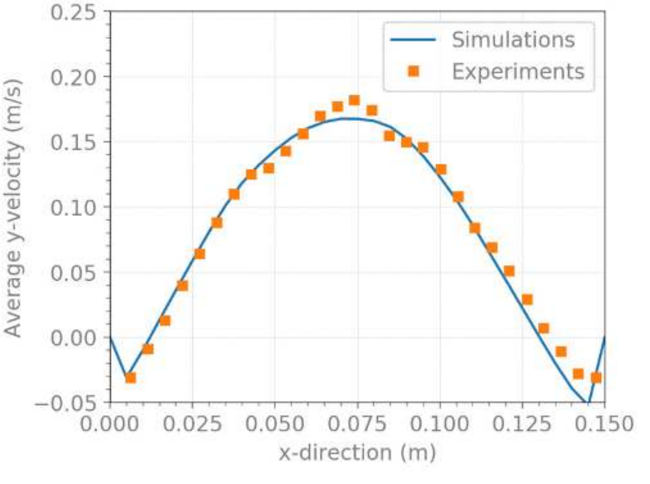
-

SCIENTIFIC PUBLICATIONS

-

Column (left), Average vertical liquid velocity profile at h = 0.25m(right





Numerical simulation on liquid transfer characteristics between colliding particles

Project Aim

Wet particle system has a potential application in many industrial processes, such as chemical, pharmaceutical and food industries. In such processes, particles collide with droplets and wet particles themselves. It is interesting to investigate how liquid transfer between particles for further tracking agglomerations forming. In this project, numerical study on liquid transfer behaviors between colliding particles will be carried out. The aim is to get a detailed and in-depth understanding on liquid transfer mechanism between particles, and further track particle agglomeration forming and breakup in industrial processes.

Progress

- Design a research plan and discuss a numerical method: Volume of Fluid (VOF) is applied for tracking gas-liquid flow, Immersed Boundary Method (IBM) is applied for particle motion
- A preliminary test of droplet spreading process on a solid boundary was conducted
- A procedure to impose contact angle on convex solid boundary is trying to be implemented with Height Function model in order to simulate droplet spreading on a particle in Basilisk
- Particle motion and collision modules will be modified and implemented based on Basilisk.

Dissertations

-

Scientific Publications

-

Project leaders

Y Tang, NG Deen

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Tianqi Tang

Cooperations

Yurong He, (Harbin Institute of Technology)

Funded by

China Scholarship Council (CSC)

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project

2019

Information

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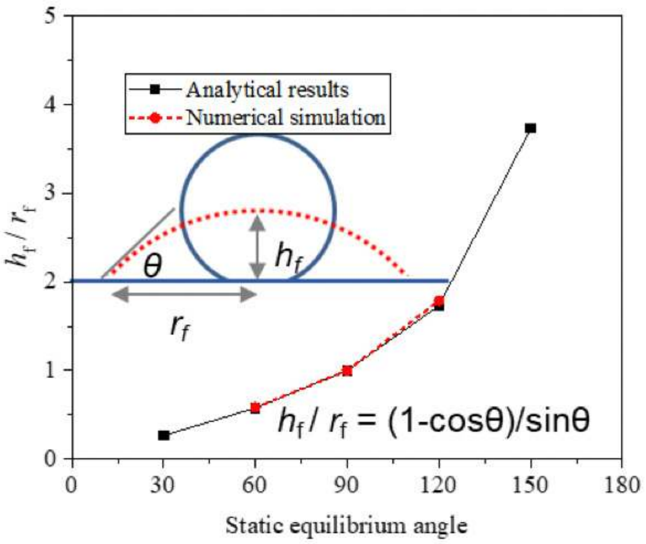
Comparison between analytical results and numerical simulation for droplet spreading on a flat



Numerical simulation and experimental study of co-combustion of biomass and coal

Project leaders
RJM Bastiaans, LPH de Goey
Research theme
Complex dynamics of fluids
Participants
Y Wang
Cooperations
Turbotec
Funded by
CSC
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project
2019
Information
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Project Aim

The goal of this project is to research the co-combustion of biomass and coal from different co-combustion forms (gas, solid and liquid). The goal is to find the best mixture ratio and best co-combustion form based on simulation and experiments results and gradually decrease the use of coal.

Progress

Yalin Wang firstly designed a feeding device which could mix the biomass and CWS (Coal-Water-Slurry) together before the boiler. Now she is doing the simulation of the mixture gas of biomass and coal using CHEM1D software under the supervision of RJM Bastiaans and LPH de Goey. She will do the experiments on the HFM setup.

Dissertations

-

Scientific Publications

1. Comparison of Combustion Kinetics of the Biomass Hydrolysis Residue with Raw Biomass Materials; Guanyi Chen, Yalin Wang, Fang Liu, Beibei Yan, Zhanjun Cheng, and Wenchao Ma
2. Energy & Fuels Article ASAP, DOI: 10.1021/acs.energyfuels.9b02143
   Patents: (Chinese patents). (1) A coal-biomass fuel coupled combustion feeding device and application method; Patent NO: CN201910216019.2; Yalin Wang, Renqing Zhang, Honglu Gao, Tianhao Xu, Jianhua Xing. (2) A building heating system coupled by phase change heat storage and heat pump; Patent NO: CN201920306697.3; Tianhao Xu, Yalin Wang, Renqing Zhang, Honglu Gao, Chang Su, Yang Song, Xiaohan Gao.

Passive measures of thermo-acoustic instability control in boilers with complex burner geometry

Project Aim

The aim of this project is to prevent the occurrence of thermo-acoustic instability in a system. This instability results in large-amplitude pressure oscillations caused by interaction between the flame and acoustic waves; they can cause major hardware damage. The research will concentrate on developing new physical insights of the phenomenon (using both experiments and numerical simulations) which will be used in construction of stable hydrogen-fueled combustion systems.

Progress

Experiments were conducted to determine the flame transfer function (using hot wire anemometer and photomultiplier tube) for various burners in varied operating conditions (mean flow velocity and equivalence ratio of methane and air mixture). This experimental data was fitted to a polynomial function to be used in dispersion relations. Reflection coefficient of flat plate perforated burners and burners will aerodynamically complex structures was obtained to determine their burner transfer matrix. It was observed that while the former burners do not reflect sound waves, the latter burners are not acoustically transparent and have sound reflection on their surface as shown in the Fig 1. A study on probability of stability of flat plate perforated burners with a variable reflection coefficient termination in the upstream of flame and burner was also undertaken.

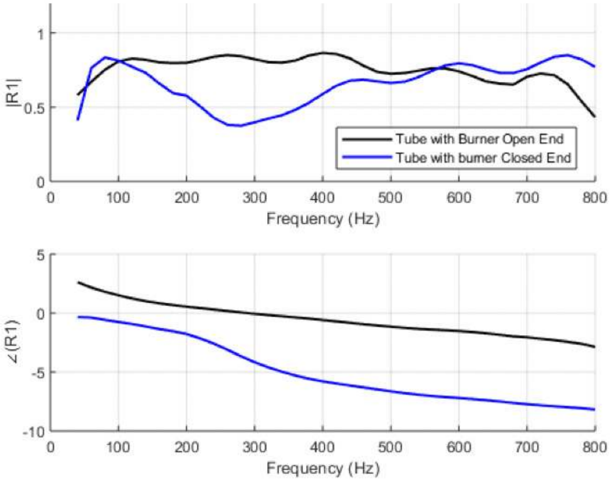
Dissertations

-

Scientific Publications

-

Reflection coefficient of an aerodynamically complex burners



Project leaders

LPH de Goey, I. Lopez Arteaga

Research theme

Complex dynamics of fluids

Participants

V. Kornilov, A Aulitto

Cooperations

Bekaert Combustion Technology, Ansaldo Energia, Siemens Industry Software, IfTA GmbH, Univ. of Genoa, KTH, Keele Univ., TU Munich, Univ. of Pisa

Funded by

Pollution Know-How and Abatement (POLKA) project funded by European Union.

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2019

Information

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Metal-to-Power. Towards implementation of metal powders as CO2-free fuels, development of experimental and numerical tools

Project leaders
LPH de Goey, RJM Bastiaans, JA van Oijen

Research theme
Complex dynamics of fluids

Participants
M Hulsbos, Y Shoshin

Cooperations
DSM, NVV, Metalot 3C

Funded by
DSM, NVV, Metalot 3C

Funded %

University	-
FOM	-
STW	-
NWO Other	84,92 %
Industry	15,08 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019

Information
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Project Aim

In this project we strive to provide knowledge on flame propagation of metal dusts, by studying the behavior of elemental dust flame fronts as a function of different parameters. The main objective is to create numerical and experimental tools which can help providing this knowledge on flame propagation of metal dusts.

Progress

A literature study is started concerning the combustion process of iron and the pneumatic conveying of powders. Also, some PIV measurements are done to visualize particulate flows. Furhter, a start has been made with the build-up of the starting point heat flux burner. A graduation project regarding the dispersion of iron powders has also been started.

Dissertations

-

Scientific Publications

-

Further development of the heat flux method - extended pressure range and fuel variety

Project Aim

This research project focuses on extending and applying one of the most accurate experimental methods for laminar burning velocity measurements - the Heat Flux Method. Previous measurements with this method have been typically conducted for gaseous fuels in moderate pressure ranges and for liquid fuels at atmospheric conditions. The current work will adapt the method to a greater range of pressures for a larger variety of fuels. A novel setup will be designed and built. Laminar burning velocity measurements will be performed for several gaseous and liquid fuels including new fuels and mixtures produced from more sustainable sources such as biomass and solar energy (solar fuels).

Progress

Extensive laminar burning velocity measurements of ethanol-air and methanol-air flames have been performed on the novel Heat Flux Burner setup for atmospheric and elevated pressures. The results have been compared with other experiments in literature and 1D modeling results using detailed kinetic mechanisms. Under conditions of elevated pressure, the flame front becomes thinner and moves closer to burnerplate. Therefore the flame may show small scale distortions, if the upstream fluctuations in flow, heat and mass transfer are not damped before the mixture reaches the reaction layer. To investigate this high pressure behavior in detail, the geometry of the perforated burnerplate was analyzed with axisymmetric simulations in Ansys Fluent with focus on influence of the geometry of the burnerplate.

Dissertations

-

Scientific Publications

-

Project leaders

LPH de Goey, JA van Oijen

Research theme

Complex dynamics of fluids

Participants

MB Raida

Cooperations

-

Funded by

University

Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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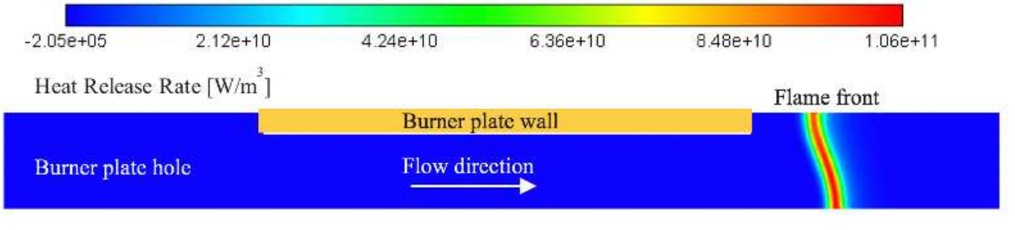
Results of numerical simulation of flame stabilization on a single hole of the burner plate at a pressure of p = 5 bar.



ESTiMatE: Modeling soot emissions of aero engines

Project leaders
JA van Oijen

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
AJ Kalbhor

Cooperations
Rolls-Royce Deutschland
Barcelona Supercomputing Center
Technische Universität Berlin
Universitat Politècnica de València
Technische Universität Darmstadt
Karlsruher Institut für Technologie
Universität Stuttgart

Funded by
EU

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2018

Information
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Project Aim

The project aims to develop an advanced sectional method-based computational model for the prediction of soot under conditions relevant to aero engines. The focus lies on the development of an effective soot modeling approach by combining a discrete sectional method with Flamelet-Generated Manifold (FGM) tabulated chemistry for application in Large Eddy Simulation (LES).

Progress

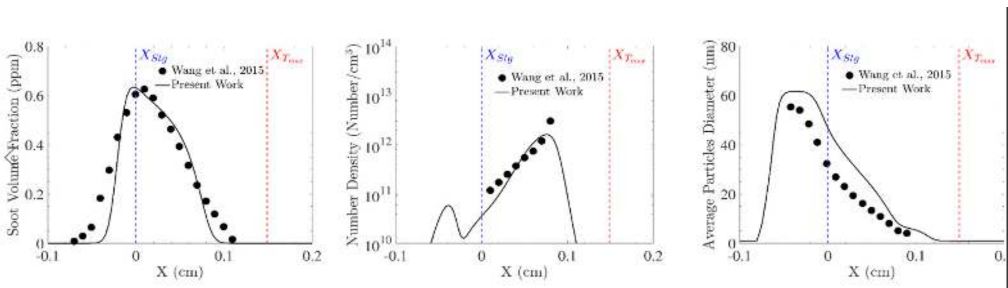
A sectional method-based soot model coupled with detailed gas-phase chemistry was implemented in the one-dimensional flame code CHEM1D and validated with experimental measurements in non-premixed as well as premixed flames. The predictive capabilities of the model were found to be sensitive to gas-phase chemistry and the treatment of soot surface radicals. The model also showed good qualitative soot predictions for kerosene and JP-8 surrogate fuels. Moreover, the effects of both simultaneous and separate addition of H2 to the fuel and H2O to the oxidizer on soot formation in laminar, counterflow ethylene diffusion flames were studied. The detailed kinetic pathway analysis showed that the chemically inhibiting effects of H2/H2O addition on soot formation are primarily through the reduced soot surface growth rates while the contribution of soot nucleation in the overall soot formation suppression is secondary.

Dissertations

-

Scientific Publications

-



: Simulated soot characteristics profiles of the baseline counterflow diffusion flame studied by Wang et al. 2015; Measured (symbols) and computed (solid line).

PROJECT AIM

Plasma-assisted combustion is a promising method to enhance flame-stability in low-temperature flames. The reduction of flame temperature is important for reducing NOx emissions. However, control over the combustion process via the creation of radicals using plasma is not well understood. The goal is to gain an understanding of the plasma activation of combustion via both numerical and experimental works. The hope is that optimal plasma type and plasma parameters can be found which achieve maximum stabilization of the combustion processes in low-temperature regime.

PROGRESS

A new experimental setup aiming at low-temperature combustion activation studies for various plasma parameters has been designed. During initial experiments, methane ignition in lean conditions is observed in streamer like plasma mode. ICCD imaging is used for plasma and ignition characterization. Along with new setup characterization, Raman spectroscopy for temperature and major species measurements is being developed for non-equilibrium conditions and results are expected soon. A numerical study of thermoacoustic mitigation using plasma has been initiated. Concurrently, an air plasma chemistry mechanism is being developed and simulated in 0D. Initial results for thermoacoustic mitigation and plasma chemistry simulations are expected soon.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

S Nijdam (EPG), JA van Oijen (P&F), NJ Dam (P&F), J van Dijk (EPG)

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

T Hazenberg, R Patel

COOPERATIONS

NWO, Bosch Thermotechniek, Bekaert Combustion Technology, Micro Turbine Technology, Plasma Pendix

FUNDED BY

NWO, Bosch Thermotechniek, Bekaert Combustion Technology Micro Turbine Technology

FUNDED %

University	-
FOM	-
STW	-
NWO Other	83 %
Industry	17 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2019

INFORMATION

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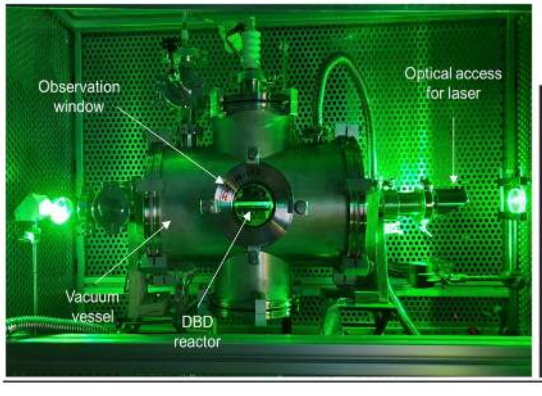
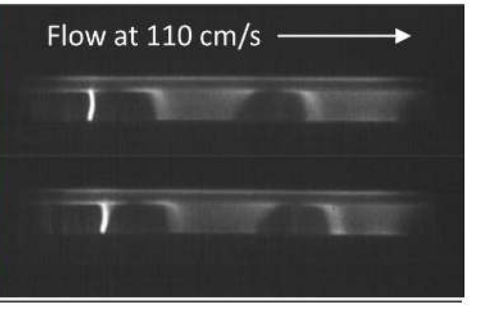
Left: photograph of new experimental setup for low-temperature plasma assisted combustion studies.
Right: Single pulse ICCD images capturing streamers assisted methane ignition





PROJECT LEADERS
JA van Oijen
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
DV Efimov
COOPERATIONS
Bosch Thermotechnology Ltd.
FUNDED BY
Bosch Thermotechnology Ltd.
FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019
INFORMATION
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PROJECT AIM

In order to reduce greenhouse gas emissions, domestic heating has to almost completely be decarbonized. Hydrogen produces no CO2 at the point of use. However, there are currently no suitable products available to replace natural gas boilers. Furthermore, there are differences between methane and hydrogen combustion. The project aims to designs a concept for future hydrogen boiler technology, by developing simulation methods. Simulation offers two benefits to such a project; in the early stages, fast coarse optimization and evaluation of novel concepts and later on, detailed optimization and sensitivity analysis to mature a chosen concept.

PROGRESS

A method has been developed for practical and realistic simulations of hydrogen combustion. Due to challenges involved with the simulation of hydrogen flames using FGM simplified chemistry, several original methodologies are developed and implemented. Main progress was made on a novel treatment of the preferential diffusion of the FGM control variables, being very important for hydrogen combustion due to high diffusivity of hydrogen. Further the model performance was investigated including the effects of the burner conjugate heat transfer. Also, a robust method for lookup in multidimensional (3D) curved manifolds was developed.

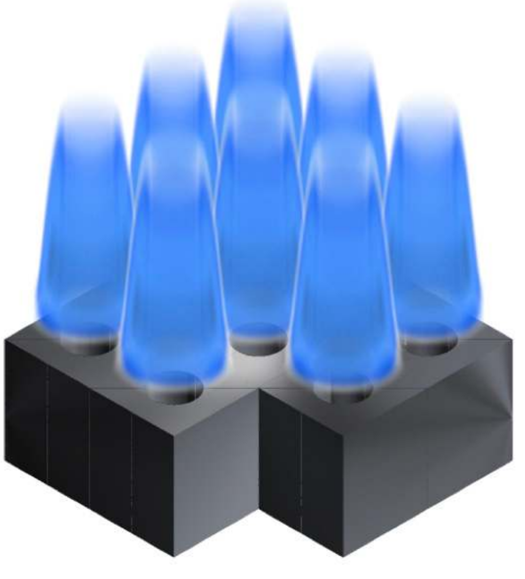
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

The simulation result for hydrogen flames on a perforated burner plate



PROJECT AIM

Heavy-duty and long-haul transportation industry is confronted with challenges on air quality (pollutant emissions) and global warming (greenhouse emissions). One of the solutions is to combine advanced combustion concepts with alternative fuels to achieve the goal of a clean and efficient engine. This project mainly focuses on the possibility of applying alcohol fuels (ethanol and butanol) in low-temperature combustion concepts. Experimental investigations are performed on a heavy-duty engine setup to compare the combustion and emission characteristics of alcohol fuels when operated in different combustion concepts.

PROGRESS

Applying butanol as a low reactive fuel in the so-called reactivity controlled compression ignition combustion (RCCI) approach is investigated .The effects of charge preparation related parameters on RCCI are explored. Tests are performed at various inlet pressure, EGR rate, and DI strategy. The results indicate that for n-butanol/n-heptane RCCI necessitates a double DI strategy and a high EGR rate in this experimental setup. Above 50% gross indicated efficiency and Euro VI-compliant soot/NOx emissions can be achieved from 4 bar to 10 bar at the cost of deteriorated combustion efficiency. However, the high load limitation is constrained by the excessively high PRRmax and cylinder pressure. Among the investigated butanol isomers, isobutanol RCCI performs noticeably well in fulfilling the emission and safety standard with the most practical handling approach and the easiest control requirement. Though being solid at room temperature, tert-butanol RCCI shows excellent performance in soot reduction, has good combustion stability (low COVgIMEP and PRRmax) and a high GIE.

PROJECT LEADERS

LMT Somers, NG Deen

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

J Han

COOPERATIONS

-

FUNDED BY

Chinese government scholarship

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT

2019

INFORMATION

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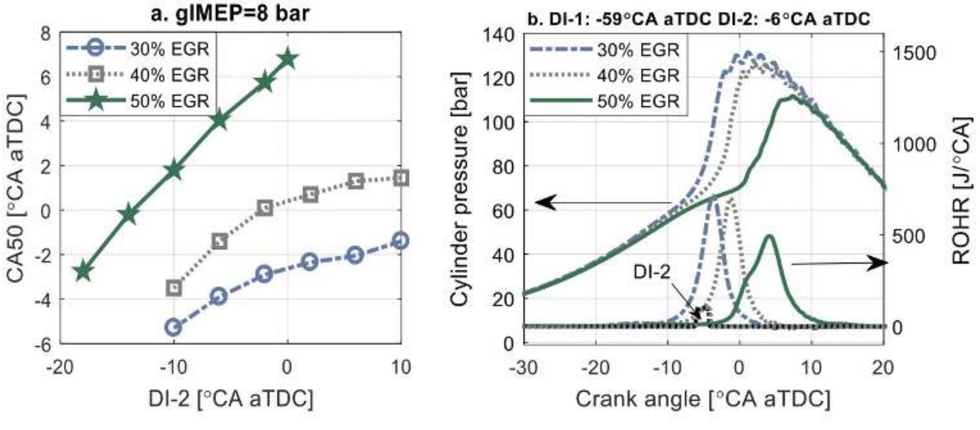
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



CA50 (a) and ROHR (b) vs DI-2 at a different EGR rate.

MICROSYSTEMS

Prof.dr.ir. JMJ den Toonder

The Microsystems group develops microsystems design approaches and out-of-cleanroom micro-manufacturing technologies that are rapid and flexible. these are applied to realize active mechanical control in micro-fluidics, to make and study meso-structured and soft materials, to create and study cells and organs on chips, and to develop advanced microsystems applications in collaboration with industrial partners. The group has a state-of-the-art microfabrication lab, and access to the Nanolab@TU/e cleanroom.

The Microsystems group is part of

MaTe, the Materials Technology Institute
ICMS, the Institute for Complex Molecular Systems
J.M.Burgerscentrum
EM, Graduate School on Engineering Mechanics
Human Organ and Disease Model Technologies

PROJECT AIM

The aim of the project is to develop chip-based models of breast-cancer prior to invasion to investigate properties of the microenvironment on the invasive behavior of the cancer cells. By employing microfluidic techniques, physiologically relevant heterogeneous tissue models are constructed, with controlled and reproducible physical and chemical properties. The focus is on investigating the mechanical and chemical microenvironmental cues.

PROGRESS

In 2019, we have developed a novel model of the pre-invasive breast cancer niche, with a heterogeneous ECM comprised of Matrigel and collagen I. These components are patterned by first encapsulating cancer cells in Matrigel beads, which are then embedded in collagen. In this work, we demonstrate more efficient bead retrieval after cell encapsulation, based on water-oil-water (WOW) double emulsification and spontaneous release. The method enables fast generation of multiple cancer models, with controlled size and composition.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Sleeboom, J., Sahlgren, C. M., & den Toonder, J. M. J. (2019). Efficient fabrication of a pre-invasive breast cancer model via double emulsification of Matrigel. Poster session presented at The 23rd International Conference on Miniaturized Systems for Chemistry and Life Sciences (MicroTAS 2019), Basel, Switzerland.
2. Sleeboom, J., van der Doelen, K., Kruyt, F., Sahlgren, C. M., & den Toonder, J. M. J. (2019). A microfluidic oxygen gradient device to assess EMT state and migrational responses of cancer cells. Poster session presented at 1st annual conference of the European Organ-on-Chip Society (EUROoC 2019), Graz, Austria.

PROJECT LEADERS

JMJ den Toonder, C Sahlgren

RESEARCH THEME

Complex structures of fluids

PARTICIPANTS

Jelle Jan Freerk Sleeboom

COOPERATIONS

-

FUNDED BY

EC

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

START OF THE PROJECT

2016

INFORMATION

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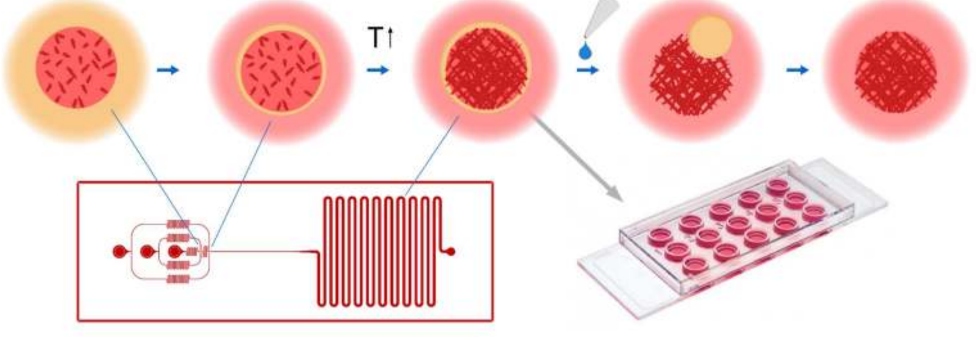

Magnetic control of micro-particles and integrated micro-actuators for high precision handheld diagnostics

Project leaders
JMJ. den Toonder
Research theme
Complex structures of fluids
Participants
Eriola Shanko
Cooperations
Philips Healthcare
Funded by
HTSM-TKI
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016
Information
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Project Aim

Magnetic particles actuated by magnetic fields are an attractive approach in the medical field, since they can be used in various applications, for example to capture and concentrate specific analyte, to mix fluids, and as labels for detection). In addition, to magnetic particles, also magnetic micro- actuators integrated into microfluidic devices can be used to control liquid flow and induce mixing, using externally generated magnetic fields. The aim of this project is to develop novel approaches on solving mixing problems to reach homogeneity of reagents and achieve high precision handheld diagnostics by using actuated magnetic particles and integrated magnetic micro-actuators.

Progress

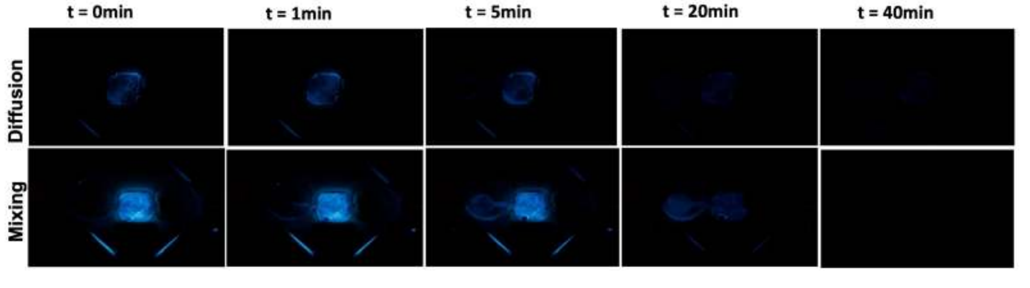
We carried dedicated experiments with a unique magnetic actuation set-up and we performed microscopic fluid flow characterization. Enhanced mixing mechanisms, hence efficient mixing, augment binding events by providing increased kinetics, for example enhancing the binding between sensor proteins and target molecules within the solution. This approach increases the chance of detection as well as boosting detection speed, sensitivity, and reproducibility in very small volumes (10-6 L). We have demonstrated this with a previously reported bioluminescent sensor platform that can detect antibodies in pico (10-12) Molar range concentrations in blood plasma using a smartphone, on the basis of a colorimetric readout principle.

Dissertations

-

Scientific Publications

1. Shanko, E., van de Burgt, Y., Anderson, P., & den Toonder, J. (2019). Microfluidic magnetic mixing at low reynolds numbers and in stagnant fluids. Micromachines, 10(11), [731]. https://doi.org/10.3390/mi10110731.
2. Eriola Shanko, Yoeri van de Burgt and Jaap den Toonder. EFFECTIVE MIXING IN A MICRO REACTION CHAMBER USING MAGNETIC MICRO BEADS FOR FASTER MOLECULAR SENSING. Poster session presented at 1st annual conference of the European Organ-on-Chip Society (EUROoC 2019), Graz, Austria.



PROJECT AIM

The aim of this project is to design and create magnetic artificial cilia (MAC), and to integrate these into a microfluidic testing device to characterize the microscopic particle manipulation behavior and antifouling property of the ciliated surface. We will study the possibility to repel and control (micro-) particles, and to block the formation of biofilms, focusing on marine anti-fouling.

PROGRESS

The fouling of surfaces submerged in a liquid is a serious problem for many applications including lab-on-a-chip devices. Inspired by the versatility of cilia in manipulating fluids and particles, we experimentally demonstrate for the first time that surfaces covered with magnetic artificial cilia (MAC) have the capacity to efficiently prevent the attachment and adhesion of real biofouling agents microalgae Scenedesmus sp., i.e. the ciliated surfaces are anti-fouling. Actuated by a rotating magnet, the MAC can perform a tilted conical motion, which leads to the removal of the algae away from the ciliated area, creating a clean area.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Zhang, S., Wang, Y., Onck, P. R., & den Toonder, J. M. J. (2019). Removal of microparticles by ciliated surfaces: an experimental study. Advanced Functional Materials, 29(6), [1806434]. https://doi.org/10.1002/adfm.201806434.
2. Saberi, A., Zhang, S., van den Bersselaar, C., Kandail, H., den Toonder, J. M. J., & Kurniawan, N. A. (2019). A stirring system using suspended magnetically-actuated pillars for controlled cell clustering. Soft Matter, 15(6), 1435-1443. https://doi.org/10.1039/c8sm01957f.
3. Shuaizhong Zhang, Ye Wang, Patrick Onck and Jaap den Toonder. ANTI-FOULING SURFACES FEATURED WITH MAGNETIC ARTIFICIAL CILIA. Poster session presented at 1st annual conference of the European Organ-on-Chip Society (EUROoC 2019), Graz, Austria.

PROJECT LEADERS
JMJ. den Toonder

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Shuaizhong Zhang

COOPERATIONS
-

FUNDED BY
CSC (100%)

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT
2015

INFORMATION

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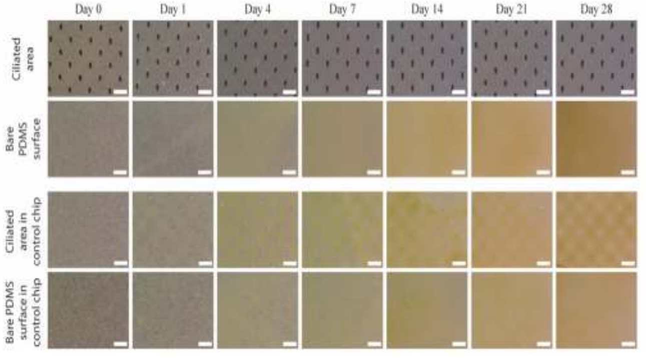
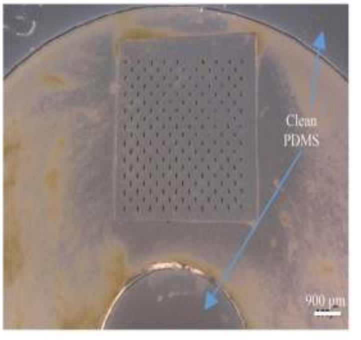
www.tue.nl/universiteit/faculteiten/faculteit-werktuigbouwkunde/onderzoek/research-groups/microsystems/





Bio-Plan: Bio-Inspired microfluidic platform for biomechanical analysis

Project leaders
JMJ den Toonder

Research theme
Complex structures of fluids

Participants
Bhavana Venkataramanachar, Shuaizhong Zhang, Zhiwei Cui, Ye Wang

Cooperations
Prof. Patrick Onck (RUG)

Funded by
EU

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2019

Information
Jaap den Toonder
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Project Aim

We will realize a novel microfluidic platform for biomechanical analysis with unprecedented possibilities of controlling fluid flow and applying and sensing time-dependent forces at subcellular scales in controlled environments. The platform will be uniquely based on bio-inspired magnetic artificial cilia, rather than on conventional microfluidic valves and pumps. Cilia are microscopic hairs ubiquitously present in nature, acting both as actuators and sensors, essential for swimming of microorganisms, transport of dirt out of our airways, and sensing of sound, i.e. they exactly fulfill functions needed in biomechanical analysis.

Progress

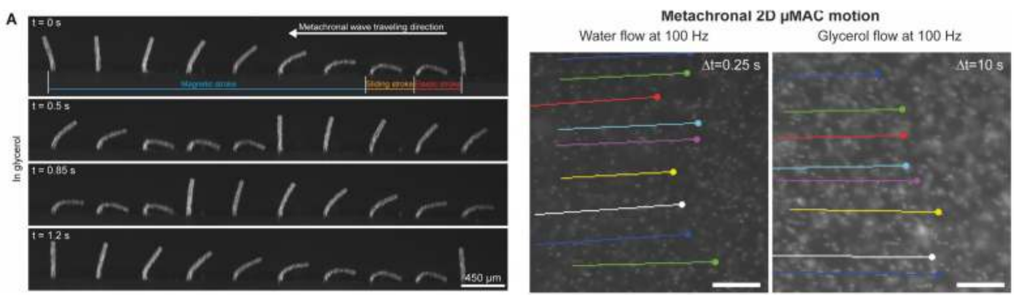
Biological cilia that generate fluid flow or propulsion are often found to exhibit a collective wavelike metachronal motion, i.e. neighboring cilia beat slightly out-of-phase rather than synchronously. Inspired by this observation, we have experimentally demonstrated that microscopic magnetic artificial cilia (μMAC) performing a metachronal motion can generate strong microfluidic flows, though, interestingly, the mechanism is different from that in biological cilia, as is found through a systematic experimental study. The μMAC are actuated by a facile magnetic setup, consisting of an array of rod-shaped magnets.

Dissertations

-

Scientific Publications

-



PROJECT AIM

Glaucoma is the leading cause of preventable blindness worldwide, estimated to cause bilateral blindness in 11 million people by 2020. A rise in the intraocular pressure (IOP) is considered to be the major risk factor for glaucoma. Glaucoma drainage devices (GDDs), which are typically hollow tube-like shunts surgically implanted in the eye, provide an alternative pathway through which AqH can effectively exit the anterior chamber, thereby lowering IOP. In this project, we aim at developing an innovative implant consisting of a novel glaucoma microshunt with an integrated responsive material. This will not only drive the AqH from the anterior chamber, but it will also enable to adjust the flow of AqH through the shunt non-invasively after surgery by the actuation of a responsive material.

PROGRESS

To have an insight into the tube diameter adjustments required for IOP control, we developed a computational model describing AqH outflow through the adjustable microshunt, its drainage into the filtering bleb and absorption by the subconjunctival capillaries. Hypotony (i.e. low IOP) and bleb scarring, which are the two most common postsurgical complications of GGD implantation, were simulated using this model to determine the worst-case scenario of IOP values our smart implant will have to control. Simulating those conditions was possible by changing the way AqH is transported and absorbed through the subconjunctival drainage pathway.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

JMJ. den Toonder

RESEARCH THEME

Complex structures of fluids

PARTICIPANTS

Inês Pereira, Hans Wyss

COOPERATIONS

Prof. Henny Beckers (MUMC)
Prof. Albert Schenning (TU/e)

FUNDED BY

InSciTe 100%

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	100 %
EU	-
Scholarships	-

START OF THE PROJECT

2019

INFORMATION

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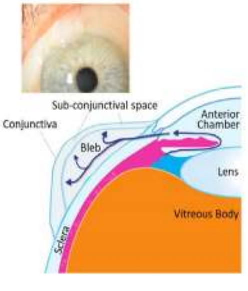

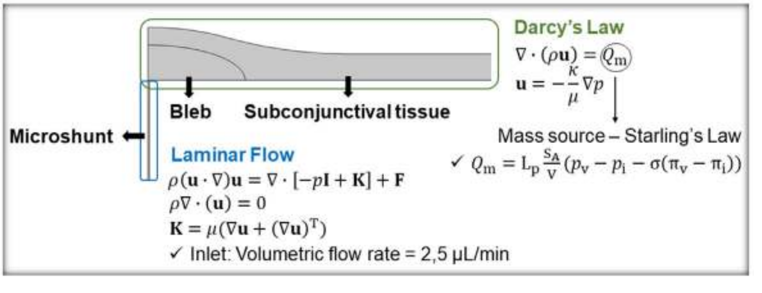

PROJECT LEADERS
JMJ den Toonder
RESEARCH THEME
Complex structures of fluids
PARTICIPANTS
Tanveer ul Islam
COOPERATIONS
Prof. Yves Bellouard (EPFL)
FUNDED BY
EU
FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

START OF THE PROJECT
2018
INFORMATION
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PROJECT AIM

The project aims at developing a lab-on-chip model of cilia towards in-vitro analysis against controlled physical parameters. Cilia are closely spaced microscopic hair-like structures protruding out of a cell surface. Structural alterations in cilia, mostly caused by genetic mutations, results into a number of severe diseases, called Ciliopathies. Our proposed model first requires development of a novel microfabricaton process to produce magnetic artificial cilia mimicking the biological cilium structure as closely as possible. As a proof-of-concept, we will create an artificial embryonic node to understand the cilium functioning in their normal and defected forms.

PROGRESS

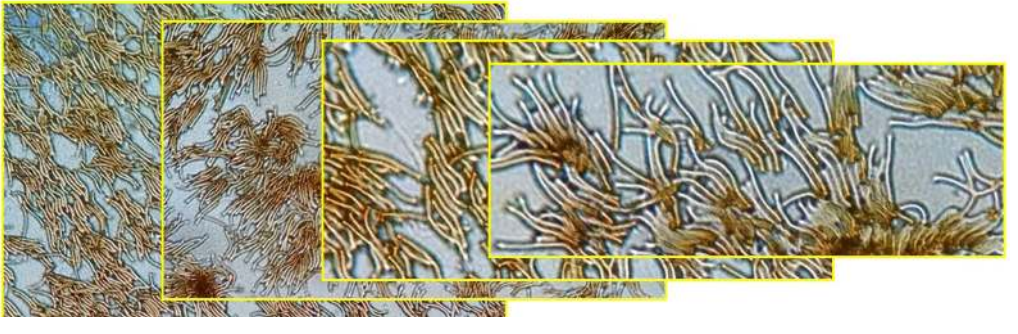
Artificial cilia are fabricated using a flexible polymer material embedded with nano-magnetic particles for actuating the cilia using a varying external magnetic field. The cilia have a diameter of 2μm and length 20 μm. Molding and demolding process for fabricating randomly placed cilia involves the use of sacrificial polycarbonate track etched (PCTE) membranes. Fabrication of cilia with a bulbous head and their precise positioning has been attempted by employing femtosecond laser machining process.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Locate: Integrated platform to design novel cancer localization strategies by ultrasound microvasculature imaging

Project Aim

Locate aims at opening new avenues towards a cost-effective imaging solution for the localization of prostate cancer and other neo-angiogenic forms of cancer using dynamic contrast-enhanced ultrasonography (CEUS). It aims to extend fundamental knowledge through the development and application of a novel integrated validation and development platform, as well as proof-of-concept implementations. The platform consists of an experimental model of the microvasculature, tailored US imaging hardware, and dedicated US signal analysis modalities.

Progress

We have demonstrated a promising 3D sugar printing method that is capable of recapitulating the vascular network geometry with a vessel diameter range of 1 mm down to 150 um. For this work a dedicated 3D printing setup was built that is capable of accurately printing the sugar glass material with control over fibre diameter and shape. By casting of printed sugar glass networks in PDMS and dissolving the sugar glass, perfusable networks with circular cross-sectional channels are obtained. Using particle image velocimetry, analysis of the flow behaviour was conducted showing a Poisseuille flow profile inside the network and validating the quality of the printing process.

Dissertations

-

Scientific Publications

1. Pollet, A., Homburg, F. G. A. E., & den Toonder, J. M. J. (2019). Mimicking the microvasculature using 3D sugar printing. Poster session presented at 1st annual conference of the European Organ-on-Chip Society (EUROoC 2019), Graz, Austria.
2. Pollet, A., Homburg, F. G. A. E., & den Toonder, J. M. J. (2019). Fabricating the microvasculature using 3D sugar printing. Poster session presented at NanoBioTech, Montreux, Switzerland.

Project leaders

JMJ den Toonder

Research theme

Complex structures of fluids

Participants

Andreas Pollet

Cooperations

Dr. Massimo Mischi, dr. Pieter Harpe

Funded by

STW 100%

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

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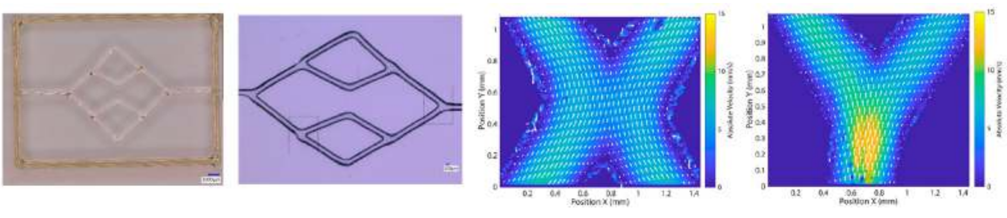

Multi-scale Modeling of Multiphase Flows

Prof.dr.ir. JAM Kuipers

The research group Multiphase Reactors - Multi-scale Modeling of Multiphase Flows group participates amongst others in the 'OnderzoekSchool ProcesTechnologie' OSPT and the J.M. Burgerscentrum for fluid mechanics (JMBC) and focuses on fundamentals of the discipline of chemical reaction engineering. Our main area of interest is the quantitative description of transport phenomena (including fluid flow) and the interplay with chemical transformations in multiphase chemical reactors and in porous media.

Through the intended co-operation with other (application oriented) research groups, both fundamental aspects and those closely related to applications will be studied through concerted action. The main research topics of the new group SMR can be divided into the following two areas: Multiphase Reactor modeling and Advanced Experimental Techniques, which will be discussed below in more detail. An important area of attention is the development of advanced reactor models for multiphase reactors with industrial relevance.

At present our research focuses on the hydrodynamics in these reactors because it is generally recognized that the lack of understanding of the flow phenomena is one of the central difficulties in the design and scale-up of multiphase reactors. In addition, the interplay of flow phenomena with chemical reactions will be studied in great detail. We use various types of CFD models (both commercial codes but mostly "in house" made codes) to study the relevant hydrodynamic phenomena at all relevant length and time scales (i.e. at the microscopic, mesocopic and macroscopic scale). In our group, both multifluid models and models which treat the dispersed phase (particles, bubbles or droplets) in a discrete manner accounting for possible encounters between the dispersed elements are being developed.

The second important area of our research deals with the development/ application of advanced experimental techniques to measure key quantities (i.e. local volume fractions and velocities of the dispersed and continuous phase). As an example we can mention the development and application of various optical techniques such as digital particle image velocimetry technique to measure in a non-intrusive manner the velocity map of both the liquid phase and dispersed gas bubbles in (dense) gas-liquid dispersions. This type of flow very often arises in a variety of gas-liquid contactors/reactors. In this area we co-operate with specialists within the J.M. Burgerscentrum for fluid mechanics.

Direct numerical simulation of mass & heat transfer in dense bubbly flows

Project Aim

The aim of the project is to model and simulate heat and mass transport with chemical reactions in dense bubbly flows. One of the challenge is to accurately predict the closures for realistic gas-liquid systems that have a separation of scales at which these transport processes occur. The idea is to use a hybrid mesh approach to resolve the different scales especially for mass transfer. In contrast, for heat transfer where the separation of scales is not so stringent, we propose to use a single field / sharp interface formulation using necessary immersed boundary condition for deriving closures for wall to liquid heat transfer and immersed object to liquid heat transfer.

Progress

The heat transfer from solid particles has been studied using an Immersed Boundary method with Adaptive Mesh Refinement (AMR). The octree based AMR method allows for the simulation of the heat transfer in fluids high Prandtl numbers (Pr≤500). The results show an excellent agreement with the well-established empirical correlations for heat transfer from a particle. Afterwards the method was extended to simulate the mass transfer from a single bubble as shown in figure 1. Also for the single bubbles a good agreement was found with the existing Sherwood correlations.

Dissertations

-

Scientific Publications

1. Panda, A., Peters, E.A.J.F., Baltussen, M.W., Kuipers, J.A.M., Fully resolved scalar transport for high Prandtl number flows using adaptive mesh refinement (2019) Chemical Engineering Science: X, 4, art. no. 100047.
2. Panda, A., Weitkamp, Y.E.J., Rajkotwala, A.H., Peters, E.A.J.F., Baltussen, M.W., Kuipers, J.A.M., Influence of gas fraction on wall-to-liquid heat transfer in dense bubbly flows (2019) Chemical Engineering Science: X, 4, art. no. 100037.
3. Rajkotwala, A.H., Panda, A., Peters, E.A.J.F., Baltussen, M.W., van der Geld, C.W.M., Kuerten, J.G.M., Kuipers, J.A.M., A critical comparison of smooth and sharp interface methods for phase transition (2019) International Journal of Multiphase Flow, 120, art. no. 103093.
4. Patel, H.V., Panda, A., Kuipers, J.A.M., Peters, E.A.J.F., Computing interface curvature from volume fractions: A machine learning approach (2019) Computers and Fluids, 193, art. no. 104263.

Project leaders

J.A.M. Kuipers

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

A. Panda, E.A.J.F. Peters, M.W. Baltussen

Cooperations

-

Funded by

NWO, Akzo Nobel, DSM, SABIC, Shell and Tata Steel

Funded %

University	-
FOM	50 %
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

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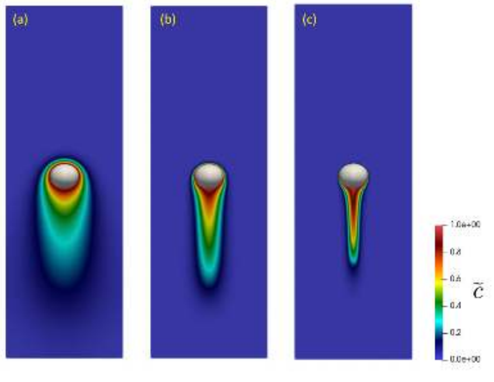

The mass transfer around a single bubble. The Schmidt number is a) 1, b) 10 and c) 100.

PROJECT LEADERS
J.A.M. Kuipers
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
P.M. Durubal, M.W. Baltussen, K.A. Buist
COOPERATIONS
-
FUNDED BY
MCEC - Netherlands Center for Multiscale Catalytic Energy Conversion
FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019
INFORMATION
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PROJECT AIM

The purpose is to develop a multiscale modeling approach for spray atomization of bio-oils by developing a Direct Numerical Simulation model which investigates interactions between droplets and droplets-particles at the mesoscale in a multi-component and multi-phase flow. In order to do so, a combined computational and experimental method will be employed. The study will enable a better understanding of the interactions of multicomponent droplets and the interactions of liquid droplets with (hot) catalyst.

PROGRESS

In order to model the droplet impact with a solid object a combined VoF and IBM method will be used. Within the VoF method, surface tension models are developed for the in-house parallel CFD code, which need improvements. In order to do so, the implementation of the balanced force method and an improved curvature calculation is studied to obtain more accurate results.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Numerical simulation of boiling flows using the local front reconstruction method

Project Aim

To develop a hybrid 3D Front Tracking (FT) method with phase transition. The resulting FT scheme will coupled with sub-grid models to properly account for micro-scale effects (for e.g. thin film between two colliding droplets/bubbles and between bubble/droplet and wall). The developed method will be used to study complex multiphase problems like binary droplet collisions and flow boiling in a microchannel.

Progress

The Local Front Reconstruction Method (LFRM) is a hybrid front tracking method without connectivity, which can easily handle complex topological changes like droplet breakup. The LFRM is extended to allow for phase transition. The method is verified by standard test cases and validated against experiment of rise and growth of single bubble in gravity. The method is then applied to study bubble growth in microchannel flow boiling. This study also highlighted the importance of thin film evaporation in overall heat transfer during flow boiling in micro channels. Under practical conditions, the length scale of the thin film is much smaller than the width of the microchannel. This poses a challenge to fully resolve the thin film while maintaining an affordable number of computational grid cells. For the thin film, it is safe to assume that the flow and heat transfer is dominated by viscous and conduction effects, respectively. This provides an opportunity to account for the thin film evaporation using a sub-grid model. As a first step, we develop a sub-grid model to account for thin film (without evaporation). A lubrication model is developed from first principles of conservation of mass and momentum in thin film. The developed model is coupled with LFRM and applied to simulate a droplet falling onto and sliding on an inclined wall. It is observed that the evolution of films thinner than the grid size is captured with reasonable accuracy when using the sub-grid film model.

Dissertations

-

Scientific Publications

1. Rajkotwala, A. H., Panda, A., Peters, E. A. J. F., Baltussen, M. W., Van Der Geld, C. W. M. , Kuerten, J. G. M. And Kuipers, J. A. M. (2019), A critical comparison of smooth and sharp interface approaches for phase transition, International Journal of Multiphase Flows, 120, 103093.

Project leaders

J.A.M. Kuipers, C.W.M. van der Geld, J.G.M. Kuerten

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Ir. A. Rajkotwala, E.A.J.F. Peters, M. W. Baltussen

Cooperations

-

Funded by

STW, Industrial partners

Funded %

University	-
FOM	-
STW	75 %
NWO Other	-
Industry	25 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

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Comparison of droplet evolution from the simulation on a coarse grid with thin film model (blue), with simulations on a coarse grid without the model (red) and on a fine grid (green)

Small molecule activation: Pyrolytic upgrading of methane to ethylene, aromatics and carbon materials - Proof of concept and modelling of a gas-fluidized bed reactor

Project leaders
J.A.M. Kuipers
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
M. Hadian, K.A. Buist
Cooperations
-
Funded by
ARC-CBBC
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019
Information
K.A. Buist
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Project Aim

Thermocatalytic decomposition of methane next to development of proper catalysts, it requiresoptimal design of the reactor and the process. To facilitate this the particle growth and breakup needs to be characterized and modeled by means of conducting kinetic measurement experiments and modeling of the heat and mass transfer and catalytic reaction in the particle scale. This model later will be incorporated in a model of the gas-solid fluidized bed reactor and fluidized bed reactor experiments.

Progress

Project is divided into two parts; an experimental part and a modelling part and both are considered in two scales; the scale of the particle and the scale of the reactor. After a thorough literature study on the thermodynamics and kinetics of the process the first part of modelling (single particle modelling) has been done based on the multi grain model (see figure 1). The fixed-bed reactor setup for kinetic measurement is built and is ready to use.

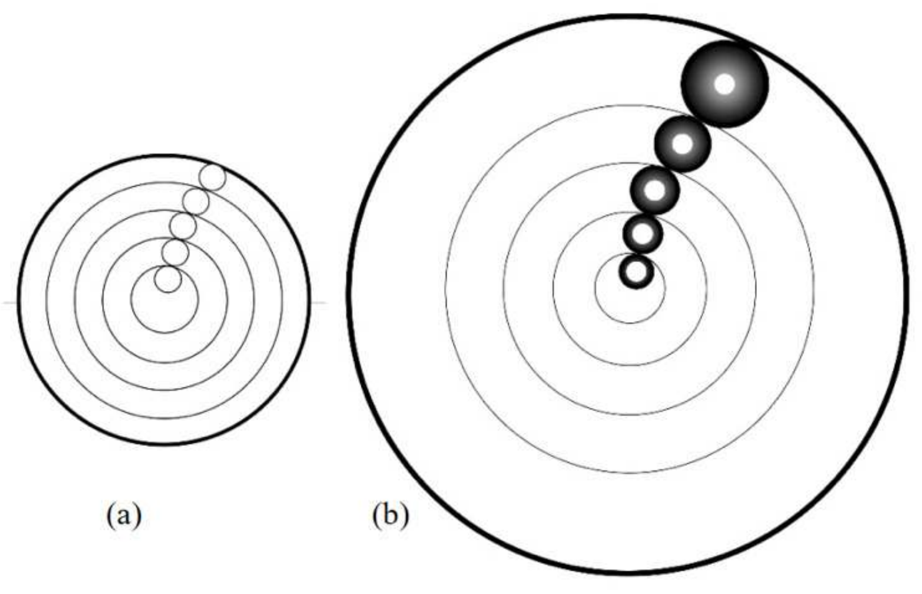
Dissertations

-

Scientific Publications

-

Multi layer catalyst particle (a) at t=0 and (b) at t>0, every catalyst particle contains several layers of micro particles (one in each layer is showed by white circle) with active site on their surfaces. The solid carbon grows on their surface (dark layer around white circles) based on the local kinetic rate.



Project Aim

In the project, a set of numerical models is developed that is capable of capturing the interaction between the gas, solid particles and liquid droplets, as it occurs in gas-solid polymerization reactors. The developed method are used to get insight in the hold-up profiles of gas, solids and liquid and heat management in the reactors. This will enable the prediction and prevention of degenerate aspects in polymerization reactors.

Progress

In order to study the behavior of liquid injection into a fluidized bed reactor, the interactions between the gas, liquid and solids need to be understood. The complexity of the system comes from the numerous interactions that take place during this process. To model this process in a larger scale, the interactions need to be accounted for. Such effects as imbibition, wet collisions and evaporative cooling cannot be fully resolved at large scales. Using DNS modelling, closures are developed which can be implemented into larger scale models. One of the degenerative aspects is the formation of agglomerates through liquid cohesion. Characteristics of these agglomerates are essential in larger scale modelling and are the main focus of this work. As the fluid dynamics of three phase flow define the main characteristics of the agglomerates, the validation of this model is key. Using an experimental set-up, the validation of these dynamics is pursued.

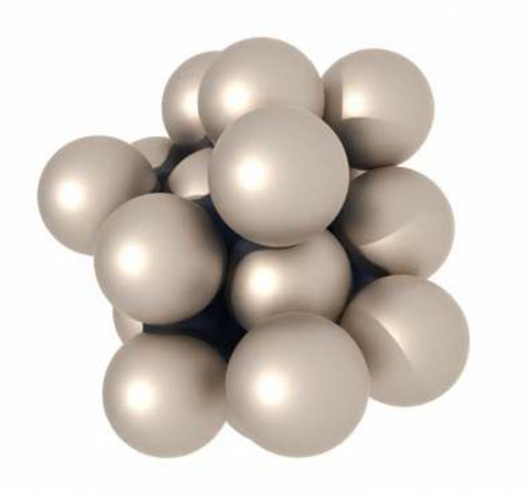
Dissertations

-

Scientific Publications

1. Direct Numerical Simulation study of droplet spreading on spherical particles, E.Milacic, M.W. Baltussen, J.A.M. Kuipers, Powder Technology 354, 2019, 11-18.

Simulated agglomerate in a mono-dispersed bed of particles for the characterization of transport coefficients and liquid cohesion



Project leaders

J.A.M. Kuipers

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

E. Milacic, M.W. Baltussen

Cooperations

-

Funded by

Dutch Polymer Institute

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

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PROJECT LEADERS
E.A.J.F. Peters, J.A.M. Kuipers
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
Mr. Harshil Patel, MSc
COOPERATIONS
Shell
FUNDED BY
NWO, Shell
FUNDED %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2015
INFORMATION
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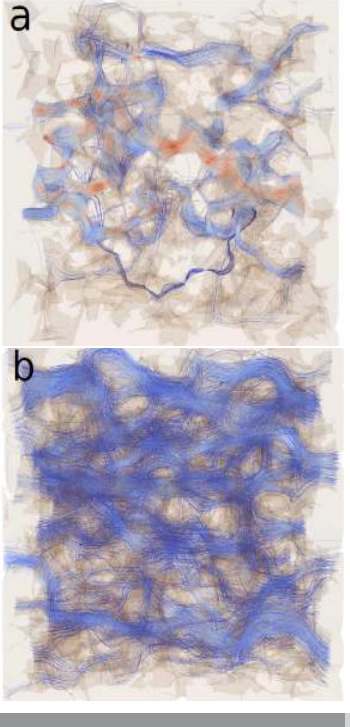

PROJECT AIM

Fluid-fluid flows through complex porous structures are encountered widely in nature and technology. One such example is water flooding process used for the enhanced oil recovery (EOR). In water flooding process high pressure and/or high temperature water is pushed through porous rocks which carries the residual oil out of it. Focus of this project is to perform the pore-scale simulations of oil-water multiphase flows through complex rock structures during such recovery. Furthermore, similar simulations are to be performed for other EOR methods such as polymer flooding or surfactant flooding.

PROGRESS

The PhD thesis of this project was defended on 28 October 2019. The key results are:

- A coupled immersed boundary method (IBM) and volume of fluid (VOF) method to simulate multiphase flow of immiscible fluids through porous media with wettability effects.
- Quantification the effect of flow and fluid properties i.e. capillary number, viscosity ratio and wettability on the mobility of the multiphase flow through model porous structures comprised of repeated single and multiple random pores.
- Extension of the coupled IBM-VOF method for any arbitrarily shaped complex solid boundary in stereolithographic surface mesh format.
- Water flooding simulations through real digitized rock that quantify the effect of rock porosity on the oil mobility, viscous finger characteristics and energy exchange rates.
- Development of novel curvature computation techniques
  - o the hybrid convolution and generalized height function (CV-GHF) method
  - o approach using neural networks.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Patel, H. V. (2019). Direct numerical simulations of multiphase flow through porous media. Eindhoven: Technische Universiteit Eindhoven.
2. Patel, H. V., Panda, A., Kuipers, J. A. M., & Peters, E. A. J. F. (2019). Computing interface curvature from volume fractions: a machine learning approach. Computers and Fluids, 193, [104263].
3. Patel, H. V., Das, S., Kuipers, J. A. M., & Peters, E. A. J. F. (2019). Direct numerical simulations of water flooding process through digitized porous rocks. Chemical Engineering Science: X, 4, [100041].
4. Patel, H.V., Kuipers, J.A.M., Peters, E.A.J.F., Effect of flow and fluid properties on the mobility of multiphase flows through porous media, Chemical Engineering Science, 193 (2019) 243-254.

Streamlines of the flow (colored by local velocity magnitude) through a digitized rock sample of a) porosity 0.086 and b) porosity 0.24

PROJECT AIM

Trickle bed reactors are high potential candidates for the production of renewable CO_2 neutral fuels. Although trickle bed reactor have higher conversions due to a lower degree of back-mixing in comparison to slurry bubble column reactors, challenges arise in the scale-up and design of these systems. The main reason for these challenges is that the performance of these trickle bed reactors is closely related to phenomena that occur at particle scale. Understanding the hydrodynamics and heat and mass transfer in the particle packing is key. Hence, the aim of this project is to study and characterize the fluid flows in trickle bed reactors using Magnetic Resonance Imaging (MRI).

PROGRESS

To test the experimental method, MRI in combination with velocity encoding is applied to quantify flow in three parallel positioned tubes with known debit. A phase contrast gradient echo sequence using a bipolar gradient along the slice selection resulted into the figures depicted below, where on the left the axial magnitude image is shown and on the right the corresponding velocity measured from the phase. Furthermore, negative measured velocities indicates that the flow is going in opposite direction. The next step in this project is to extend this method to quantify flow in packed bed systems.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

J.A.M Kuipers

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Noah Romijn, M.W. Baltussen, K.A. Buist

COOPERATIONS

-

FUNDED BY

MCEC - Netherlands Center for Multiscale Catalytic Energy Conversion

FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2019

INFORMATION

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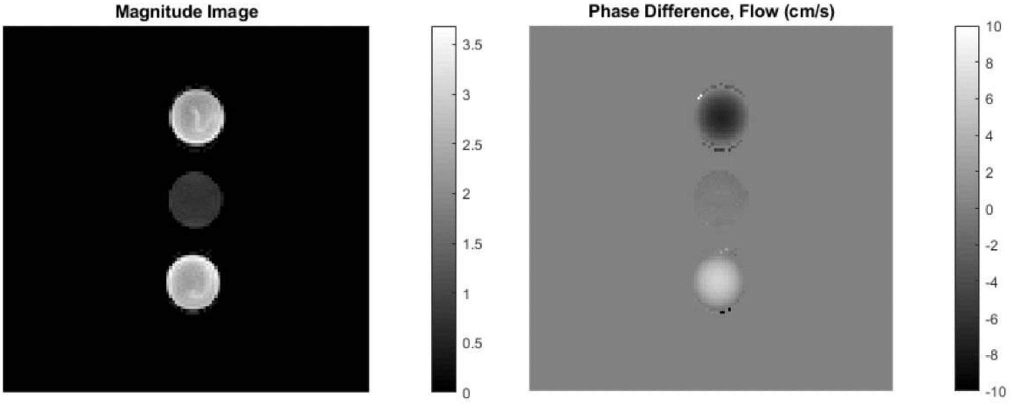

On the left an axial slice and on the right the axial velocity profile of three parallel tubes measured with MRI is shown.

PROJECT LEADERS
JAM Kuipers
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
D.R. Rieder, E.A.J.F. Peters
COOPERATIONS
BASF, Shell
FUNDED BY
Advanced Research Center – Chemical Building Blocks Consortium
FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019
INFORMATION
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PROJECT AIM

Modelling the preparation process of supported catalysts including diffusion, imbibition and adsorption. By using a multiscale approach (subsequently deriving models for different length scales) the wide range of relevant dimensions, spanning several orders of magnitude will be covered. The final goal is the derviation of a general model that allows the prediction of the distribution of active material in a supported catalyst. The results will be validated with a model Ni-Pd-Silica system.

PROGRESS

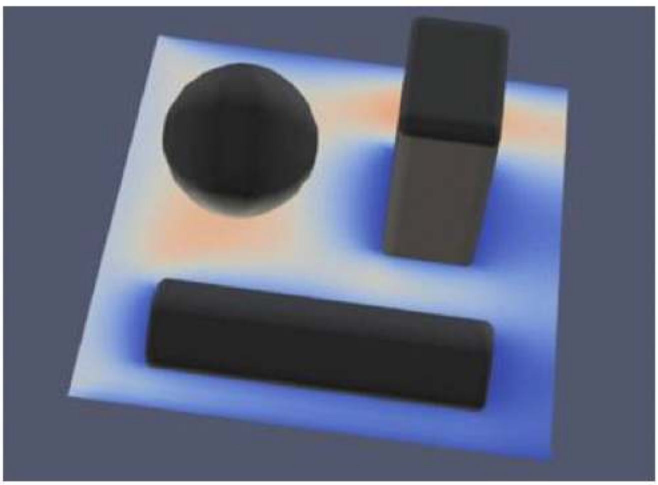
Starting from the 1st April 2019, the main focus lay on the assessment of the available literature concerning modelling of catalyst preparation by impregnation and incipient wetness. Next to the technical training in the CFD in-house code, an immersed boundary method (IBM) was implemented, which allows the description of analytically defined (as seen below) and arbitrary geometries on Cartesian grids. Additionally, a regular informal forum for the project-related researchers was instantiated.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



PROJECT AIM

Direct steam condensation is applied for the sterilization of infant milk to ensure a high level of food safety. The high temperature difference between the dairy based product and steam is often to such an extent that the product is damaged and process efficiency is lowered if the mixing and condensation does not occur in an efficient manner. The aim of this project is to develop a predictive model for the heat and mass transfer in order to optimize the design of the unit operation.

PROGRESS

Project was kicked off in June 2018. Currently the experimental facilities are being constructed.

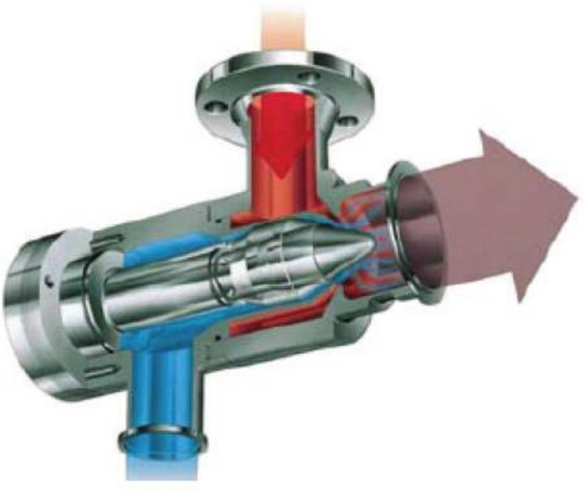
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Sketch of internal flows of a DSC unit



PROJECT LEADERS
J.A.M. Kuipers

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
S. Safavi Nic, J.A.M. Kuipers, K.A. Buist

COOPERATIONS
Danone Nutricia Research

FUNDED BY
Danone Nutricia Research

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2018

INFORMATION
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Direct numerical simulation of phase transition in dense bubbly flows

Project leaders
J.A.M. Kuipers
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
H. Mirsandi, E.A.J.F. Peters, M.W. Baltussen
Cooperations
Tata Steel
Funded by
FOM, Akzo Nobel, DSM, SABIC, Shell and Tata Steel
Funded %

University	-
FOM	50 %
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015
Information
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Project Aim

In many practical applications phase transition (evaporation and boiling) in dense bubbly flows occurs. This phenomenon is very complex because of the interplay between flow and coupled mass and heat transport. In this project we will develop and employ Direct Numerical Simulation (DNS) technique to study dense bubbly flows with phase transition. Initially, we will focus on phase transition in single component systems but multi-component systems will be studied as well. The DNS code will be extended with multi-component transport equations and thermal energy equations to study respectively mass transfer and heat transfer at the micro scale.

Progress

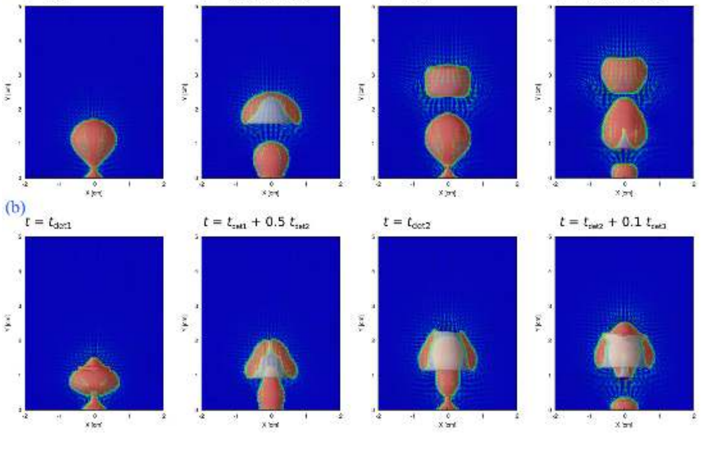
The bubble formation from a submerged orifice in a steel-argon system was studied using the Local Front Reconstruction Method. The bubble formation was compared to the bubble formation in air-water systems, as shown in figure 1. The simulations showed that the detached bubbles are generally smaller in the air-water system, but the differences become less significant at higher gas flow rates. Using the critical gas flow rate and the critical volume of the bubble, which is derived from the balance of the buoyancy and surface tension forces, the results of the bubble formation in both systems is comparable when the three-phase contact angle is the same.

Dissertations

-

Scientific Publications

1. Kong, G., Mirsandi, H., Buist, K.A., Peters, E.A.J.F., Baltussen, M.W., Kuipers, J.A.M., Hydrodynamic interaction of bubbles rising side-by-side in viscous liquids (2019) Experiments in Fluids, 60 (10), art. no. 155.
2. Kong, G., Mirsandi, H., Buist, K.A., Peters, E.A.J.F., Baltussen, M.W., Kuipers, J.A.M., Oscillation dynamics of a bubble rising in viscous liquid (2019) Experiments in Fluids, 60 (8), art. no. 130.
3. Mirsandi, H., Smit, W.J., Kong, G., Baltussen, M.W., Peters, E.A.J.F., Kuipers, J.A.M., Bubble formation from an orifice in liquid cross-flow (2019) Chemical Engineering Journal, in press.



Comparison of bubble formation in liquid steel (a) and water (b). The flow rate of the gas is 20 m3/s.

Experimental study on the atomization of complex fluids in spray dryers

Project Aim

The atomization process in a spray dryer largely influences final particle size distribution and efficiency of the process. It is highly dependent on upstream fluid dynamics inside the nozzle and downstream interactions between discrete and continuous phases. However, the effect of liquids with high solids content on both fluid dynamics inside the atomizer and the atomization processes outside the nozzle is not very well understood. In addition, the high solid content in the liquid might result in non-Newtonian behavior of the liquid. Therefore, the main goal of the project is to develop a fundamental understanding of the atomization of complex fluids, such as milk-like fluids in spray dryers, using an experimental approach.

Progress

During this period, the initial literature review was carried out and research plan was developed. The appropriate experimental and advanced fluid flow diagnostics techniques were identified to investigate inner nozzle fluid dynamics and spray characterization. Furthermore, appropriate system choices are being made in terms of operation and set-up design.

Dissertations

-

Scientific Publications

-

Project leaders

J.A.M. Kuipers

Research theme

Complex dynamics of fluids

Participants

V. V. Swami, K.A. Buist, M.W. Baltussen

Cooperations

ISPT

Funded by

TKI E&I, FrieslandCampina, Danone-Nutricia, DSM

Funded %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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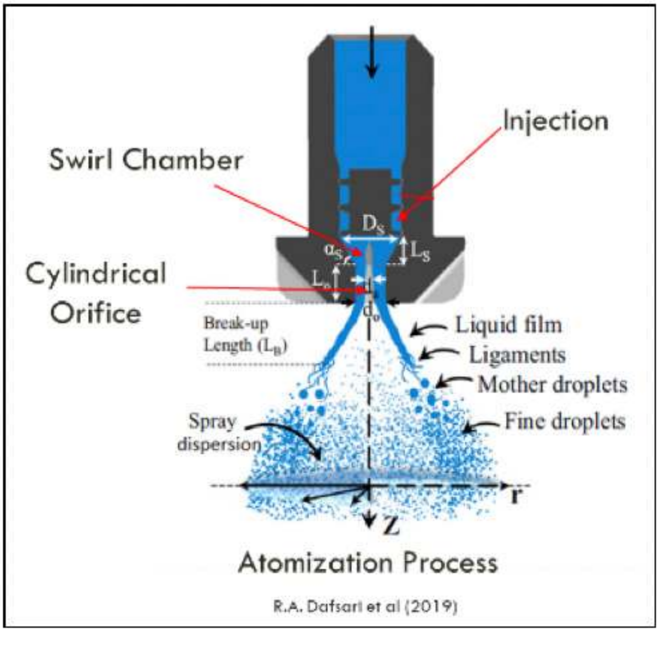

Simulation of large scale gas liquid solid flows with stochastic Euler-Lagrangian methods

Project leaders
J.A.M. Kuipers
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
S.S. Kamath, J.T. Padding, K.A. Buist, J.A.M. Kuipers
Cooperations
-
Funded by
NWO-CW
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015
Information
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Project Aim

To develop a model for large scale dense bubbly flows using stochastic Euler-Lagrangian methods. Deterministic methods such as the Discrete Bubble Model provide detailed enough information on the type of flow and also track the position of all bubbles at the same time. This becomes computationally quite expensive, especially in the dense bubbly flow regime which is the situation for most industrial slurry columns. On the other hand, multi-fluid models do not resolve bubble interactions which makes the model susceptible to large errors.

Progress

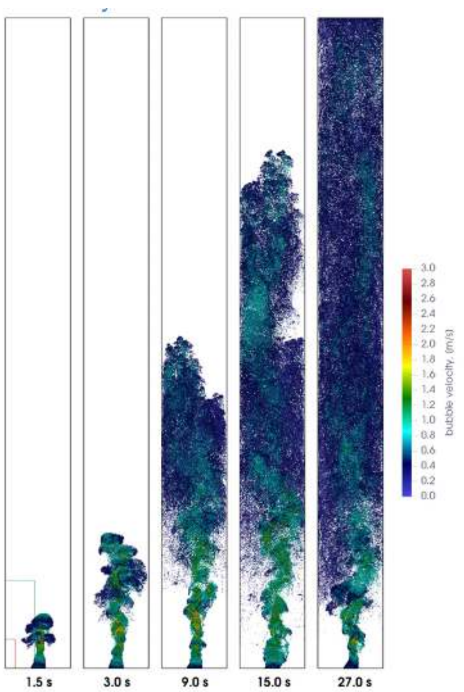
A stochastic DSMC model has been verified with a DBM model within a 3D periodic system and validated with the experimental data of a lab-scale bubble column (Deen 2001). The model has been parallelized in an MPI framework and also is coupled with an equivalently parallelized flow solver such that the code scales up to 6000 cores on SURFSara. Another application of this code has been tested at sea-locks where the large-scale bubble screens have been simulated to study the effectiveness of the screens numerically.

Dissertations

-

Scientific Publications

-



Snapshot of a 10 m long square bubble column with 1 m of side length and a non-uniform gas injection. This was simulated in SURFSara Cartesius with 768 cores in 5 days using the developed code

Flow structure formation and coupling with turbulence in large-scale slurry bubble column

Project Aim

Our aim is to obtain a better understanding of the hydrodynamics and heat- and mass-transfer limitations, and the role of turbulence in large scale slurry bubble columns using state-of-the-art computer simulations. We are concentrating on development of a high performance parallel code and new models and approaches to predict phase interactions and aim to achieve a detailed resolution of turbulent structures as well as prediction of the bubble dynamics by using Direct Simulation Monte Carlo (DSMC).

Progress

After careful validation of the developed high performance code for the laboratory scale bubble columns of Deen et al (2001), the simulation was extended to a bubble column of 1x1x10 m, as shown in figure 1. The results showed that the bubble behavior in the small scale column are different from these large scale columns. For example, the well-defined plume in the small scale columns is broken down in a more uniform distribution. The height of the breakage seems to be independent of the size of the column, but only happens after about 1.5 m.

Dissertations

1. M. Masterov, Towards industrial-scale bubble columns, the development and application of the high performance computing framework, December 2019.

Scientific Publications

-

Project leaders

J.A.M. Kuipers

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

M.V. Masterov, M.W. Baltussen

Cooperations

-

Funded by

Netherlands Center for Catalityc Energy Conversion (MCEC)

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

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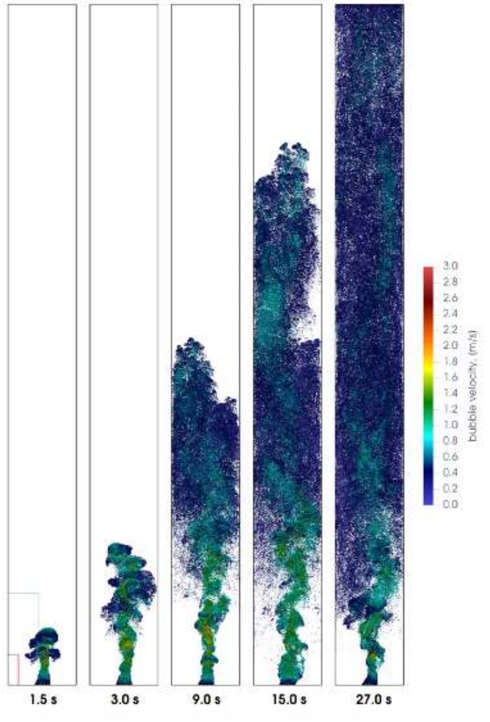

Snapshot of a 10 m long square bubble column with 1 m of side length and a non-uniform gas injection.

Direct numerical simulation of heat and mass transport in fixed bed reactors

Project leaders
J.A.M. Kuipers
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
V. Chandra, E.A.J.F. Peters
Cooperations
-
Funded by
Netherlands Center for Multiscale Catalytic Energy Conversion
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015
Information
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Project Aim

The Fischer-Tropsch process is a widely used catalytic energy conversion process to convert a variety of resources such as gas and coal to synthetic fuels. The catalytic reactions in this process are extremely fast, thus resulting in the transport of the reactants to the active catalytic sites often limiting the reaction rate. As the Fischer-Tropsch synthesis (FTS) is a highly exothermic process, the management of heat is a crucial aspect in its design. In this project we will be studying FTS in a slender packed bed reactor using Direct Numerical Simulation techniques. A finite-volume based Immersed Boundary Method will be used to fully resolve the transport phenomena at the pore-scale level.

Progress

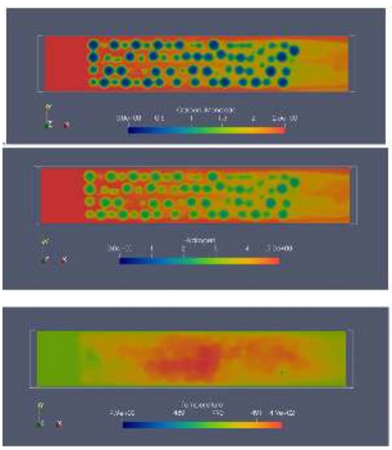
A numerical model based on the fundamental continuum transport equations is developed to simulate the Fischer-Tropsch synthesis in a slender packed column. Internal and external mass transport limitations are considered in a fully resolved manner where a two-way coupling between mass and heat transport is accounted for. A Langmuir-Hinshelwood type kinetic model is used for the reaction rate in the catalyst phase which is then intrinsically coupled to the fluid phase transport by enforcing the appropriate boundary condition using the Immersed Boundary Method. The fixed bed reactor consists of 220 particles packed in a random manner using the Discrete Element Method where cooling from the wall to the bed is also considered. The influence of temperature on conversion and selectivity is investigated. The figure below depicts the distribution of syngas and temperature along the mid-plane of the reactor.

Dissertations

-

Scientific Publications

1. Direct numerical simulation of hydrodynamic dispersion in open-cell solid foams. Chandra, V., Das, S., Peters, E. A. J. F., & Kuipers, J. A. M., Chemical Engineering Journal, 358 (2019) 1305.
2. Direct numerical simulation of a non-isothermal non-adiabatic packed bed reactor, V. Chandra, E.A.J.F. Peters, J.A.M. Kuipers, Chemical Engineering Journal, 385 (2020) 123641.



Project Aim

In most chemical processes flow systems are multiphase flows and not transparent. A very common flow type in chemical industry is fluid flowing through a bed of solid particles where the particles are catalytically active. The reactor performance is related to the flow field of the fluid within it. We use MRI to visualize the flow, which cannot be seen with traditional optical (camera) techniques, and obtain quantitative data in cases where processes taking place in the interior remain obscure, which is often a major limitation.

Progress

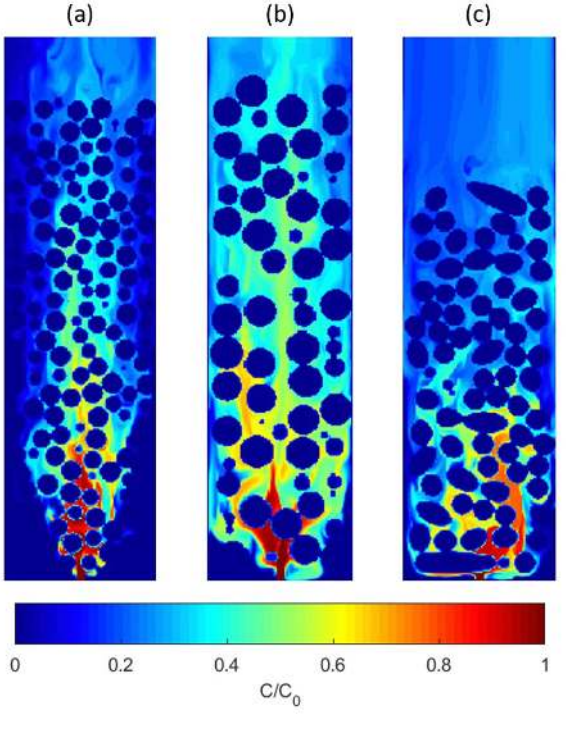
Dispersion of an inert tracer in packed beds, made of random arrangements of mono-disperse spheres and spherocylinders, at moderate values of column-to-particle diameter ratios, was studied through MRI experiments and numerical simulations with a CFD approach based on the IBM-DNS method. Irregular particle arrangements in a cylindrical container were generated using available open-source DEM codes. The research activity was focused on mass transfer phenomena and the analysis of longitudinal and transverse dispersion. Fig. 1 is a concentration field for the cross-section of the packed bed along the length of the column.

Dissertations

-

Scientific Publications

-



Tracer concentration maps for the three packed beds at Rep=50: (a) spheres with d = 3 mm, (b) spheres with d= 5 mm, (c) spherocylinders with d = 3 mm, h = 9 mm..

Project leaders
J.A.M. Kuipers

Research theme
Complex dynamics of fluids

Participants
P. Lovreglio, K.A. Buist, E.A.J.F. Peters, L. Pel

Cooperations
-

Funded by
MCEC

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2014

Information
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Modeling of dynamic solid particle bed and liquid behavior – applied to the blast furnace hearth

Project leaders
J.A.M. Kuipers
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
T.M.J. Nijssen, K.A. Buist, J.A.M. Kuipers
Cooperations
-
Funded by
M2i, STW
Funded %

University	-
FOM	-
STW	50 %
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
Information
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Project Aim

The bottom section of the blast furnace consists of a system of liquid iron and a packed bed of coke particles. The continuous addition of liquid iron and periodic tapping of the iron induces a cyclic movement of the solid bed, periodically packing and moving the coke particles. The state of this bed and the flows through it largely determine the erosion and lifetime of the refractory bricks in this section, however, the dynamics and interactions in this system are ill-understood. Therefore, a CFD-DEM model is used to study the effects of cyclic movement, particle size distribution and shape as well as particle dissolution rate on the dynamic solid particle bed and liquid behavior.

Progress

Extensive work was done on the development of a Basset force implementation for unresolved CFD-DEM. This new implementation allows for the consideration of the Basset force without the computationally heavy evaluation of the integral over the entire history of each particle. Furthermore, work was done on extending an the existing VOF/CFD-DEM solver towards heat- and mass transfer. Lastly, a model blast furnace was developed and constructed. In this furnace, Magnetic Particle Tracking (MPT) experiments are conducted, investigating the solids movement in the blast furnace hearth.

Dissertations

-

Scientific Publications

-

Model blast furnace hearth used for Magnetic Particle Tracking experiments

PROJECT AIM

This project aims to develop a Multiphase Computational Fluid Dynamics (MCFD) model to study the deoxygenation of Bio-oils. The challenge of the project lies in the combined complexities of the hydrodynamic interactions between the three different phases; gas, liquid and solid, including turbulence, and the additional chemical conversion. The complex composition of the bio-oils add to the difficulty of both the chemical conversion and the hydrodynamic behaviour of the droplet phase.

PROGRESS

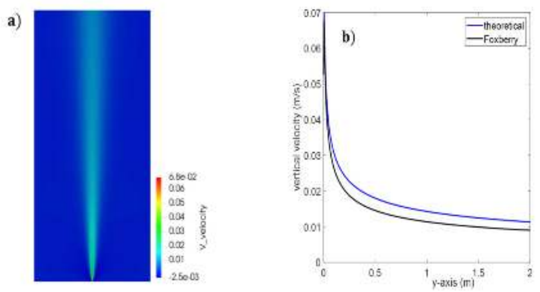
To build he complex model described above, the first step is to simulate the hydrodynamic interaction between the gas phase and the solid particles, using for that purpose the in-house numerical code. A number of test cases have been developed in order to master the capabilities of the code including single phase (free jet presented in Figure 1) and multiphase simulations (Bubble column presented in Figure 2).

DISSERTATIONS

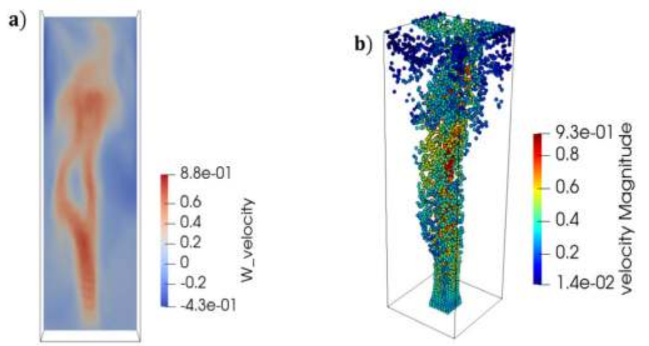
-

SCIENTIFIC PUBLICATIONS

-



Vertical free jet simulation. a) velocity contourn, b) vertical velocity along the jet axis.



Typical outputs of the bubble column simulation. a) contour of axial velocity, b) snapshot of the bubble flume, particle are colored according to their velocity

PROJECT LEADERS
J.A.M. Kuipers

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
K.A. Buist, M.W. Baltussen, J.G. Ramirez

COOPERATIONS
-

FUNDED BY
NWO

FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019

INFORMATION
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PROJECT LEADERS
J.A.M. Kuipers, Robert Terörde
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Jiangtao Lu, E.A.J.F. Peters, Fred Borninkhof
COOPERATIONS
BASF
FUNDED BY
Advanced Research Center Chemical Building Blocks Consortium
FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019
INFORMATION
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PROJECT AIM

Catalysts used in industry often contain cobalt, nickel or copper where the final step in the manufacturing process of the catalyst involves the reduction of the metal oxides with hydrogen. The resulting catalysts are widely used in the chemical industry for the production of base chemicals and energy carriers. The reduction process is highly complex due to the interplay among the reactor-scale transport, the particle-scale transport and the particle-scale reaction. In this project, a multi-scale reactor model will be developed and experimentally validated using pilot plant as well as real plant data. The established model will be used to assess the optimal reaction conditions for the reduction of metal oxides with hydrogen in fixed bed reactors.

PROGRESS

A phenomenological model for reactor scale transport is coupled a one-dimensional particle model, with the former one describing the fluid information and the latter one describing the detailed profile inside particles. In other words, at each grid point of the reactor model the particle model is solved. The fluid and solid phases are coupled through the film theory, which describes the interfacial transfer. The complexity of this coupled model is that, the fluid information is required as the boundary condition for solving the particle model while the solid information is at the same time required as the source term for solving the reactor model. The coupled model is verified by comparing with the reactor model assuming the isothermal condition.

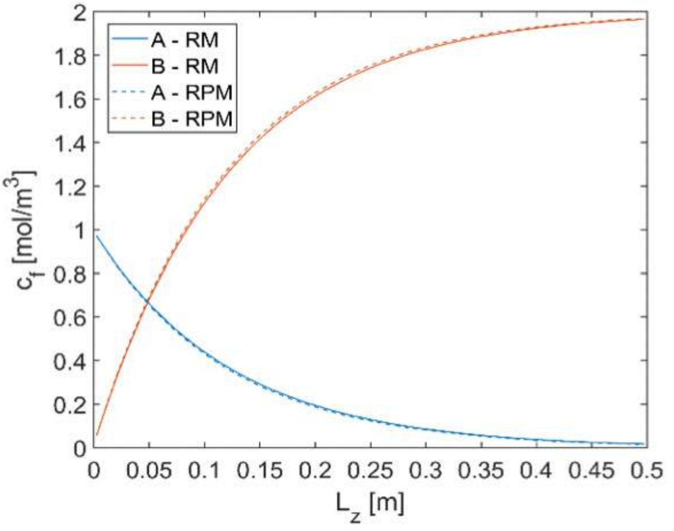
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Concentration of species A and B reacting A→2B along the column for a reactor model with (RPM) and without a particle model.



Energy Efficient Milky Sprays (EEMS): Numerical study of the effect of solids content and main components of model liquids on atomization efficiency of the nozzle

Project Aim

The spray drying efficiency is highly dependent on the atomization process, since it affects directly the droplet size distribution. In order to get more insights on the process a rheological analysis of the fluid dynamics inside a high pressure nozzle and its subsequent break-up (i.e. primary atomization) is required. To facilitate this, Direct Numerical Simulation (DNS) of the sheet break-up is performed inside and outside the nozzle. The output of these simulations will be experimentally validated, within a parallel project, with the aid of different measuring techniques such as Phase Doppler Anemometry (PDA) or Structured Laser Illumination Planar Imaging (SLIPI).

Progress

Project is divided in two parts: First, high fidelity simulations are performed inside the nozzle in order to capture the interaction of the air core with the liquid sheets as well as its implications on the stability of the liquid sheet. Second, the simulation domain will be extended to the near region out of the nozzle in order to capture the rupture of the liquid sheet. After a thorough literature study, the Local Front Reconstruction Method (LFRM) has been chosen to track the interface and it is currently under development.

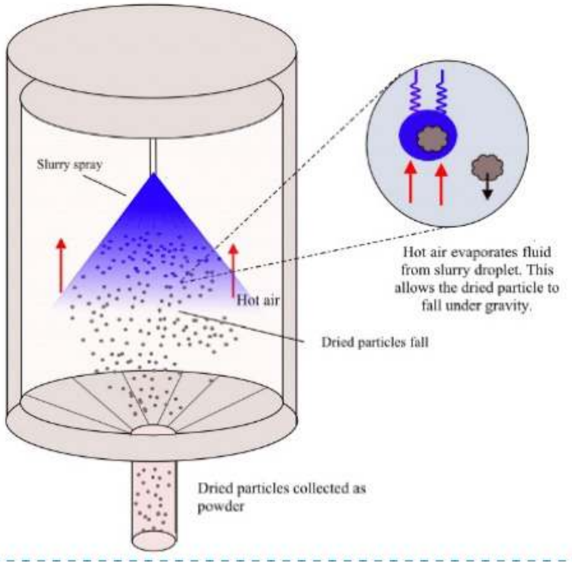
Dissertations

-

Scientific Publications

-

Schematic representation of the drying process: On the upper part of the chamber the atomization of the liquid (spray) occurs, giving rise to small droplets. Further down, hot air is injected and powder is produced by removing moisture from the droplets



Project leaders

J.A.M. Kuipers

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

C. Garcia Llamas, M.W. Baltussen, K.A. Buist

Cooperations

TKI, FrieslandCampina, Danone, DSM, ISPT

Funded by

TKI

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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PROJECT LEADERS
J.A.M. Kuipers

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
M.W. Baltussen, K.A. Buist, A. Tavanaei

COOPERATIONS
-

FUNDED BY
Netherlands Center for Multiscale Catalytic Energy Conversion (MCEC

FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019

INFORMATION
M.W. Baltussen
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M.W.Baltussen@tue.nl

PROJECT AIM
The aim of the project is to study the hydrodynamics, heat and mass transfer for the Fischer-Tropsch (FT) process with biomass feedstock in a Trickle Bed Reactor (TBR). Currently, Bubble Slurry Columns are being used to perform the FT process. The TBR has lower back mixing and hence higher conversion but the technology is not well developed mostly because of the complex particle-scale phenomena inside the reactor. The Liquid-Gas interactions will be simulated by using the Volume of Fluid technique while the Immersed Boundary Method will be used to simulate Fluid-Solid Interactions. All the simulations will be validated by MRI measurements in a parallel research project.

PROGRESS
The most important scientific progress is the testing of the Volume of Fluid code. In total, 50 unit tests have been developed to check the performance of the code. Besides the current check of the method, the tests will be used to perform continuous integration of the code. In the Volume of Fluid code, there are inaccuracies of the simulations with respect to the calculation of the surface tension. In the current implementation, strong deformations in the gas-liquid surface will not be captured correctly. Therefore, we started implementing the balanced force method of (Patel, et al., 2018) 1. Afterwards, the calculation of the surface tension can be further improved by implementing an improved curvature calculation, using e.g. the height function or combined method.

[1] Patel, H., Kuipers, J. & Peters, E., 2018. Computing interface curvature from volume fractions: a hybrid approach. Computers and Fluids, Issue 161, pp. 74-88.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-

PROJECT AIM

Gas-liquid two-phase porous media flows are common in industrial processes as well as nature. An important industrial example is the trickle-bed, which is a column packed with catalytically active particles with the co-current downflow of gas and liquid. This project will focus on the hydrodynamics of the gas and liquid flow in such trickle-beds. Hydrodynamic parameters of trickle bed reactors are controlled by the internal bed structure and associated interactions with the gas and liquid flow. The main goal of this project is to relate the gas-liquid flow to the packing characteristics such as particle shape, size, and polydispersity of particle sizes.

PROGRESS

In this project a multiphase CFD approach will be used to study gas-liquid flow in a tube filled with (non-spherical) particles. The initial stages consist of extending the in-house massively parallel multiphase flow solver for this task. The cylindrical tube as well as the non-spherical particles where implemented by means of a ghost cell immersed boundary method. The first steps of the project, which consist of verification and validating tests for the single-phase flow inside the pipe without and with particles, are in progress.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS
J.A.M. Kuipers

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
M.W. Baltussen, E.A.J.F. Peters, A. Eghbalmanesh

COOPERATIONS
-

FUNDED BY
NWO

FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019

INFORMATION
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Chemical process intensification

Prof.dr.ir. M van Sint Annaland

Chemical Process Intensification /Multiphase Reactors Group / Dept. of Chemical Engineering & Chemistry / TUE

The research group Chemical Process Intensification (SPI) is part of the faculty of Chemical Engineering and Chemistry at the Eindhoven University of Technology. The main objective of the research group is the development of novel integrated reactor concepts based on improved fundamental knowledge using validated advanced (multi-phase) reactor models. This is achieved by employing a combination of state-of-the-art numerical models (at different levels of detail using the multi-level modeling approach), advanced (non-invasive) experimental techniques and experimental demonstration of novel reactor concepts (proof of concept).

A key competence of the group is the development and use of use of advanced (multi-phase) reactor models, coupled to mass and heat transfer and chemical reactions, in order to study integrated reactor concepts. Our modelling work ranges from 'as detailed as necessary' to 'as large-scale as possible'; we employ models for redox kinetics on a single particle scale and detailed simulations of gas-liquid flows, discrete bubble/particle models, up to industrial-scale phenomenological models and process systems modelling. We use both in-house created models and open-source based models. A cornerstone of our research is careful (experimental) validation and verification.

Another aspect is the development of advanced, non-intrusive, experimental techniques to measure key quantities (i.e. local volume fractions and velocities of the dispersed and continuous phase). We have developed a PIV-DIA technique (particle image velocimetry coupled to digital image analysis) that measures accurately, in a non-intrusive manner, the solids fluxes in (dense) gas-solid fluidized beds. Moreover, we established an infra-red technique for whole-field concentration measurements in gas-solid fluidized beds, and we have demonstrated and built a facility that can measure gas and solids fluxes under reactive conditions (i.e. elevated temperatures up to 400 °C) using endoscopic PIV. The group also owns state of the art equipment for catalyst characterization, membrane characterization and reactor characterization. The equipment list includes – but is not limited to – magnetic suspension balance, two TGA's, DSC, XRD, SEM, AES, viscometers, different membrane permeation setups, kinetic setups, etc.

Our experimental and modelling expertises form a strong alliance in the development of novel intensified reactor concepts. As an example we mention here the development of a fluidized bed membrane reactor concept for the production of ultra-pure hydrogen with integrated CO2 capture via chemical looping. This involves dedicated studies into various oxygen carriers used for chemical looping by experiments (e.g. thermogravimetric analysis) in conjunction with detailed particle models to describe the redox kinetics, fundamental studies into reactor design and operation of fluidized bed membrane reactors using multiphase flow models (accounting for mass transport and perm-selective membranes), and process systems modelling on industrial scale. The knowledge and tools developed in our group provide a sound basis to place this research activity on a firm footing.

Project Aim

The main objective of this project is to set up a numerical simulative method for the analysis of the behavior of a fluidized bed with the presence of liquid. Even if this kind of system is widely used (i.e. bulk polyolefin production), there are several uncertainties on design optimization and safety management. For this purpose, will be developed simulative models of decreasing complexity and increasing scale, from a low scale Euler-Lagrange-Lagrange simulation to a whole scale FB reactor using an Euler-Lagrange approach.

Progress

We set up a phenomenological model for the fluidized bed polymerization in presence of a liquid (evaporating) cooling agent, solving mass and energy balances on a model bubbling bed. In addition a DPM model has been adapted to include particle-gas heat and mass transfer. The liquid phase will be taken into account solving transport equation for the droplets, with enclosures taken from a bed permeability model.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir M. van Sint Annaland
Dr.ir. Ivo Roghair

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Dario M. Balice

Cooperations

-

Funded by

DPI

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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PROJECT LEADERS
Prof.dr.ir. M. Van Sint Annaland
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Eindhoven University of Technology
Utrecht University
COOPERATIONS
-
FUNDED BY
Shell
FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017
INFORMATION
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PROJECT AIM

Dense Energy Carriers are chemicals produced from carbon dioxide and water using solar energy in biological, photochemical, thermochemical or electrochemical processes. In addition to being carbon-neutral, they also represent a solution for easily storing solar energy. Recently, different Dense Energy Carriers production routes have been proposed, but their sustainability and economic potential aren't always clear. This project aims at finding the most promising processes for Dense Energy Carriers synthesis from an economic, environmental and societal point of view.

PROGRESS

In a future in which fossil fuels will not be available anymore, air could be a renewable source of carbon dioxide. For this reason, great consideration has been given to Direct Air Capture (DAC), a process aimed at capturing CO2 from ambient air. The main DAC processes described in literature have been studied and modelled, with the aim of assessing and optimizing their performances. Moreover, a novel process has been proposed and evaluated. The results obtained have shown that adsorption-based approaches to DAC are the most promising.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Agglomeration of Geldart A particles

PROJECT AIM

The main objective of this project is to provide further insight into the interplay between the various mechanisms in bubbly flows involving mass and heat transport or phase transitions at larger scales. To achieve this goal, we will use the Euler-Lagrange (E-L) and Euler-Euler (E-E) approach to study large scale systems, employing the closure information developed in other projects. Experimental validation using results from other projects for mass and heat transfer. Delivery of scaling laws for dense bubbly flows involving mass & heat transport and phase transitions.

PROGRESS

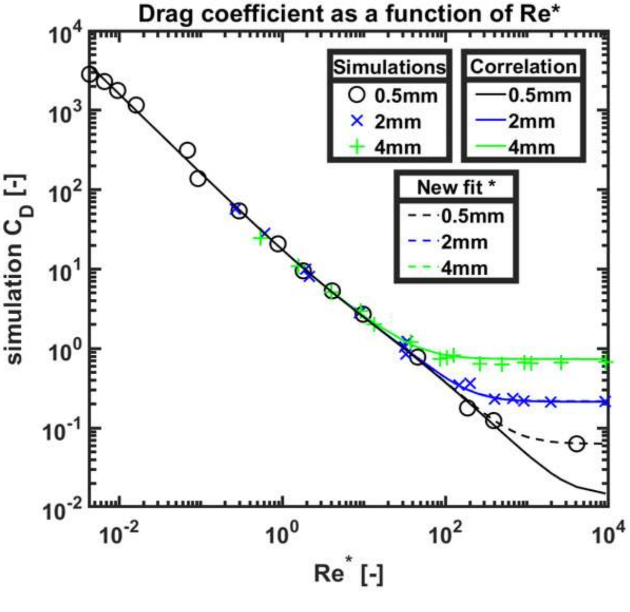
A bubble nucleation setup has been completed and debugged. The DIA has also being adapted to perform the analysis of the experiments. First experiments showed qualitatively agreement with the numerical simulations: the bubble size distribution shows the growth on the substrate shifting towards bigger bubbles. In addition, simulations of single bubbles rising in non-Newtonian fluids showed it is possible predict the drag coefficient using an adapted correlation for Newtonian fluids, unless going to extreme cases. To conclude, the scale-up towards larger scale simulations has been started with preliminary calculations.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



PROJECT LEADERS

Prof.dr.ir J.A.M. Kuipers
Prof.dr.ir M. van Sint Annaland

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Ir. Alessandro Battistella
Dr.ir. Ivo Roghair
Prof.dr.ir M. van Sint Annaland

COOPERATIONS

Delft University of Technology
University of Twente

FUNDED BY

FOM (IPP), AzkoNobel, DSM,Sabic, Shell, Tata Steell

FUNDED %

University	-
FOM	50 %
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2015

INFORMATION

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Interfaces with mass transfer

Prof.dr.CWM van de Geld

The group ‘Interfaces with Mass Transfer’ studies gas-liquid interfaces through which mass transfer is taking place. In recent years the research is carried out at the Department of Chemical Engineering and Chemistry, but early work was performed at the Department of Mechanical Engineering, with which strong ties still exist. In the past decades, single boiling bubble detachment and dropwise condensation were focal points of the group, but a variety of related topics such as steam injection, quench cooling of hot plates and endovenous laser ablation have been studied as well. Particle migration in turbulent pipe flow came up as a logical extension of the study of bubble migration in turbulent channel flow.

The approach has always been the design of dedicated experiments accompanied with theoretical analysis based on solutions of well-argued simplifications, supported by more complex numerical simulations where needed. Results encompass empirical correlations and insight in, for example, the importance of added mass forces in bubble detachment.

PROJECT AIM

The aim of the project is to improve our fundamental understanding of coupled heat mass & transfer phenomena in droplets and bubbles and to provide experimental validation material for numerical models. In our first experiment, the growth rate of a vapor bubble in a microchannel is studied using high speed imaging. In the second experiment, the evaporation of a droplet from a plate under a convective gas flow is studied, both optically and by thermal imaging.

PROGRESS

Measurements of vapor bubble size histories were performed for three different fluids under various tube wall temperatures. The measured data was compared with a 1-D model, in which heat transfer between the bubble and the tube wall is presumed to take place by conduction through the liquid film in between the bubble and the wall. Under some conditions agreement with the model could be established while for other cases large disagreements were found, which are believed to be caused by temporal and spatial variations in the liquid film thickness. The interface temperature of an evaporating droplet from a plate was measured by thermographic imaging. The effect of an approaching gas flow parallel to the plate surface on the droplet interface temperature was studied. The approaching gas flow leads to a radially a-symmetric interface temperature profile, which is believed to be driven by radially a-symmetric Marangoni flows inside the drop (see Fig. 1).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

C.W.M. van der Geld

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

L. Boer, E.J. Gelissen, A.H. Rajkotwala, M. Del Hoyo, E.A.J.F. Peters, M.W. Baltussen, C.W.M. van der Geld, J.G.M. Kuerten, J.A.M. Kuipers. S. Srinivasagam

COOPERATIONS

TNO, Bronkhorst, ASM, PMI, Océ, TetraPak, Shell, AkzoNobel

FUNDED BY

TTW and participants

FUNDED %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2016

INFORMATION

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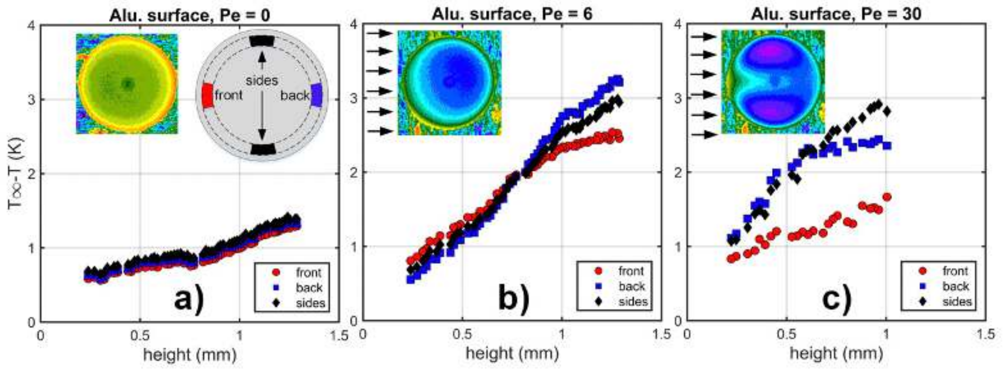
Droplet interface temperature (relative to that of the approaching gas flow) versus droplet height. For several values of Péclet, which is the non-dimensional gas velocity. The snapshots show thermographic images of the droplets.



Centre for analysis, scientific computing and applications (CASA)

Prof.dr.ir. B Koren

Prof.dr. MA Peletier

Prof.dr. JJM Slot

TU/e's Centre for Analysis, Scientific Computing and Applications (CASA) embodies the chairs Applied Analysis and Scientific Computing, which both participate in the J.M. Burgerscentrum.

CASA's research objective is to develop new and improve existing mathematical methods - both analytical and numerical - for a wide range of applications in science and engineering. Extensive collaborations exist with researchers in other disciplines, at universities, large technological institutes as well as industries, both nationally and internationally. Current CASA research related to fluid dynamics concerns aerodynamics, aeroacoustics, magnetohydrodynamics, fluid-structure interactions, porous media flows, viscous and viscoelastic flows, free-surface flows, particle flows and shape optimization.

HYdraulic MOdelling for DRilling Automation (HYMODRA)

Project Aim

The scientific objective of HYDRA is to develop a framework for multi-phase hydraulic modeling and model complexity reduction for drilling operations, delivered in software directly usable in industry. The resulting models uniquely combine high predictive capacity and low complexity enabling their usage in both virtual drilling scenario testing and drilling automation.

Progress

Application of the Reduced Basis method on the Drift Flux Model (DFM), to simulate multi-phase flows, leads to an unstable system. To circumvent this issue, a port-Hamiltonian (pH) formulation of the DFM has been introduced. This pH system will be discretized and reduced by structure-preserving reduction techniques in the future. In addition, a data-based approach has been investigated to reduce the system without the need of the underlying physical model. In addition, validation of the simulation results has been conducted by comparison against field data and a new reservoir model has been introduced.

Dissertations

-

Scientific Publications

1. M.H. Abbasi, L. Iapichino, B. Besselink, W. Schilders, N. van de Wouw, “Error estimation in reduced basis method for systems with time-varying and nonlinear boundary conditions”, Computer Methods in Applied Mechanics and Engineering, in press, 2019.
2. M.H. Abbasi, S. Naderi Lordejani, N. Velmurugan, C. Berg, L. Iapichino, W. Schilders, N. van de Wouw, “A Godunov-type Scheme for the Drift Flux Model with Variable Cross Section”, Journal of Petroleum Science and Engineering (2019) 179: 796-813, DOI: 10.1016/j.petrol.2019.04.089.

Project leaders

Nathan van de Wouw, WHA Schilders

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Mohammad Hossein Abbasi

Cooperations

Laura Iapichino (Netherlands)
Glenn-Ole Kassa (Norway)
Florent Di Meglio (France)
Bart Besselink (Netherlands)
Sajad Naderi Lordejani (Netherlands)
Naveen Velmurugan (France)

Funded by

EU

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2016

Information

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PROJECT LEADERS
Prof. Barry Koren, Arris Tijsseling

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Prof. Jan ten Thije Boonkkamp,
Dr. Hanz Martin Cheng

COOPERATIONS
A/Prof. Jerome Droniou (Monash University), Dr. Kim Ngan Le (Monash University)

FUNDED BY
TU/e

FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019

INFORMATION
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PROJECT AIM
I am currently exploring in parallel two of the commonly used approaches for advection-diffusion problems: Eulerian methods and characteristic-based methods. The aim of the project is to develop robust numerical schemes for linear advection-dominated equations, applicable on generic polytopal meshes. Following this, we will look at extending these numerical schemes onto problems encountered in practical applications, such as sediment or tracer transport, miscible flow models for porous media, or the Navier-Stokes equations for computational fluid dynamics.

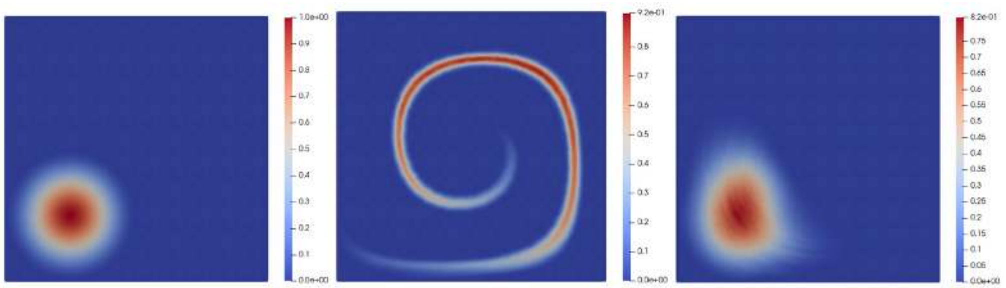
PROGRESS
1) I have proposed a generalisation of the complete flux scheme (developed originally by the group of A/Prof. Jan ten Thije Boonkkamp), which enables it to handle anisotropic diffusion tensors.

2) As an extension of my PhD thesis, I have recently developed, together with Prof. Jerome Droniou, the ball-approximated characteristics (B-char). This is a novel and efficient way of implementing characteristic-based schemes with piecewise constant approximations. This method conserves mass, and is thus suitable for applications in engineering.

DISSERTATIONS
1. Design and analysis of numerical schemes with characteristic methods on generic grids for flows in porous media. Monash University, 2019. https://monash.figshare.com/articles/Design_and_Analysis_of_Numerical_Schemes_with_Characteristic_Methods_on_Generic_Grids_for_Flows_in_Porous_Media/9630767.

SCIENTIFIC PUBLICATIONS
1. H. M. Cheng and J. Droniou. An efficient implementation of mass conserving characteristic-based schemes in 2D and 3D. SIAM Journal on Scientific Computing. In press.
2. H. M. Cheng, J. Droniou, and K.-N. Le. A combined GDM—ELLAM—MMOC scheme for advection dominated PDEs. Submitted.

Numerical solutions obtained from B-char for the deformational flow test (Left: Initial condition; Middle: half-time; Right: Final time). This test is typically used to check the robustness of numerical schemes for tracer transport. The accuracy of the B-char method is comparable to other numerical schemes, but is obtained at a much lower computational cost.



SLING, project 1: Liquid impact simulations including phase transition

Project Aim

LNG is emerging as a transition fuel for the transport industry, to bridge the gap between inefficient fossil fuels and future sources of energy. Part of the infrastructure for LNG as fuel is transport by ship in isolated tanks at -160°C. A problem that occurs here is damage to the tank due to sloshing. The goal of this project is to gain insight in the flow phenomena that impact the sloshing loads, specifically the multi-fluid composition, properties of the fluids and phase transition. This is to be achieved through numerical simulation using a newly developed method.

Progress

The physical and numerical model has been extended with phase transition, which has been studied for simple test cases.

Dissertations

-

Scientific Publications

1. R. de Böck, A.S. Tijsseling, and B. Koren . A monotonicity-preserving higher-order accurate finite-volume method for Kapila's two-fluid flow model, Computers and Fluids (193), 2019.

Project leaders

Prof. dr. ir. B. Koren (TU/e)

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

dr. ir. A.S. Tijsseling

Cooperations

TUD, UT, RUG, CWI.

Users: Accede, Anthony Veder, Bureau Veritas, CCS, ClassNK, CSSRC, Damen, DEMCON, Femto, GTT, Marin, Shell, Total

Funded by

STW

Funded %

University	-
FOM	-
STW	37 %
NWO Other	-
Industry	63 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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EUROS Work Package 1.3: Uncertainty quantification in wind and waves

Project leaders
prof.dr. D.T. Crommelin (CWI,UvA)
prof.dr.ir. B. Koren

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
ir. A.W. Eggels (PhD student)

Cooperations
Research cooperation with: CWI, TU Delft and WUR. Users: Ballast-Nedam, Deltares, DNV-GL, ECN, ENECO, Fugro, Heerema, IHC, KNMI, Van Oord, Sytems Navigator

Funded by
NWO-TTW (STW)

Funded %

University	-
FOM	-
STW	58 %
NWO Other	-
Industry	42 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

Information
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Project Aim

The goal of the project is to develop a fully stochastic approach to include correlation of wind and waves in calculating the loads on wind turbines, by making use of the probability distribution in wind loads and existing wind-wave models. The challenge is to develop a complete and efficient framework to treat different sources of uncertainty in one single computational space. This framework contains methods for uncertainty propagation, as well as dependency and sensitivity analysis.

Progress

The project has been finished.

Dissertations

1. A.W. Eggels, Uncertainty quantification with dependent input data - including applications to offshore wind farms.

Scientific Publications

1. Eggels, A.; Crommelin, D. Quantifying Data Dependencies with Rényi Mutual Information and Minimum Spanning Trees. Entropy 2019, 21, 100.

HYDRAULICS MODELING FOR DRILLING AUTOMATION (HYDRA)

PROJECT AIM

The aim of the project is to develop a framework for multi-phase hydraulic modelling and model complexity reduction for Managed Pressure Drilling (MPD) operations to explore oil, gas, minerals and geo-thermal energy. Considering the safety critical aspect of MPD, the primary focus is to enable an accurate and precise control of the down-hole pressure while predicting various transient operational scenarios. The objective of this work is to develop models that uniquely combine high predictive capacity and low complexity, and thus enable their usage in virtual drilling scenario testing and in drilling automation strategies for real-time down-hole pressure management.

PROGRESS

We proposed a new model order reduction approach to obtain effective dimensionality reduction for transport-dominated problems with multiple moving and possible merging discontinuous features. We developed power preserving compositional modelling for the Managed Pressure Drilling set-up. We developed port-Hamiltonian (pH) representations with respect to a Stokes-Dirac structure for single- and two-phase flow models with spatially varying cross-section. We employed mixed-finite-element method to develop a structure-preserving spatial discretization of the infinite-dimensional pH representation of two commonly used two-phase flow models: the Two-Fluid Model and the Drift Flux Model.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. H. Bansal, S. Rave, L. Iapichino, W. Schilders and N. van de Wouw, Model order reduction framework for problems with moving discontinuities, submitted to European Numerical Mathematics and Advanced Applications Conference 2019 Proceedings (ENUMATH 2019).

PROJECT LEADERS

Wil Schilders, Nathan van de Wouw, Laura Iapichino

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Harshit Bansal

COOPERATIONS

Barry Koren (The Netherlands)
Hans Zwart (The Netherlands)
Stephan Rave (Germany)
Philipp Schulze (Germany)
Mohammad Abbasi (The Netherlands)
Kelda Drilling Controls (Norway)

FUNDED BY

Shell NWO-FOM PhD Scholarship

FUNDED %

University	-
FOM	50 %
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2016

INFORMATION

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PoroFlow: Non-equilibrium models for flow in heterogeneous porous media

Project leaders
Prof. Dr. Iuliu Sorin Pop (Hasselt)
Prof. Dr.Ir. Barry Koren (TU/e)

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Koondanibha Mitra (TU/e)
Prof. Dr. Iuliu Sorin Pop (Hasselt)
Prof. Dr.Ir.. Barry Koren (TU/e)
Prof. Dr. C.J. van Duijn (TU/e, Utrecht)

Cooperations
Dr. Xiulei Cao (TU/e)
Prof. Dr. F.A. Radu (Bergen)
Prof. Dr. Ing. R. Helmig (Stuttgart)
Dr. T. Köppl (Munich)
Prof. Dr. C. Rohde (Stuttgart)
Prof. B. Schweizer (Dortmund)

Funded by
Shell/FOM/NWO

Funded %

University	-
FOM	100 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

Information
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Project Aim

This project addresses issues related to the mathematical modelling, numerical simulation and upscaling of flow in the porous media. The main focus is on heterogeneous and fractured systems and on non-equilibrium models where dynamic or hysteresis effects are included in the difference between the two phase pressures, and/or in the relative permeabilities.

Progress

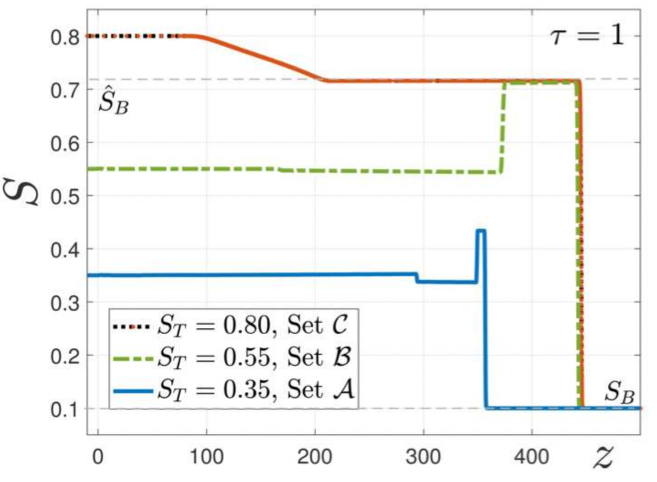
We completed the work on equilibrium models by considering the most general case of two-phase flow with hysteresis in both capillary pressure and relative permeability, and dynamic capillary effect included. By conducting travelling wave analysis, entropy solutions were derived for the system. Existence of solutions with stable and growing plateaus were shown. Numerically obtained travelling wave solutions are given in Figure 1. They match precisely with the predictions. They also explain why in infiltration experiments, stable saturation plateaus are observed. The travelling wave analysis was also used to explain the propagation speed of fingers in the gravity fingering phenomenon.

Dissertations

1. Mitra, K. (2019). Mathematical Complexities in Porous Media Flow. Eindhoven University of Technology, Hasselt University.

Scientific Publications

1. Mitra, K. & van Duijn, C. J. (2019). Wetting fronts in unsaturated porous media: the combined case of hysteresis and dynamic capillary pressure. Nonlinear Analysis: Real World Applications, 50, 316-341.
2. Behi-Gornostaeva, E. E., Mitra, K. & Schweizer, B. (2019). Traveling wave solutions for the Richards equation with hysteresis. IMA Journal of Applied Mathematics, 84(4), 797-812.
3. Mitra, K., Köppl, T., Pop, I.S., van Duijn, C. J. & Helmig, R. (2020). Fronts in two-phase porous media flow problems: the effects of hysteresis and dynamic capillarity. Studies in Applied Mathematics, 1-44.



Numerically obtained solutions for a two-phase infiltration problem in homogeneous porous media. The shown profiles are obtained for different top saturation values if hysteresis and dynamic capillarity is considered. Observe that, they show non-monotone profiles and growing saturation plateaus.

Urban physics and wind engineering

Prof.dr.ir. B Blocken

Urban Physics is the science and engineering of physical processes in urban areas. The work of the Urban Physics group was originally focused on wind flow and related processes around buildings and in urban areas, including topics such as air pollutant dispersion, pedestrian-level wind conditions, wind-driven rain on buildings, surface convective heat transfer and natural ventilation. These topics were mainly addressed by numerical simulation with computational fluid dynamics, where validation was performed based on either dedicated measurement campaigns on site or in wind tunnels at other institutes, or on experimental data available in the literature. Recently, the work in the group has been expanded to a wider range of topics in the field of Wind Engineering and Industrial Aerodynamics beyond the realm of Urban Physics, including several projects in Sports Aerodynamics. In 2017, a new atmospheric boundary layer wind tunnel was inaugurated at TU/e, which considerably expands the experimental capabilities of the group.

Towards accurate numerical modelling of the urban atmospheric boundary layer

Project Aim

The aim of this project is to develop, implement, verify and validate a methodology for the numerical computation of the atmospheric boundary layer (ABL) including atmospheric stability in CFD, with emphasis on the urban environment. The objectives are: (a) implement and assess models for atmospheric stability in urban ABL RANS and LES simulations; (b) implement suitable inflow turbulence models and wall functions & assess adequacy for use in non-neutral ABLs, and (c) validate with wind tunnel experiments.

Progress

LES has been conducted of the ABL in three conditions: neutral, stable and unstable. The OpenFOAM code, coupled with the SOWFA library is used. In contrast to stable conditions, unstable ABLs require larger domains, leading to an increase in computational cost. Contrary to the turbulence-dominated unstable ABLs, the less turbulent stable ABLs are very sensitive to the cell size and other computational settings, including the subgrid-scale model. Simulations so far have been carried out in empty domains and with cyclical boundary conditions. Progress is being made to include urban geometries with a synthetic turbulence inflow method.

Dissertations

-

Scientific Publications

-

Project leaders

Prof. dr. ir. B. Blocken (TU/e, KU Leuven), Dr. ir. T. van Hooff

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Ir. G.C. Fernandes

Cooperations

-

Funded by

NWO-TTW

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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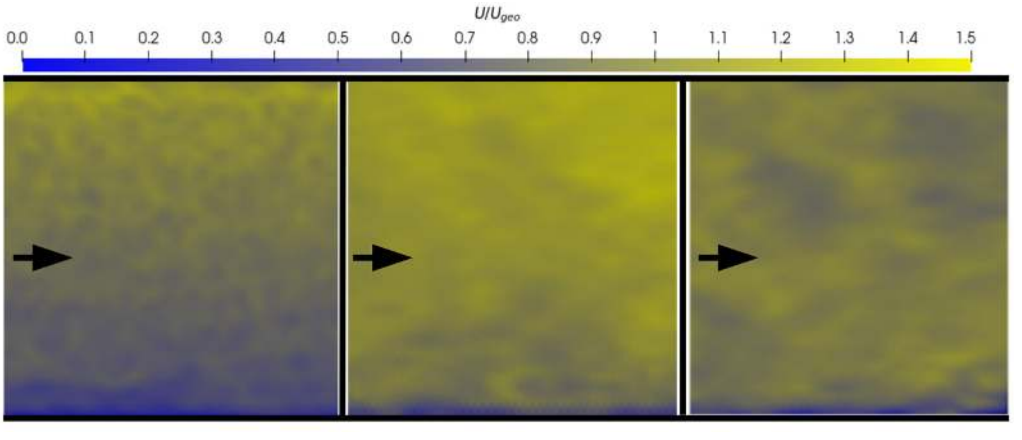
Instantaneous velocity contours in a vertical cross section for three ABL conditions: stable (left), neutral (center) and unstable (right), where the flow direction is from left to right for all cases in an empty domain. Contours shown correspond to an area of 400mx400m. Contours are normalized with the geostrophic wind velocity.



PROJECT LEADERS
Prof.dr.ir. B. Blocken (TU/e and KU Leuven), Dr.ir. H. Montazeri (KU Leuven and TU/e)

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
L. Xia, MSc

COOPERATIONS
-

FUNDED BY
The China Scholarship Council

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT
2017

INFORMATION
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PROJECT AIM
The overall objective of this research project is to develop, validate and apply computational models to evaluate the performance of water spray systems (WSSs) in mitigating the heat stress in the outdoor environment. This research project will be executed based on the following sub-objectives:

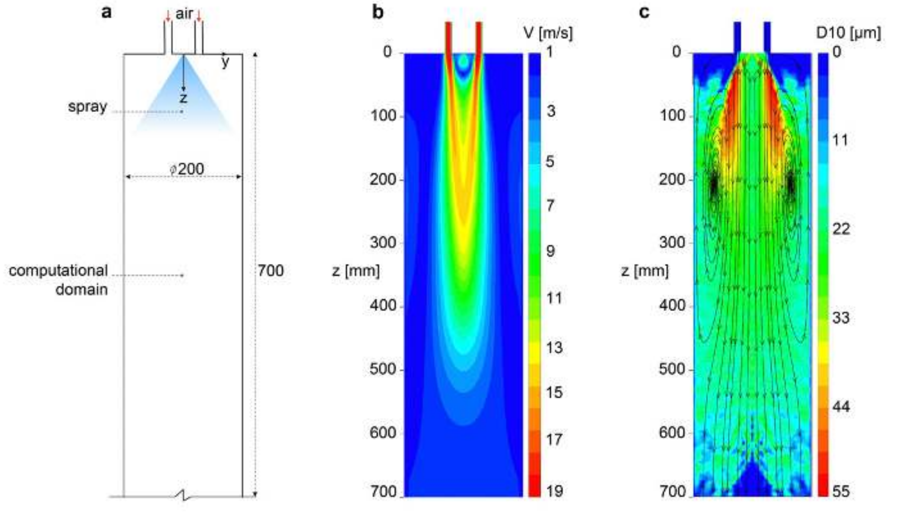
1 - Develop and validate CFD models for WSSs in turbulent flow.
2 - Characterize and optimize WSSs for outdoor cooling.
3 - Investigate the cooling potential of WSSs for generic urban areas.
4 - Apply WSSs for a real case study.

PROGRESS
A detailed two-phase flow CFD validation and sensitivity analysis have been carried out by comparing the numerical results with the experiments by Sommerfeld et al. 1998 [1]. In addition, CFD simulations have been performed for multiple water spray nozzles in an atmospheric boundary layer to gain insight into the cooling performance of a WSS under different arrangements of spray nozzles, such as injection height and interval distance. The changes in Universal Thermal Climate Index (UTCI), air temperature, and relative humidity are analyzed to characterize the cooling capacity of the WSS.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
1. M. Sommerfeld and H. H. Qiu, "Experimental studies of spray evaporation in turbulent flow," Int. J. Heat Fluid Flow, vol. 19, pp. 10–22, 1998.

(a) Sketch of the computational domain based on the experiment [1]. (b) CFD validation: comparison of calculated and measured droplet Sauter mean diameter. (c) Contours of air axial velocity and (d) air temperature in the center plane.



Project Aim

The present project aims at investigating microscale and local-scale wind conditions in complex environments, as seaport areas, in order to improve the ship navigation in these areas under strong wind conditions. On-site measurements, wind-tunnel testing and 3D steady RANS simulations are carried out on various seaport areas worldwide. Data obtained from RANS simulations are used to develop a real-time software that provides local-scale wind conditions based on standard weather station recordings to help the tugboat pilots when mooring and maneuvering cruise ships and vessels through seaport areas.

Progress

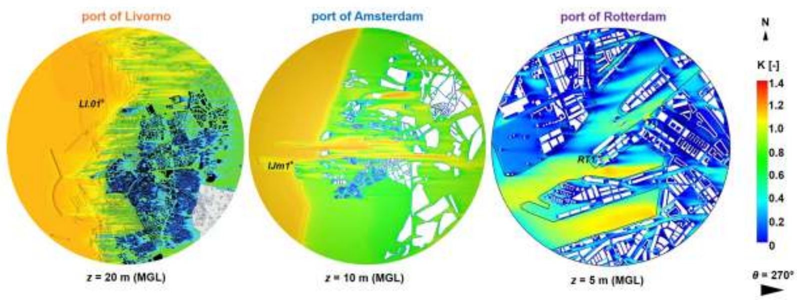
Three seaport areas are considered as case studies: Livorno (Italy), Amsterdam (Netherlands) and Rotterdam (Netherlands). In a first stage, the simulated data are validated with the on-site measurements. A satisfactory agreement is found in terms of mean local wind speed and wind direction; for all cases about 90% of the simulated data fell within ±30% from the measured data. In a second stage (still ongoing), wind forces (i.e. longitudinal force, lateral force and yaw moment) on moored ships and ships in open-sea like conditions are evaluated through CFD simulations and wind-tunnel testing.

Dissertations

-

Scientific Publications

1. Ricci A., Burlando M., Repetto M.P., Blocken B., 2019. Simulation of urban boundary and canopy layer flows in port areas induced by different marine boundary layer inflow conditions. Science of the Total Environment 670, 876-892.
2. Ricci, A., Burlando, M., Repetto., M.P., Blocken, B. Simulation of urban boundary and canopy layer flows in port areas induced by different marine boundary layer inflow conditions. Burgers Symposium - Conference Centre ‘De Werelt’ in Lunteren (Netherlands), June 21-22, 2019.
3. Ricci, A., Burlando, M., Repetto, M.P., Blocken, B. Full-scale and reduced-scale 3D RANS simulations for the case study of Livorno city (Italy). Proceeding of ICWE 15 - The 15th International Conference on Wind Engineering, Beijing, China, September 1-6, 2019.
4. Ricci, A., Vasaturo, R., Blocken, B. A software application to predict local scale wind conditions in the Port of Amsterdam. Proceeding of ICWE 15 - The 15th International Conference on Wind Engineering, Beijing, China, September 1-6, 2019.



Project leaders

Prof.dr.ir. B. Blocken (TU/e, KU Leuven)

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Dr.ir. A. Ricci

Cooperations

Eindhoven University of Technology (TU/e), KU Leuven (Belgium)
University of Genoa (Italy)

Funded by

TU/e, KU Leuven (Belgium)

Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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Project leaders
Prof.dr.ir. B. Blocken (TU/e, KU Leuven)
Research theme
Complex dynamics of fluids
Participants
Thijs van Druenen
Cooperations
Team Jumbo-Visma, Equipe Cycliste Groupama-FDJ
Funded by
Industry
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
Information
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Project Aim

At racing speeds exceeding 40 km/h the aerodynamic drag contributes 90% ore more of the cyclist's total resistance. As margins between winning and losing are often very small, even minor reductions in drag can have a large impact on the final result. In this project, insight in cycling aerodynamics is obtained by the performance of wind tunnel experiments and numerical (CFD) simulations. Drag reduction is obtained by studying the cyclist's posture on the bike or position within a group. In addition, the effect of roughness/texture on fabrics and equipment is investigated.

Progress

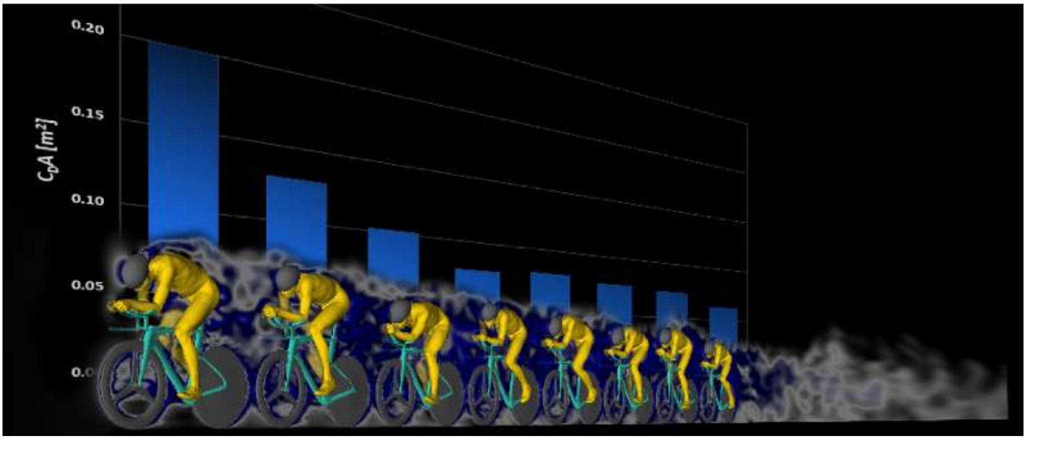
A systematic study is being performed to create a set of best practice guidelines for the application of numerical (CFD) simulations to the field of cycling. The results will be supported by grid-sensitivity analyses and validation by wind tunnel measurements. In addition to this, numerical studies were performed on the position (see figure) and type of helmet of an elite sprinter, and on optimal time trial formations (see figure).

Dissertations

-

Scientific Publications

1. Blocken B, van Druenen T, Toparlar Y, Andrianne T. 2019. CFD analysis of an exceptional cyclist sprint position. Sports Engineering 22:10.
2. van Druenen T, van Hooff T, Montazeri H, Blocken B. 2019. CFD evaluation of building geometry modifications to reduce pedestrian-level wind speed. Building and Environment 163.



Numerically optimizing the team time trial formation for Team Jumbo-Visma for the Tour de France 2019, which they won with a 20 s lead on Team Ineos.

PROJECT AIM

Air curtains, which are plane impinging jets, are used to separate a conditioned environment, typically in terms of temperature or concentration, from an unconditioned environment, while allowing unobstructed traffic between the two environments. The present project aims to optimize the separation efficiency of air curtains by exploring the influence of jet and environmental parameters on the behavior of turbulence structures and the dynamics of the flow. The project combines advanced numerical simulation and experimental techniques in fluid dynamics for the parametric and systematic analysis of air curtain systems and the evaluation of their performance.

PROGRESS

With the start of a new phase in the project (initiation of a PhD program after the earlier PD Eng study) an extensive literature review and project planning has been conducted. This has been accompanied with the participation in JMBC courses and other relevant workshops. During this period, most efforts have been put into complementing my previous research findings and writing related scientific publications. The latter particularly concerns research on the effects of the environmental parameters (cross-jet density/temperature and pressure gradients) on air-curtain performance and its influence on whole building energy consumption.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Analysis of the heating energy demand of a generic shop with an air curtain by coupled CFD and BES. Alanis Ruiz, C.A., van Hooff, T., Blocken, B. & van Heijst, G.J.F., 23 Oct 2019, Proceedings of Indoor Air Quality, Ventilation and Energy Conservation in Building, Bari, Italy: IAQVEC, p.n. 273 6p.

PROJECT LEADERS

Prof.dr.ir. B. Blocken (TU/e, KU Leuven), Prof.dr.ir. G.J.F. van Heijst, Dr.ir. T. van Hooff (KU Leuven, TU/e)

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

C. Alanis Ruiz

COOPERATIONS

TU/e, ANSYS CFD

FUNDED BY

Research Foundation – Flanders (FWO)

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT

2019

INFORMATION

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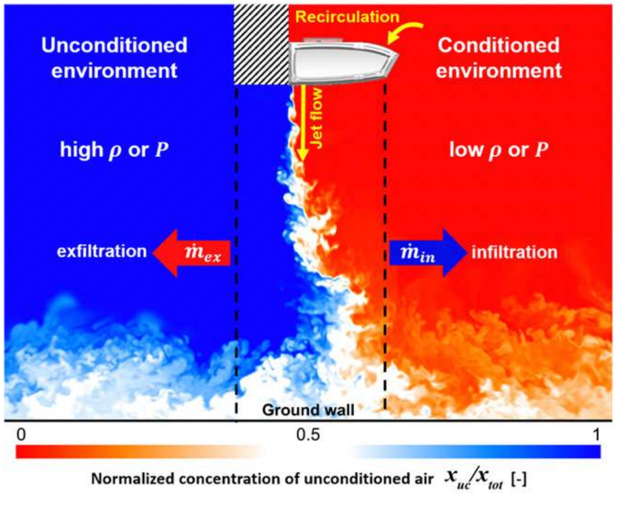

Project leaders
Prof.dr.ir. B. Blocken (TU/e, KU Leuven), Dr.ir. T. van Hooff (KU Leuven, TU/e)

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
R.P.M. Vervoort

Cooperations
ENS technology

Funded by
ENS Technology

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019

Information
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Project Aim

Particulate matter (PM) is one of the most dangerous forms of air pollution. Adverse health effects are well documented in the scientific literature, indicating a (dose-dependent) causal relationship between PM exposure and human morbidity and mortality. By reducing exposure to PM these risks can be limited. This study focuses on the assessment and optimization of indoor and outdoor PM concentration reductions in the built environment, by local removal using electrostatic precipitation (in semi-enclosed environments). The study comprises multiple main objectives in which both experimental (full-scale and reduced-scale) and numerical work is conducted.

Progress

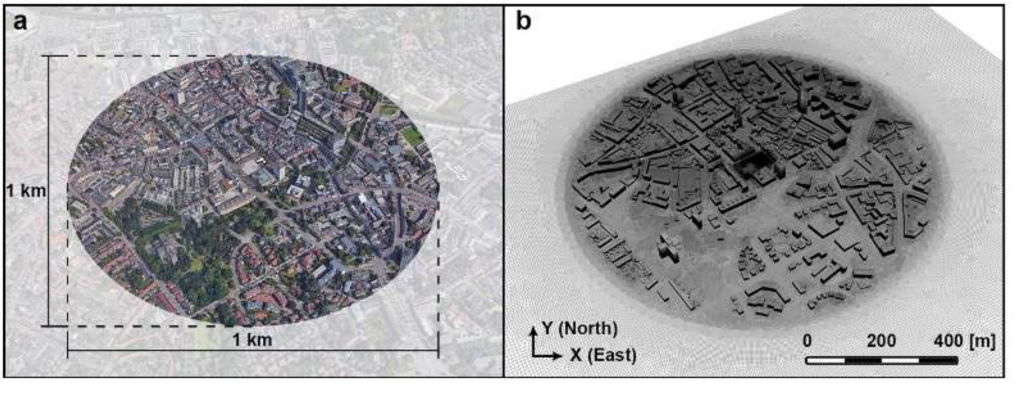
One of the project aims is to generate a validated modeling procedure for the assessment of local PM mitigation strategies in the built environment. A full-scale measurement campaign - including 20 to 30 electrostatic precipitation units - was conducted at the exit of a parking garage at the Stadhuisplein in the city center of Eindhoven. For this configuration, computational fluid dynamics (CFD) analyses using steady Reynolds-averaged Navier-Stokes (RANS) simulations were performed. Model validation is in progress and results are expected in the coming year.

Dissertations

1. PDEng dissertation (11-03-2019). Aerodynamic optimization of particulate matter removal using electrostatic precipitation units.

Scientific Publications

1. Vervoort, R., Blocken, B., & van Hooff, T. (2019). Reduction of particulate matter concentrations by local removal in a building courtyard: Case study for the Delhi American Embassy School. Science of The Total Environment, 686, 657–680. https://doi.org/10.1016/j.scitotenv.2019.05.154.



(a) Aerial view of the area surrounding the Stadhuisplein in Eindhoven (500 m radius) and (b) corresponding structured computational grid (≈ 176 million hexahedral cells). Aerial view obtained from Google Earth

Project Aim

This PhD project is a part of the wider European Research Council (ERC) project “THUNDERR - Detection, simulation and modeling of thunderstorm outflows to design wind-safer and cost-efficient structures”. It aims on extending the knowledge about the complex and hazardous thunderstorm downburst extreme winds and their devastating effects on low-rise buildings and structures through CFD simulations. When simultaneously used with the downburst-simulator and full-scale measurement data, it should provide adequate knowledge in order to propose an easy-to-use engineering standard for designing the low-rise structures able to withstand such wind loads.

Progress

In the first stage of the present PhD project, URANS simulations were performed in order to reproduce the simplified and detailed geometry of the wind-simulator (“WindEEE Dome”), where specific downburst-like winds were previously generated. In a second stage, more sophisticated numerical approaches (e.g. SAS, DES, LES) will be tested with the detailed geometry of WindEEE Dome and numerical and experimental results will be compared. In the third stage, the best-performing numerical approach will be adopted to simulate a full-scale downburst wind recorded through on-site measurements carried out by the University of Genoa in the Port of Genoa.

Dissertations

-

Scientific Publications

1. J. Zuzul, M. Burlando, G. Solari, B. Blocken, A. Ricci, Comparison between the impinging jet model and experimental stationary downbursts, ICWE 2019, Proceedings of the 15th International Conference on Wind Engineering, 1-6 September 2019, Beijing, China.

Project leaders

Prof.dr.ir. G. Solari (Uni Genova), Prof.dr.ir. Bert Blocken (TU/e, KU Leuven)

Research theme

Complex dynamics of fluids

Participants

J. Žužul, MSc, Dr. M. Burlando (Uni Genova), Dr.ir. A. Ricci (KU Leuven, TU/e)i

Cooperations

TU/e, University of Genoa (Italy)

Funded by

European Research Council (ERC)

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2018

Information

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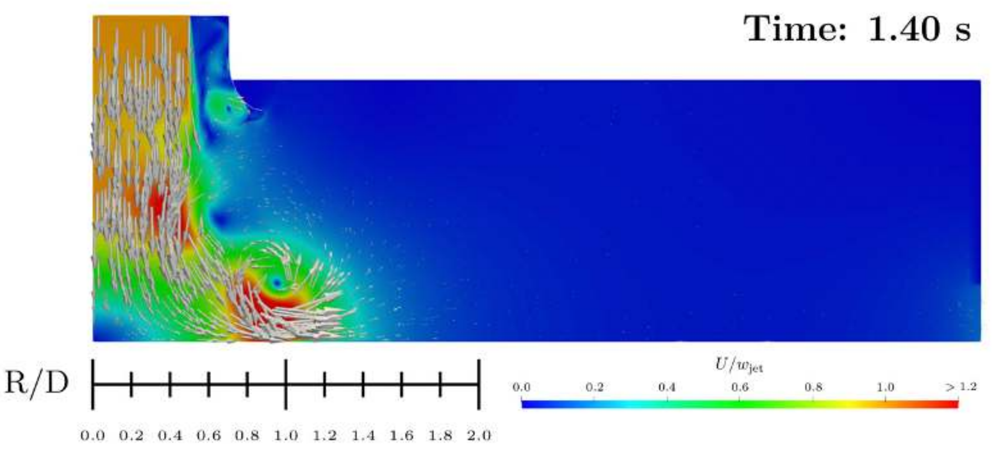

PROJECT LEADERS
Prof.dr.ir. B. Blocken (TU/e, KU Leuven), Dr. ir. H. Montazeri (KU Leuven)

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Dr.ir. A. Rezaeiha (TU/e, KU Leuven)
S. Sahebzadeh, MSc

COOPERATIONS
-

FUNDED BY
Ministry of Science, Research and Technology, Iran

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT
2018

INFORMATION
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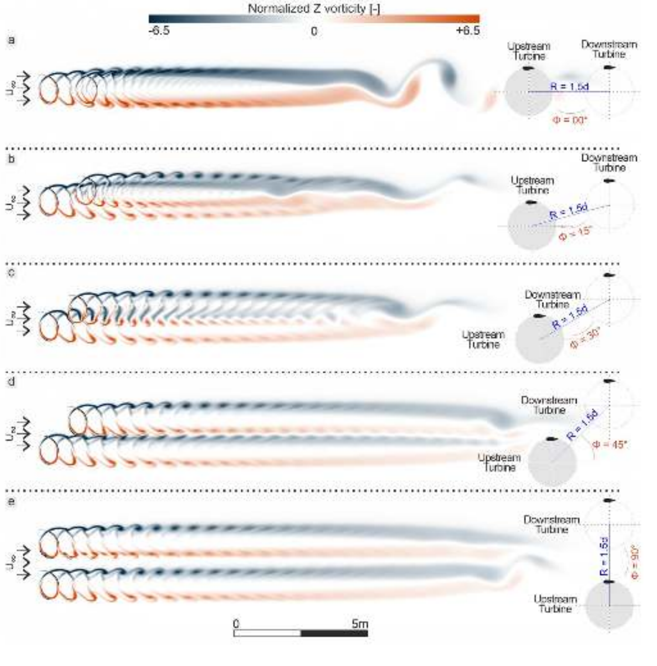
PROJECT AIM
The aim of this PhD research project is to provide fundamental knowledge on aerodynamics, power performance and wake interactions of an array of vertical axis wind turbines (VAWTs) placed in close proximity. In addition, possibilities for layout optimization and array design for building-integrated VAWTs will be explored.

PROGRESS
The effect of relative distance, angle, phase lag and rotation direction on the power and aerodynamic performance of two closely spaced VAWTs was studied by a large number of high fidelity Unsteady Reynolds Averaged Navier Stokes (URANS) simulations. The mechanisms contributing to the power enhancement of closely spaced VAWTs were identified and investigated in order to be utilized in further performance enhancement of such VAWT arrays. In addition, generalized guidelines for layout design and optimization of a two-rotor array of VAWTs as the smallest generating cell in a potential VAWT mini-wind farm were developed.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-



Contours of normalized z-vorticity in three sample cases with a relative distance of R=1.5d and a relative angle of (a) Φ=0°, (b) Φ=15°, (c) Φ=30°, (d) Φ=45° and (e) Φ=90°.

Project Aim

The research aims at developing and analyzing potential natural ventilation strategies to enhance the quality of the indoor thermal environment and reduce the cooling demand of residential buildings in hot-humid climates, such as the climate on Sulawesi, Indonesia. The effects of ceiling and attic ventilation concepts on the indoor environment as a strategy to optimize airflow in and heat removal from residential buildings in hot-humid climates will be investigated by numerical simulation using computational fluid dynamics (CFD) and building energy simulations (BES). The CFD simulations will be validated with wind-tunnel experiments.

Progress

The impact of ceiling height on indoor air velocity (U), indoor airflow pattern and volume flow rate (Q) in isothermal conditions has been studied in CFD. The CFD simulations have already been conducted for three cases, with a ceiling height (height between floor and ceiling) of 3 m, 3.5 m and 4 m. A start has been made with the preparation of the wind-tunnel measurements, which will be used in the validation study. The reduced-scale wind tunnel models are currently in preparation.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. B. Blocken (TU/e, KU Leuven), Dr.ir. T. van Hooff (KU Leuven, TU/e)

Research theme

Complex dynamics of fluids

Participants

M Mutmainnah

Cooperations

MoRA/ Indonesian government

Funded by

The Ministry of Religious Affairs of Indonesia (MoRA)

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project

2018

Information

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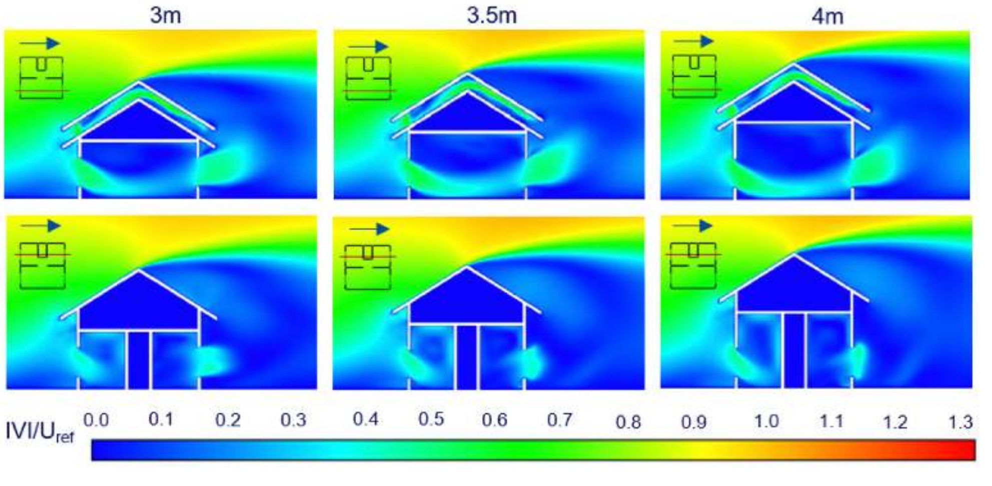
Contours of dimensionless mean velocity magnitude (|V|/Uref) obtained with steady RANS CFD simulations for different ceiling heights (3 m, 3.5 m, 4 m).



PROJECT LEADERS
Prof.dr.ir. B. Blocken (TU/e, KU Leuven), Dr. R. Guichard (INRS, France), Dr. A. Ricci (KU Leuven, TU/e), Dr. S. Gillmeier (TU/e)

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
A. K. Radhakrishnan Jayakumari

COOPERATIONS
Eindhoven University of Technology (TU/e), INRS (French National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases)

FUNDED BY
INRS

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2018

INFORMATION
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PROJECT AIM

The aim of this project is to systematically investigate and quantify the effect of meteorological conditions on the performance of mechanical ventilation systems in pollutant containment zones, by predicting the internal-external pressure differences. Understanding the impact that wind may have, can help to address practical solutions to enhance the performance of ventilation systems and thereby, can prevent hazardous pollutants escaping into the atmosphere. The investigations will be carried out using (i) field measurements, (ii) wind tunnel (WT) testing; (iii) computational fluid dynamics (CFD) techniques and (iv) simulations with a ventilation network model.

PROGRESS

As an initial stage of the investigation, field measurements were carried out in an active asbestos removal worksite in France. In order to gain further understanding of the problem at hand, internal-external pressure differences at various locations of the containment zone, wind velocities and local wind directions were simultaneously measured. Results from this measurement campaign were analyzed and presented at an international workshop (PHYSMOD 2019). The second stage of the project involves WT tests on a reduced-scale (1:40) generic building with active mechanical ventilation system. The design of the WT model and further preparations are ongoing.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. A. K. R. Jayakumari, R. Guichard, A. Ricci, S. Gillmeier, B. Blocken, 2019. Wind effects on the pollutant containment zone in an asbestos removal worksite - field measurements. In: Proc. Workshop on Physical Modeling of Environmental Flow & Dispersion Phenomena (PHYSMOD) 2019.

from left to right: asbestos removal site in France; anemometric station on building roof; wind tunnel set-up.

Analysis of wind flow and urban wind energy potential around generic high-rise buildings in close proximity using computational fluid dynamics

Project Aim

The PhD project aims to (i) analyze wind flow and urban wind energy potential around generic high-rise buildings placed in close proximity under the influence of various building arrangements and heights; and (ii) improve the urban wind power potential using building corner modifications. The evaluations are based on on-site and wind-tunnel measurements and three-dimensional computational fluid dynamics (CFD) simulations.

Progress

The research performed within this project in 2019 is summarized in the following two items: (A) Characterization of wind power potential for an isolated array of generic high-rise buildings placed in close proximity. The studied parameters are (i) the gap width between upstream buildings (W), (ii) the distance between upstream and downstream buildings (D), and (iii) the height difference between upstream and downstream buildings (ΔH); (BI) Improvement of wind energy potential and reduction of reference turbulence intensity (Iref) for an isolated array of generic high-rise buildings placed in close proximity using building corner modifications.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. B. Blocken (TU/e, KU Leuven), Prof.dr. A.S. Yang (Taipei Tech), Dr.ir. H. Montazeri (KU Leuven, TU/e)

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Dr.ir. A. Rezaeiha (TU/e, KU Leuven)

Cooperations

Department of Energy and Refrigerating Air-Conditioning Engineering, National Taipei University of Technology, Taipei, Taiwan

Funded by

Ministry of Science and Technology, Taiwan (Contract No. 107-2917-I-027-001), Ministry of Education, Taiwan

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project

2018

Information

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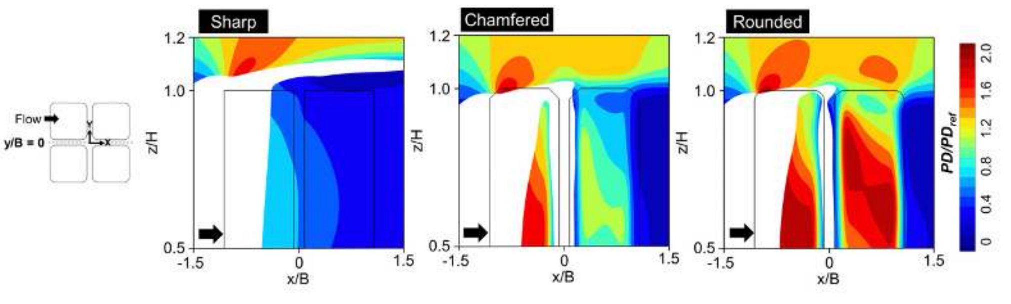

Contour plots of normalized power density with the reference turbulence intensity (Iref) threshold of 0.16 (marked in white color) over the vertical plane at y/B = 0 for different building corner shapes.

Computational analysis of the impact of façade geometrical details on wind flow and pollutant dispersion

Project leaders
Prof.dr.ir. B. Blocken (TU/e, KU Leuven), Dr.ir. Hamid Montazeri (KU Leuven, TU/e)

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
X. Zheng, MSc

Cooperations
-

Funded by
China Scholarship Council (CSC)

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project
2016

Information
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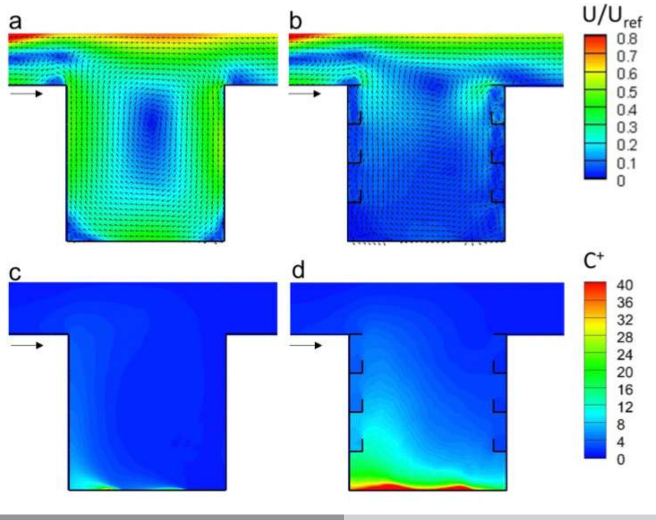
Project Aim
The main objective is to obtain fundamental knowledge on the impact of facade geometrical details on airflow around buildings. This leads to the following sub-objectives: (i) Investigate the performance of Large-eddy simulation (LES) and steady Reynolds-averaged Navier-Stokes (RANS) for wind flow around buildings with balconies; (ii) Evaluate the impact of different types of building balconies on mean wind speed and surface pressure; (iii) Examine the impact of building balconies on wind flow and pollutant dispersion in urban street canyons.

Progress
LES simulations have been performed for street canyons with and without balconies to investigate the impact of building balconies on pollutant dispersion in street canyons. The evaluation was based on validation with wind-tunnel measurements of pollutant concentration for a generic urban street canyon. Four cases were considered: (1) a street canyon without balconies, (2) a street canyon with balconies on both windward and leeward sides, (3) a street canyon with balconies on the windward side, and (4) a street canyon with balconies on the leeward side.

Dissertations
-

Scientific Publications
1. Zheng, X., Montazeri, H. & Blocken, B. Numerical analysis of pollutant dispersion in street canyons with façade appurtenances. The 15th International Conference on Wind Engineering Beijing, China; September 1-6, 2019.

Normalized mean wind speed (U/Uref) in the vertical cross-section (center plane) of (a) street canyon without balconies, (b) street canyon with balconies on both windward and leeward sides, (c-d) Same for normalized mean concentration (C+).



Reports of Individual Research Groups

UNIVERSITY OF TWENTE.

Science and Technology (TNW)

- Physics of Fluids (TNW-PoF)
- Physics of Complex Fluids (TNW-PCF)
- Soft Matter, Fluidics and Interfaces (CT-SFI)

Engineering Technology (ET)

- Engineering Fluid Dynamics (ET-EFD)
- Thermal Engineering (ET-TE)
- Multiscale Mechanics (ET-TSMSM)
- Water Engineering Management (ET-WEM)

Electrical Engineering, Mathematics and Computer Science (EEMCS)

- Applied Analysis (EEMCS-AA)
- Mathematics of Computational Science (EEMCS-MACS)
- Multiscale Modelling and Simulation (EEMCS-MMS)

Physics of fluids

Prof.dr. D Lohse

Prof.dr. D van der Meer

Prof.dr.ir. J Snoeijer

Prof.dr. M Versluis

Prof.dr. X Zhang

The Physics of Fluids group in Twente works on a variety of aspects in fluid mechanics, in particular on those related to bubbles. The focus of our work is the fundamental understanding the phenomena of the physics of fluids, bubbles and jets, which we undertake by experimental, numerical and theoretical means. Besides in the J.M.Burgers Center, our research is embedded in the Research Institute of Mechanics, Processes and Control IMPACT, the MESA+ Institute, and the Research Institute for Biomedical Technology BMTi of the University of Twente. The group receives external research funds mainly from FOM, but also from STW, NWO, SenterNovem, EU and several companies. The focus research areas of the group are:

Turbulence and Two-Phase Flow

Fully developed turbulence is one of the big unsolved problems in fluid dynamics. The main question is the distribution of rare events, which has important implications for, e.g., flight safety. We approach this problem from a fundamental point of view, both experimentally, theoretically, and numerically. One particular important type of turbulence is turbulence (partly) driven by body forces, such as buoyancy. This can happen by either thermally driving the turbulence or also by driving the turbulence through bubbles or dispersed particles. Both will be advected by the flow but also act back on the surrounding liquid (two-way coupling). To be able to describe flow with many bubbles or particles efficiently, one needs an effective force description, on which and with which we work in several projects within our group. Finally, we are also interested in the radial dynamics of single bubbles in hydrodynamic or acoustic fields.

Granular Flow

Granular flows are fundamentally different from any other type of flow. In our research we focus on the clustering phenomenon that finds its origin in the inelastic collisions between the particles. There is much emphasis on the onset of clustering,which happens via a phase transition which is studied in both compartmentalized and continuous systems. Another line of our research deals with the impact of objects on very fine, decompactified sand, in which we explore the applicability of fluid models to granular systems. We uncovered links to distant phenomena like asteroid impact and a dry variety of quicksand.

Micro- and Nanofluidics

The physics of fluids at the microscale can be quite different from macrofluidic behavior. Here we study disturbing bubbles in microchannels found in ink jet printing. By patterning surfaces on sub-micron scales we try to identify individual ‘nanobubbles’ which may lead to a quantitative understanding of wall slip. These patterned surfaces may also serve as nucleation sites for cavitation bubbles generated through intense negative pressures.

Prof.dr. A Prosperetti

Prof.dr. R Verzicco

Biomedical Flow

Bubbles have various applications in the biomedical field. Coated microbubbles are used in ultrasound imaging to enhace the contrast in cardiac or liver perfusion images. Bubbles can be targeted to specific cells for molecular imaging to non-invasively detect the presence and location of diseases such as cancer or atherosclerosis. Furthermore, the bubbles can be exploited to generate acoustic streaming and jetting near cell boundaries which leads to permeation, destruction or removal of target cells.

PROJECT LEADERS
Detlef Lohse, Roberto Verzicco

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
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COOPERATIONS
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FUNDED BY
ERC, FOM, NWO, MCEC, ERC, DFG

FUNDED %

University	-
FOM	80 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	20 %
Scholarships	-

START OF THE PROJECT
2015

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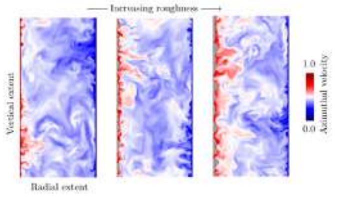

PROJECT AIM

This project aims to gain a deeper and broader insight into the dynamics of highly turbulent fluid flow. The research is carried out by means of high fidelity and massively parallel computer simulations. In particular we focus on three systems. The first is Taylor-Couette turbulence with sand grain roughness. The second system is Couette flow with unstable thermal stratification. The third system is free convection with roughness. We focus on understanding the dominant mechanisms and flow structures that contribute to drag and heat transport.

PROGRESS

Simulations of the respective systems have revealed key mechanisms and flow structures that contribute to overall drag and heat transport. One of those key mechanisms is the increase in plume ejections in Taylor-Couette flows, which are caused by the presence of inner cylinder roughness (see figure below). Crucially, the increase in plume ejections heralds an increase in dimensionless drag of the system. In close relation to this work, we find similar mechanisms in Rayleigh-Bénard turbulence and vertical natural convection, where the presence and directionality of roughness are strongly correlated with increased thermal plumes and increased heat transport.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. P. Berghout, X. Zhu, D. Chung, R. Verzicco, R.J.A.M. Stevens, and D. Lohse, Direct numerical simulations of Taylor–Couette turbulence: the effects of sand grain roughness. J. Fluid Mech. 873, 260–286 (2019).
2. X. Zhu, R.J.A.M. Stevens, O. Shishkina, R. Verzicco, and D. Lohse, Nu~Ra1/2 scaling enabled by multiscale wall roughness in Rayleigh–Bénard turbulence, J. Fluid Mech. 869, R4 (2019).
3. Z. Wan, P. Wei, R. Verzicco, D. Lohse, G. Ahlers, and R.J.A.M. Stevens, Effect of sidewall on heat transfer and flow structure in Rayleigh–Bénard convection. J. Fluid Mech. 881, 218–243 (2019).
4. F. Sacco, R. Verzicco, and R. Ostilla-Mónico, Dynamics and evolution of turbulent Taylor rolls. J. Fluid Mech. 870, 970–987 (2019).
5. M. MacDonald, N. Hutchins, D. Lohse, and D. Chung, Heat transfer in rough-wall turbulent thermal convection in the ultimate regime. Phys. Rev. Fluids 4, 071501 (2019).
6. J.M. Favre and A. Blass, A comparative evaluation of three volume rendering libraries for the visualization of sheared thermal convection. Parallel Comput. 88, 102543 (2019).
7. H. Jiang, X. Zhu, X. Yang, R. Verzicco, and D. Lohse, Convective heat transfer along ratchet surfaces in vertical natural convection. J. Fluid Mech. 873, 1055–1071 (2019).
8. K. Alards, R.P.J. Kunnen, R.J.A.M. Stevens, D. Lohse, F. Toschi, and H.J.H. Clercx, Sharp transitions in rotating turbulent convection: Lagrangian acceleration statistics reveal a second critical Rossby number, Phys. Rev. Fluids 4, 074601 (2019).

PROJECT AIM

Fill the gap between fluid dynamics and chemical engineering and colloidal & interfacial science by means of quantitatively understand the diffusive droplet dynamics and the fluid dynamics of liquid-liquid (micro)extraction processes. Therefore, to illuminate the fundamental fluid dynamics of diffusive processes of immersed (multicomponent) (surface) droplets on all scales (over 9 orders of magnitude in length scale). This would be achieved by doing one-to-one comparisons between controlled experiments and numerics/theory for idealized setups.

PROGRESS

1. Made a linear stability calculation for an evaporating solution in a Hele-Shaw cell, experiments and simulations were done. The instability creates accumulation of dye in arch like regions.

2. Investigated the bouncing behavior of an oil droplet in a density stratified mixture. At first, the droplet sinks slowly due to gravity, but then, before having reached its density matched position, jumps up suddenly.

3. Studied the important parameters which control supra-particle formation in particle-laden droplets of surfactant-free emulsions (better known as colloidal Ouzo droplets). We discovered the crucial role of size, surface roughness and hydration time of the constituent colloidal particles in controlling the morphology of the supra-particles.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Li, Y., Diddens, C., Prosperetti, A., Chong, K. L., Zhang, X., & Lohse, D. (2019). Bouncing oil droplet in a stratified liquid and its sudden death. Phys. Rev. Lett., 122(15), 154502.
2. Tan, H., Wooh, S., Butt, H. J., Zhang, X., & Lohse, D. (2019). Porous supraparticle assembly through self-lubricating evaporating colloidal ouzo drops. Nature communications, 10(1), 1-8.
3. Tan, H., Diddens, C., Mohammed, A. A., Li, J., Versluis, M., Zhang, X., & Lohse, D. (2019). Microdroplet nucleation by dissolution of a multicomponent drop in a host liquid. Journal of fluid mechanics, 870, 217-246.
4. Zeng, B., Wang, Y., Zhang, X., & Lohse, D. (2019). Solvent Exchange in a Hele–Shaw Cell: Universality of Surface Nanodroplet Nucleation. The Journal of Physical Chemistry C, 123(9), 5571-5577.

PROJECT LEADERS

Detlef Lohse

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

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FUNDED BY

ERC

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

START OF THE PROJECT

2014

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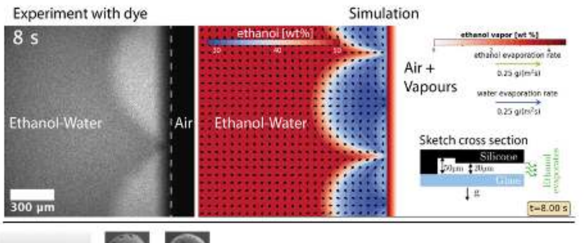

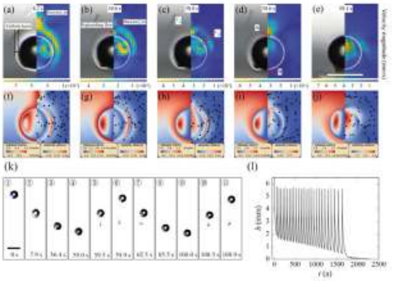

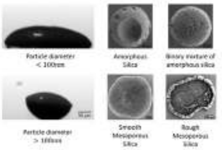

PROJECT LEADERS
Detlef Lohse
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
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COOPERATIONS
Emmanuel Villermaux (IRPHE, France)
FUNDED BY
ERC
FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

START OF THE PROJECT
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PROJECT AIM

Liquid drops deposited on a hot surface can levitate on a cushion of their own vapor when the surface is heated above a critical temperature (called the Leidenfrost point). This non-wetting situation has two major consequences: (i) drops can move almost without friction and (ii) the vapor film acts as an insulating layer dramatically reducing heat transfer. The later property is often undesirable in applications involving heat exchange. It is thus critical to understand, and model the conditions of formation of the vapor cushion as a function of the liquid and surface properties and temperature.

PROGRESS

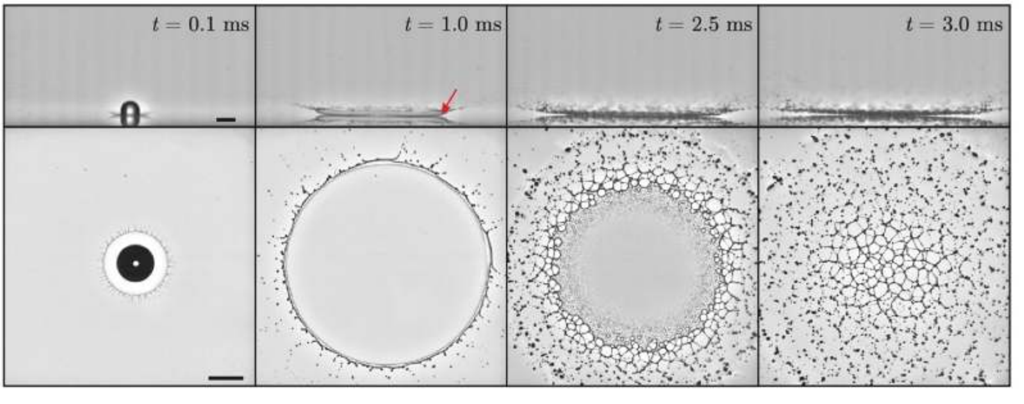
First, we study the onset of contact between impacting drops of pure or binary liquids and heated substrates using state-of -the-art interferometry techniques. We report the absence of contact at temperatures below the usual Leidenfrost point, highlighting the existence of transient non-wetting states. Our experiments also reveal that the transition to contact above the Leidenfrost temperature is mediated by an instability of the vapor layer. In a second project, we focus on impacts that lead to the fragmentation of the impacting liquid (Fig.1). We discuss the mechanisms responsible for fragmentation as a function of temperature and impact speed.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Project Aim

- Quantitatively study the influence of the dissolved gas in water on bubble nucleation and subsequent steady growth of the bubbles.

- Investigate plasmonic bubble dynamics in binary liquids to understand how the parameters such as latent heat, boiling temperature, gas solubility and others influence the dynamics of plasmonic bubbles. Binary liquids are chosen because they allow to tune those parameters easily via the mixing ratio. Water-alcohol and alcohol-alcohol mixtures including ethanol/1-propanol/acetone - water and 1-butanol/2-propanol/acetone - ethanol have been studied.

Progress

The effect of dissolved air on the bubble nucleation was quantitatively studied. First, the plasmonic bubble nucleation in water with different gas saturation levels was investigated. This was extended to the nucleation of plasmonic bubbles in six binary liquid combinations. We found that the time delay between the beginning of the laser heating and the bubble nucleation is determined by the absolute amount of dissolved gas in the liquid. Moreover, we revealed the dependence of the bubble volume on the vaporization energy of the liquid, consisting of the latent heat of vaporization and the energy needed to heat to the boiling temperature.

Dissertations

-

Scientific Publications

1. M.W. Detert, B. Zeng, Y. Wang, H. Le The, H.J.W. Zandvliet, and D. Lohse. Plasmonic Bubble Nucleation in Binary Liquids. J. Phys. Chem. C 0, 1–7 (2019).
2. X. Li, Y. Wang, M. Zaytsev, G.P.R. Lajoinie, H. Le The, J. Bomer, J.C.T. Eijkel, H.J.W. Zandvliet, X. Zhang, and D. Lohse. Plasmonic Bubble Nucleation and Growth in Water: Effect of Dissolved Air. J. Phys. Chem. C 0, 8 (2019).

Project leaders

Detlef Lohse, Harold Zandvliet

Research theme

Complex dynamics of fluids

Participants

Mikhail Zaytsev, Xiaolai Li, Mavin Detert, Binglin Zeng

Cooperations

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Xuehua Zhang (University of Alberta)
Thijs Verkaaik (Utrecht University)

Funded by

NWO, TNO, BASF, Albermarle

Funded %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	-
TNO	25 %
GTI	-
EU	-
Scholarships	25 %

Start of the project

2014

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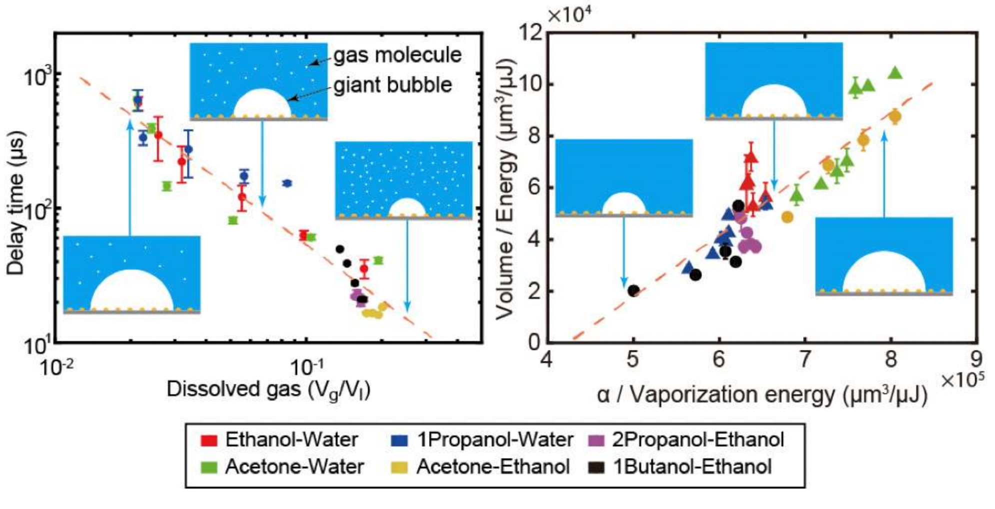

PROJECT LEADERS
Detlef Lohse
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
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COOPERATIONS
University of Twente
FUNDED BY
NWO
FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017
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PROJECT AIM

Freezing or solidification of an impacting droplet is omnipresent in nature and technology. It is a complex phenomenon involving several physical processes, including drop scale fluid motion, heat transfer between the liquid and the substrate, and the related phase-transition. The aim of this project is to develop a comprehensive understanding of freezing kinetics during the impact of a droplet. We mainly focus on the freezing behaviors that arise due to the rapid solidification of an impacting droplet at a sufficiently high substrate undercooling.

PROGRESS

During the course of this project we developed an optical technique based on total-internal reflection that allows direct visualization of nucleation and growth of the solidified phase in the vicinity of droplet-substrate, which is otherwise inaccessible through any other optical technique. This allowed us peculiar freezing morphologies that originate from the complex interplay between the droplet scale hydrodynamics and phase-transition effects, as shown in Fig1. We also study the solidification of binary liquids that partially freeze before the impact; see Fig.2. Furthermore, we developed a numerical code, based in open source code Gerris, to model the freezing of impacting droplets, Fig.2.

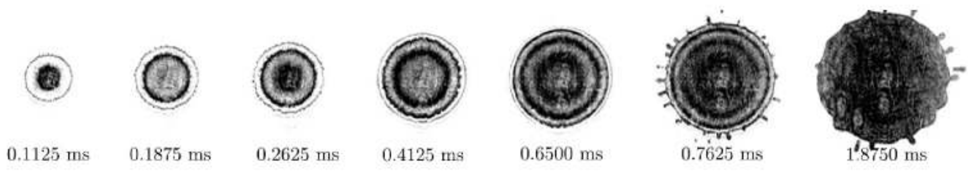
DISSERTATIONS

-

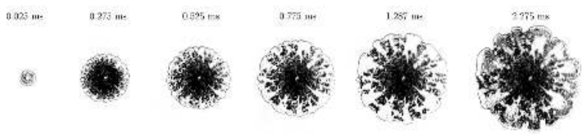
SCIENTIFIC PUBLICATIONS

-

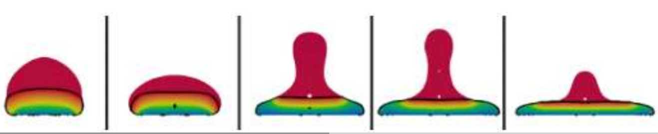
Experimental snapshots highlighting the sequential advection of frozen fronts during the impact of a droplet on a sufficiently undercooled substrate; Ref [2].



Sequence of experimental snapshots highlights the growth of the solidified phase along the undercooled substrate in finger-like patterns while a partially frozen binary droplet impacts on it.



Numerical results highlighting the influence of impact velocity on the overall solidification behavior



Project Aim

If the elastic modulus of a solid is sufficiently low, capillary effects can be observed on the surfaces of these materials. As a result, hyperelastic or viscoelastic materials can show some of the same capillary instabilities commonly seen in fluid flows. Examples of such instabilities include the free-surface cusps and Rayleigh-Plateau instability. The aim of this project is to study these instabilities analytically, experimentally and numerically to get a further understanding of elasto-capillary behavior.

Progress

We have created a numerical model to simulate the elastic crease/cusps (figure 1a), allowing us to analytically describe the bifurcation behavior of this system. Currently we have made the first steps in comparing our numerical and analytical results to experimental results obtained by our collaborators. To study the Rayleigh-Plateau instability in soft solids, we use an approximate slender theory for a neo-Hookean cylinder. We find that while stiffer solids result in a periodic array of cylinders connected to thin strings, softer solids lead to a beads-on-a-string configuration (figure 1b) that is analogous to the thinning of viscoelastic liquid jets.

Dissertations

-

Scientific Publications

-

Project leaders

Jacco Snoeijer

Research theme

Complex structures of fluids

Participants

Martin Essink, Minkush Kansa, Jacco Snoeijer

Cooperations

Stefan Karpitschka, Michiel van Limbeek (MPI Goettingen), Miguel A. Herrada (Universidad de Sevilla, Spain), Jens Eggers (University of Bristol, UK), Anupam Pandey (Cornell University, US)

Funded by

NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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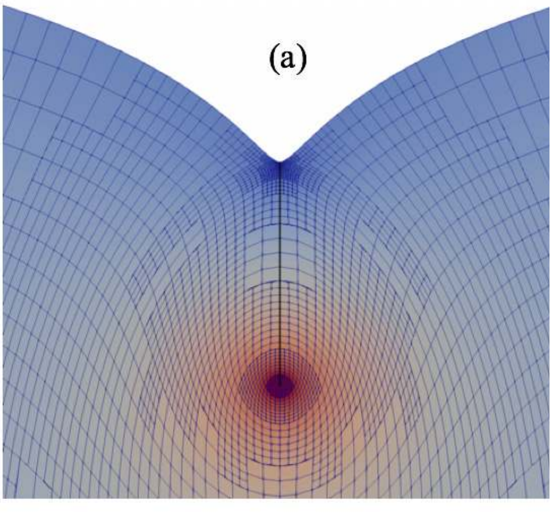

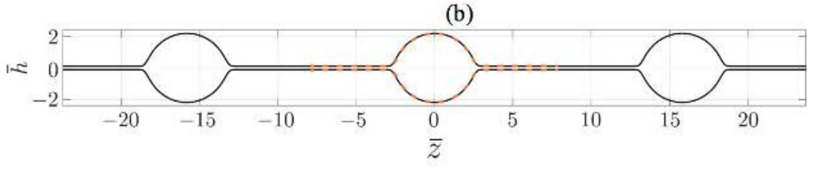

(a) Elastic crease and (b) Beads-on-a-string configuration observed for neo-Hookean solid, at elastocapillary number a=500

Project leaders
Detlef Lohse
Research theme
Complex dynamics of fluids
Participants
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Sander Huisman, UT
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Rodrigo Ezeta Aparicio, UT
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ERC-NWO
Funded %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	-
TNO	-
GTI	-
EU	50 %
Scholarships	-

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Project Aim

1. To study the effect of dispersed droplets on the rheology and momentum transport of the turbulence in Taylor-Couette flow.
2. To study the effect of bubbly drag reduction on the surface that is more realistic than smooth surface.
3. To study the particle trajectory and turbulent statistics with the presence of coherent structures.

Progress

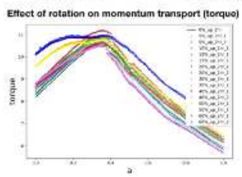
1. Obtained the effect of rotation and volume fraction on momentum transport.
2. Measurements of air bubble drag reduction (DR) at Reynolds numbers between 0.5 and 1.8 million with surface roughness similar to heavy marine fouling, showed that the roughness actually has a positive influence of the air bubble drag reduction. Of course, less drag is found for a smooth surface with air bubble DR, but compared to a rough surface without air bubbles, the addition of air bubbles to the flow has a larger effect.
3. Visualized the trajectories of particles and obtained the turbulent statistics in various rotation ratios.

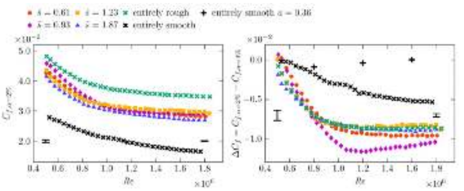
Dissertations

-

Scientific Publications

1. Drag reduction in boiling Taylor–Couette turbulence[arXiv]. R. Ezeta, D. Bakhuis, S.G. Huisman, C. Sun, and D. Lohse. J. Fluid Mech. 881, 104–118 (2019).
2. Statistics, plumes, and azimuthally travelling waves in ultimate Taylor–Couette turbulent vortices[arXiv]. A. Froitzheim, R. Ezeta, S.G. Huisman, S. Merbold, C. Sun, D. Lohse, and C. Egbers. J. Fluid Mech. 876, 733–765 (2019).
3. Statistics of rigid fibers in strongly sheared turbulence[arXiv]. D. Bakhuis, V. Mathai, R.A. Verschoof, R. Ezeta, D. Lohse, S.G. Huisman, and C. Sun Phys. Rev. Fluids 4, 072301 (2019).





Project Aim

In this project we use large eddy simulations to model the interaction between wind farms with many turbine rows in the downstream direction and the atmospheric boundary layer. We focus on the effect of the layout of the wind farm on its total power output and power fluctuations. We want to understand the influence of the properties of the very large-scale motions in the atmospheric boundary layer and the role of the turbulent fluctuations on the wind farm performance. Subsequently we want to translate this understanding to simpler models that can be used to predict properties of extended wind farms.

Progress

We used large-eddy simulations of wind farms in a stable boundary layer to study the effect of the low-level jets on the performance of extended wind farms. We show that low-level jets can increase wind farm performance, while also the wind veer caused by the Coriolis force has a pronounced effect on wind farm performance. Flow visualization reveals that a low-lying capping inversion limits the growth of the wind farm internal boundary layer and forces the wind to go around the wind farm. In a separate project, we study the effect of such flow blockage effects on wind farm performance. Besides, we are studying the performance of wind farms in hilly terrains.

Dissertations

-

Scientific Publications

1. M. Zhang, M.G. Arendshorst, R.J.A.M. Stevens, Large eddy simulations of the effect of vertical staggering in extended wind farms, Wind Energy 22(2), 189-204 (2019).
2. S. Nagarada Gadde, R.J.A.M. Stevens, Effect of Coriolis force on a wind farm wake, J. Phys. Conf. Ser. 1256, 012026 (2019).

Project leaders

Richard Stevens

Research theme

Complex dynamics of fluids

Participants

Luoqin Liu
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Jessica Strickland
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Cooperations

Charles Meneveau (Johns Hopkins University, USA)
Dennice F. Gayme (Johns Hopkins University, USA)
Michael Wilczek (Max Planck Gottingen, Germany)
Luis A. Martínez-Tossas (NREL, USA)
Joachim Peinke (Oldenburg)

Funded by

NWO

Funded %

University	-
FOM	50 %
STW	50 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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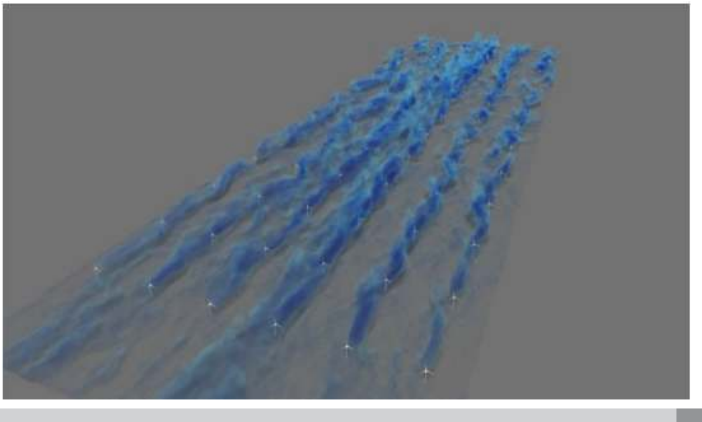
Visualization of the low speed wind regions indicated in blue in a very large wind-farm which shows the creation of turbulent wakes behind the turbines (visualization by David Bock, NCSA Visualization, XSEDE)



Impacting experiments on slippery surfaces: Characterization of their stability

Project leaders
Detlef Lohse, Jacco Snoeijer

Research theme
Complex dynamics of fluids

Participants
Srinath Lakshman, Walter Tewes

Cooperations
Doris Vollmer, Mainz, Uwe Thiele, Muenster

Funded by
EU Marie Sklodowska-Curie

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2017

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Project Aim
To explore the expansive potential of Lubricant Impregnated Slippery Surfaces (LubISS). Characteristic for LubISS is that the textured or porous surface is impregnated by a liquid or a gel. The motility of the lubricating film greatly reduces the lateral adhesion. Deposited liquid or solid particles, can slide off easily as soon as the surface is tilted by a few degrees. However, to develop durable and environmentally friendly LubISS, the understanding of the interplay, and the physical- and chemical interactions between the solid surface topography, the lubricating film and the liquid under static and flow conditions is necessary.

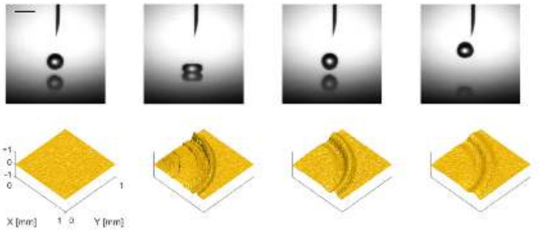
Progress
1. Film deformation and relaxation under a bouncing drop (completed)

Impact experiments are performed for a water droplet (D = 2 mm and v = 0.22 and 0.38 m/s) bouncing over silicone oil films (η = 50 – 200 mPa.s and h = 5 – 15 μm). 2. Deformation evolution in liquid-liquid interactions (in progress)

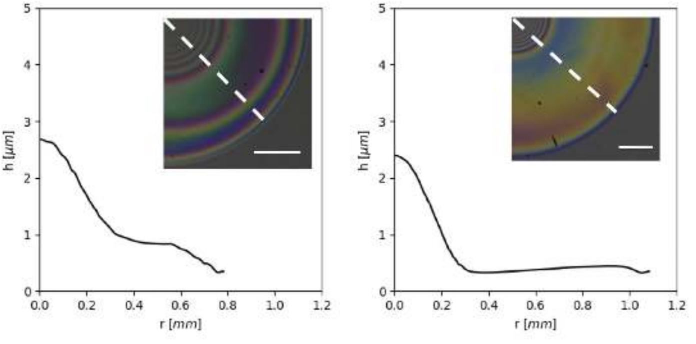
Currently, impact experiments are performed for a water droplet (D = 2 mm and v = 0.22 and 0.38 m/s) bouncing over freshly cleaved (i.e. dry and smooth) mica surfaces.

Dissertations
-

Scientific Publications
-



Top row: Side view visualizations of a water drop bouncing over a silicone oil film (Scale bar represents 2.5 mm). Bottom row: Surface deformations of the film caused by drop bouncing. Parameters: v = 0.22 m/s, η = 100 mPa.s and h = 10 μm



Left column: Drop deformation at v = 0.22 m/s. Right column: Drop deformation at v = 0.38 m/s. Insets: Corresponding color interferometry images (Scale bars represents 0.25 mm).

Project Aim

When suspended particles are pushed by liquid flow through a constricted channel they might either pass the bottleneck without trouble or encounter a permanent clog that will stop them for- ever. But they might as well flow intermittently with great sensitivity to the neck-to-particle size ratio D/d. In this work, we experimentally explore the limits of the intermittent regime for a dense suspension through a single bottleneck as a function of this parameter. To this end, we make use of high time- and space-resolution experiments to obtain the distributions of arrest times between successive bursts.

Progress

The time-distributions compare well with the ones found for as disparate situations as the evacuation of pedestrians from a room, the entry of a flock of sheep into a shed or the discharge of particles from a silo. Nevertheless, the intrinsic properties of our system seem to introduce a sharp transition from a clogged state (power-law exponent below two) to a continuous flow, where clogs do not develop at all. This contrasts with the results obtained in other systems where intermittent flow, with power-law exponents above two, were obtained.

Dissertations

-

Scientific Publications

-

Project leaders

Alvaro Marin

Research theme

Complex dynamics of fluids

Participants

Alvaro Marin, Mathieu Souzy

Cooperations

Iker Zuriguel (Univ. Navarra, Spain)

Funded by

University of Twente, European Research Council

Funded %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	50 %
Scholarships	-

Start of the project

2017

Information

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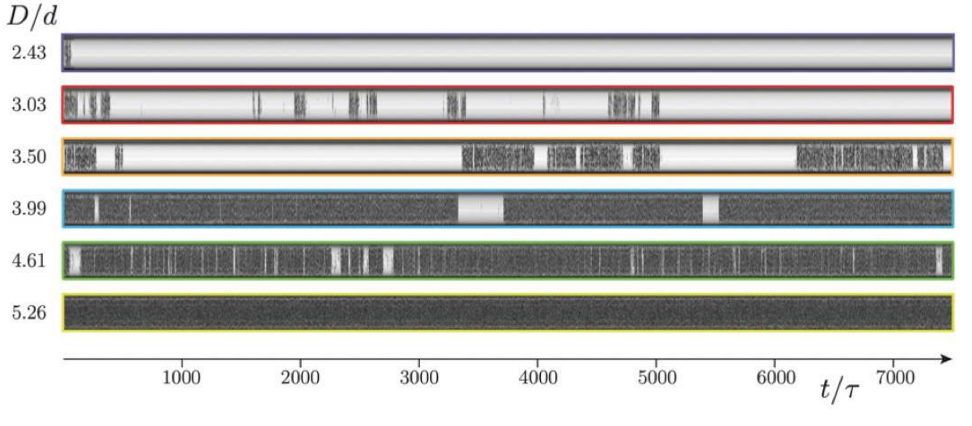

Project leaders
Alvaro Marin
Research theme
Complex dynamics of fluids
Participants
Alvaro Marin
Cooperations
Stefan Karpitschka, Diego Noguera-Marín, Miguel A. Cabrerizo-Vílchez, Massimiliano Rossi, Christian J. Kähler, Miguel A. Rodríguez Valverde
Funded by
European Research Council
Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2015
Information
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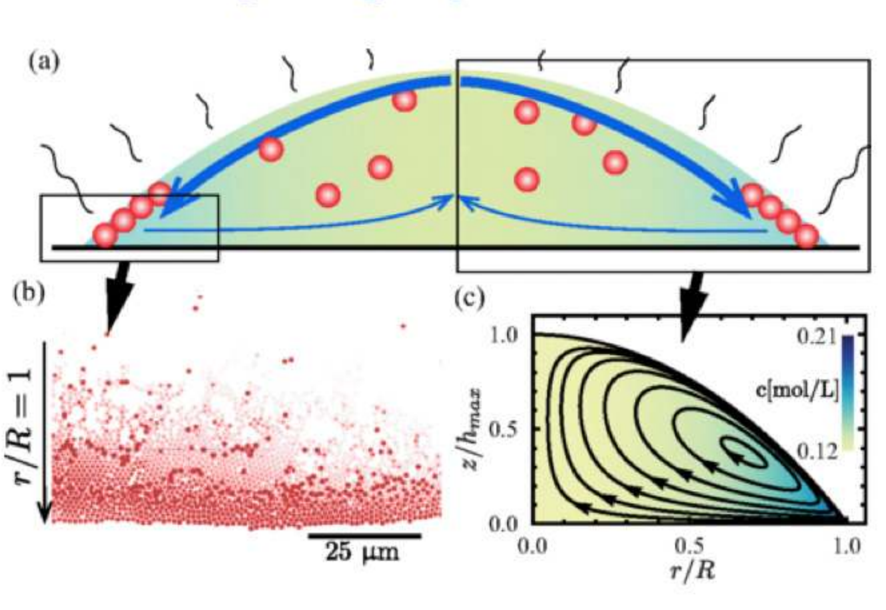
Project Aim
Evaporating salty droplets are ubiquitous in nature, in our home and in the laboratory. Interestingly, the transport processes in such apparently simple systems differ strongly from evaporating "freshwater" droplets since convection is partly inverted due to Marangoni stresses. Such an effect has crucial consequences to the salt crystallization process and to the deposits left behind.

Progress
In this work we show unprecedented measurements that, not only confirm clearly the flow inversion, but also elucidate their impact on the distribution of nonvolatile solutes. Contrary to what has been often reported in the literature, such a flow reversal does not prevent the formation of ring-shaped stains: particles accumulate at the contact line driven solely by the interfacial flow. We can therefore conclude that the classical "coffee-stain effect" is not the only mechanism that can generate ring-shaped stains in evaporating droplets.

Dissertations
-

Scientific Publications

1. Solutal Marangoni flow as the cause of ring stains from drying salty colloidal drops. Alvaro Marin, Stefan Karpitschka, Diego Noguera-Marín, Miguel A. Cabrerizo-Vílchez, Massimiliano Rossi, Christian J. Kähler, and Miguel A. Rodríguez Valverde. Phys. Rev. Fluids 4, 041601(R) – Published 29 April 2019



Fundamental fluid dynamics challenges in inkjet printing (FIP)

Project Aim

The main scientific goal of the program is to create insight in unresolved issues in the current inkjet printing processes and to improve and extend the functionality of the inkjet printing to meet future requirements. The functional modeling of the inkjet printing process not only concerns the numerical simulations but also the physical theory, which explains the results, and the experiments, which validate the results. The topics investigated range from piezo actuators, printhead dynamics, and jetting to droplet evaporation and absorption of ink in porous media.

Progress

Meanwhile all FIP positions are filled and a lot of related side projects are involved. We've published papers on a wide variety of topics related to inkjet printing. It has been revealed that particles in the ink induce nozzle failure through bubble nucleation (a). The formation of cascading structures in the final stage before the pinch-off of ink jets has been studied (b). Related to evaporation, we've shown that surfactant laden droplet evaporation from hydrophobic surfaces is governed by substrate wettability modification though surfactant adsorption.

Dissertations

-

Scientific Publications

1. A. Fraters, M. van den Berg, Y. de Loore, H. Reinten, H. Wijshoff, D. Lohse, M. Versluis, and T. Segers. Inkjet nozzle failure by heterogeneous nucleation: bubble entrainment, cavitation, and diffusive growth. Physical Review Applied 12(6), 064019 (2019).
2. W. Kwieciński, T. Segers, S. Van Der Werf, A. Van Houselt, D. Lohse, H.J. Zandvliet, and S. Kooij. Evaporation of dilute sodium dodecyl sulfate droplets on a hydrophobic substrate. Langmuir 35(32), 10453-10460 (2019).
3. A. Fraters, T. Segers, M. van den Berg, H. Reinten, H. Wijshoff, D. Lohse, and M. Versluis. Shortwave infrared imaging setup to study entrained air bubble dynamics in a MEMS-based piezo-acoustic inkjet printhead. Experiments in Fluids 60(8), 123 (2019).
4. W.M. van der Kruk, S.A. Smit, T. Segers, X.M. Li, and C.H. Venner. Drop-on-Demand Printing as Novel Method of Oil Supply in Elastohydrodynamic Lubrication. Tribology letters 67(3), 95 (2019).
5. M. A. Hack, W. Tewes, Q. Xie, C. Datt, K. Harth, J. Harting, J. H. Snoeijer. Self-Similar Liquid Lens Coalescence. Submitted, (2019). arXiv:1912.06420.
6. D. Faasen, A. Jarray, H. J.W. Zandvliet, E. S. Kooij, W. Kwieciński. Hansen solubility parameters obtained via molecular dynamics as a route to predict siloxane surfactant adsorption. Submitted (2019).
7. H. Tan, C. Diddens, A. Mohammed, Y. Li, M. Versluis, X. Zhang, D. Lohse. Microdroplet nucleation by dissolution of a multicomponent drop in a host liquid, J. Fluid Mech., 870, 217-246, (2019).
8. Y. Li, C. Diddens, A. Prosperetti, K.L. Chong, X. Zhang, D. Lohse. Bouncing Oil Droplet in a Stratified Liquid and its Sudden Death, Phys. Rev. Lett. 122, 154502 (2019)
9. Y. Li, C. Diddens, P. Lv, H. Wijshoff, M. Versluis, D. Lohse. Gravitational Effect in Evaporating Binary Microdroplets, Phys. Rev. Lett. 122, 114501 (2019).
10. A. Gauthier, C. Diddens, R. Proville, D. Lohse, D. van der Meer. Self-propulsion of inverse Leidenfrost drops on a cryogenic bath. Proc. Natl. Acad. Sci. U. S. A., 116(4), 1174-1179, (2019).

Project leaders

Detlef Lohse

Research theme

Complex dynamics of fluids

Participants

Detlef Lohse, Michel Versluis, Jacco Snoeijer, Tim Segers, Christian Diddens, Michiel Hack, Maaike Rump, Wojtek Kwiecinski, Yaxing Li, Yogesh Jethani, Uddalok Sen, Martin van den Broek, Hans Reinten, Herman Wijshoff, Marc van den Berg, Youri de Loore

Cooperations

University of Twente, Technical University of Eindhoven, Océ Technologies B.V.

Funded by

NWO and Océ Technologies B.V. (A Canon company)

Funded %

University	10 %
FOM	-
STW	-
NWO Other	45 %
Industry	45 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

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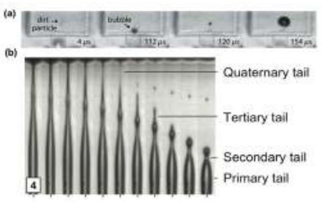

PROJECT LEADERS
Michel Versluis

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Tim Segers, Benjamin van Elburg, Sarah Cleve, Ali Rezaei, Saeed Saleem, Nathan Blanken, Charlotte Nawijn, Guillaume Lajoinie

COOPERATIONS
University of Gent (Belgium), Bracco (Geneva), University of Delft, UMC Utrecht, Oxford University (UK), Universite de Grenoble (France), University of Colorado (USA), INRIA institute (France), University Hospital of Nice (France), University of Cambridge (UK), NTNU Trondheim

FUNDED BY
Univ Twente, 4TU Precision Medicine, NWO, EU, Connecting Industry TKI

FUNDED %

University	10 %
FOM	-
STW	62 %
NWO Other	-
Industry	13 %
TNO	-
GTI	-
EU	15 %
Scholarships	-

START OF THE PROJECT
2015

INFORMATION
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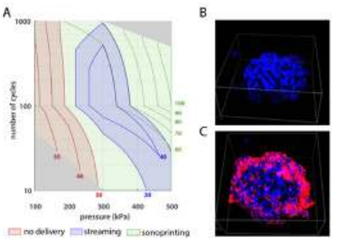

A. Drug delivery regimes (no delivery, delivery by microstreaming or delivery by sonoprinting) for loaded microbubbles on cell monolayer as a function of the ultrasound parameters. B. Drug delivery on a tumor cell clump (in blue) using liposomes (red). C. Drug delivery on a tumor cell clump when the liposomes are loaded onto a microbubble.

PROJECT AIM

This project aims at understanding, on a fundamental level, the interaction of ultrasound and tissues and the behavior of bubbles and cavitation agent when exposed to ultrasound or light. Subsequently, we use this new understanding to develop novel applications for medical imaging and therapy.

PROGRESS

We have demonstrated the feasibility of using laser-activated cavitation agents for multimodal (ultrasound/ photoacoustic) imaging. We have refined our capacity to produce highly controlled monodisperse bubbles, giving us the means to better use their nonlinear response in practice. We have achieved new understanding of the interaction of drug-loaded microbubbles with cells, first by showing the different interaction regimes between bubbles and cell monolayers and then by demonstrating the therapeutic efficacy of bubbles on larger, 3D, cell constructs.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. M. Versluis, E. Stride, G. Lajoinie, T. Segers, B. Dollet, Ultrasound Contrast Agents Modeling, Ultrasound in Medicine & Biology.
2. S. Roovers, J. Deprez, D. Priwitaningrum, G. Lajoinie, N. Rivron, H. Declercq, O. De Wever, E. Stride, S. Le Gac, M. Versluis, J. Prakash, S.C. De Smedt, I. Lentacker, Sonoprinting liposomes on tumor spheroids by microbubbles and ultrasound, JCR 316 (2019).
3. G. Lajoinie, O. Koshkina, F. B. Bombelli, E. Swider, L. J. Cruz, P. B. White, R. Schweins, Y. Dolen, E. van Dinther, N. K. van Riessen, S. E. Rogers, R. Fokkink, I. K. Voets, E. R. H. van Eck, A. Heerschap, M. Versluis, C. L. de Korte, C. Figdor, I. J. M. de Vries & M. Srinivas, Multicore Liquid Perfluorocarbon-Loaded Multimodal Nanoparticles for Stable Ultrasound and 19F MRI Applied to In Vivo Cell Tracking, Adv. Funct. Mater., 1806485 (2019).
4. M. de Matos, R. Deckers, E. van Elburg, G. Lajoinie, B.S. de Miranda, M. Versluis, R. Schiffelers and R. J. Kok, Ultrasound-Sensitive Liposomes for Triggered Macromolecular Drug Delivery: Formulation and In Vitro Characterization, Frontiers in pharmacology 10, 1463 (2019).
5. S. Roovers, G. Lajoinie, I. De Cock, T. Brans, H. Dewitte, K. Braeckmans, M. Versuis, S. C. De Smedt, I. Lentacker, Sonoprinting of nanoparticle-loaded microbubbles: Unraveling the multi-timescale mechanism, Biomaterials 217, art. no. 119250, (2019).
6. S. Roovers, T. Segers, G. Lajoinie, J. Deprez, M. Versluis, S. De Smedt, & I. Lentacker, The Role of Ultrasound-Driven Microbubble Dynamics in Drug Delivery: From Microbubble Fundamentals to Clinical Translation, Langmuir (2019).
7. M. Visscher, G. Lajoinie, E. Blazejewski, G. Veldhuis and M. Versluis, Laser-activated microparticles for multimodal imaging: ultrasound and photoacoustics, Physics in Medicine & Biology 64 (3) (2019).
8. T. Segers, A. Lassus, P. Bussat, E. Gaud and P. Frinking, Improved coalescence stability of monodisperse phospholipid-coated microbubbles formed by flow-focusing at elevated temperatures, Lab Chip 19, 158-167 (2019).

Multiphase flows, enhanced scalar mixing in bubbly flows and investigating the fundamental nature of rising particles

Project Aim

Both solid particle and bubbles are a common to both natural and industrial flows and are often of primary importance. In this project we approach this project from two directions: firstly, focusing on the industrial applications of enhancing mixing of a passive scalar (e.g. temperature) by means of bubbles or other types of particles which can affect turbulence at its core. Secondly, we investigate the fundamental behavior of light particles in an effort to better model and understand the behavior of these objects, we investigate particle geometry and mass distribution in an effort to determine the importance of all relevant parameters.

Progress

Using the Twente Mass and Heat Transfer Tunnel a turbulent channel flow can be created with a large scale temperature gradient (a thermal mixing layer). The power spectrum densities of the temperature fluctuations, figure 1a, were found to have steeper slopes with increasing gas volume fractions, implying that the small spacial gradients are effectively being smoothed out by the bubble induced mixing. The bubbles are tracked for statistical analysis of velocities and bubble sizes as shown in Fig. 1b. Effects of geometry and mass distribution were investigated for light solid particles an example of an oblate ellipsoid rising, shown in figure 1c.

Dissertations

-

Scientific Publications

1. B. Gvozdić, O.-Y. Dung, D. P. M. van Gils, G.-W. H. Bruggert, E. Alméras, C. Sun, D. Lohse and S. G. Huisman. Twente mass and heat transfer water tunnel: Temperature controlled turbulent multiphase channel flow with heat and mass transfer. Rev. Sci. Instrum. 90, 075117 (2019).

Project leaders

Detlef Lohse, Chao Sun

Research theme

Complex dynamics of fluids

Participants

Jelle Will, On-Yu Dung, Willem Pieter Waasdorp , Dominik Krug, Sander Huisman

Cooperations

-

Funded by

-

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

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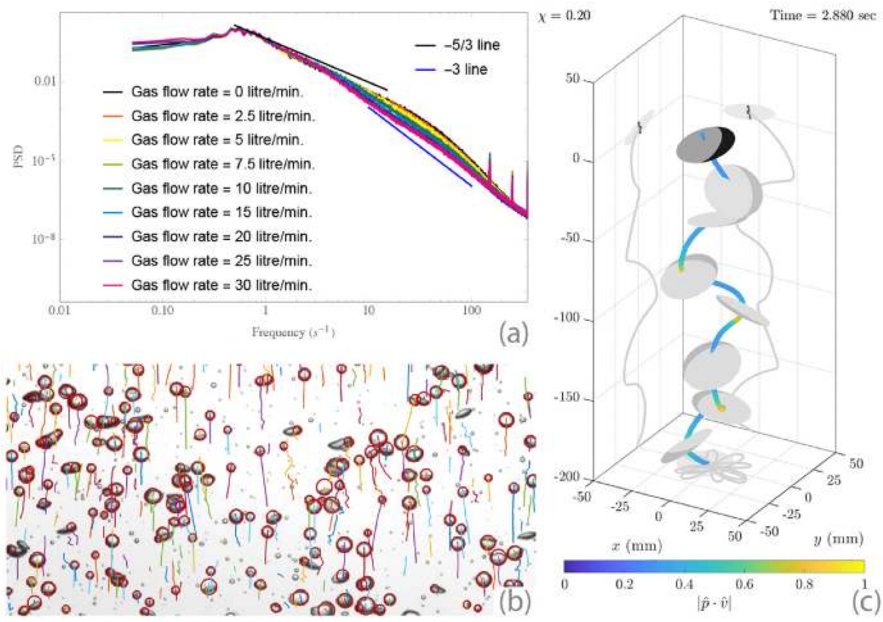

Blood flow and endovascular stenting, comparative in-vivo and in-vitro studies

Project leaders
M Versluis, M Reijnen

Research theme
Complex dynamics of fluids

Participants
M Mirgolbabaee, M van Helvert, L van de Velde, S Engelhard, G Lajoinie, E Groot Jebbink

Cooperations
Rijnstate hospital Arnhem
Erasmus medical center,
Radboudumc

Funded by
University, Industry, NWO

Funded %

University	20 %
FOM	-
STW	30 %
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2013

Information
Erik Groot Jebbink
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Project Aim

A large number of clinical studies report about the performance of endovascular stent placement. However, no tools are available to measure and report about the important local interaction between blood flow and stents. In order to improve the outcome of treatment a more profound insight in local hemodynamics is desirable, which can augment treatment planning and follow-up, as well as reduce the rate of reinterventions. The goal of this project is to combine observations of flow dynamics in patients with the results from in vitro studies, to gain insight in fluid mechanical mechanisms that are relevant for clinical planning and surveillance.

Progress

The first clinical trial has been completed, contrast enhanced high framerate (>1000) plane wave measurements were performed in 20 patients after endovascular treatment of stenotic lesions in the femoral arteries. Data analysis is currently performed and flow patterns will be linked to 1-year follow-up data. The second trial is still ongoing. In vitro models are being constructed to investigate limb occlusions after EVAR and to optimize our PIV methods. In addition a new line of research was initiated concerning the role of local hemodynamics during radio-embolization of liver tumors.

Dissertations

1. Simon Overeem - Geometrical changes of stent graft configurations after complex endovascular surgery.

Scientific Publications

1. Overeem, S. P., de Vries, J. P. P., Boersen, J. T., Slump, C. H., Reijnen, M. M., Versluis, M., & Jebbink, E. G. (2019). Haemodynamics in Different Flow Lumen Configurations of Customised Aortic Repair for Infrarenal Aortic Aneurysms. European journal of vascular and endovascular surgery, 57(5), 709-718.
2. Groot Jebbink, E., Holewijn, S., Versluis, M., Grimme, F., Hinnen, J. W., Sixt, S., ... & Reijnen, M. M. (2019). Meta-analysis of individual patient data after kissing stent treatment for aortoiliac occlusive disease. Journal of Endovascular Therapy, 26(1), 31-40.

Turning Drops into Bubbles: Cavitation by Vapor Diffusion through Elastic Networks

Project Aim

Some members of the vegetal kingdom can achieve surprisingly fast movements making use of a clever combination of evaporation, elasticity, and cavitation. In this process, enthalpic energy is transformed into elastic energy and suddenly released in a cavitation event which produces kinetic energy. Here, we study this unusual energy transformation by a model system: A droplet in an elastic medium shrinks slowly by diffusion and eventually transforms into a bubble by a rapid cavitation event.

Progress

The experiments reveal the cavity dynamics over the extremely disparate timescales of the process, spanning 9 orders of magnitude. We model the initial shrinkage as a classical diffusive process, while the sudden bubble growth and oscillations are described using an inertial-(visco)elastic model, in excellent agreement with the experiments. Such a model system could serve as a new paradigm for motile synthetic materials.

Dissertations

-

Scientific Publications

1. Turning Drops into Bubbles: Cavitation by Vapor Diffusion through Elastic Networks. M.A. Bruning, M. Costalonga, J.H. Snoeijer, and A. Marin Phys. Rev. Lett. 123, 214501 – Published 19 November 2019.

Project leaders

Alvaro Marin

Research theme

Complex dynamics of fluids

Participants

Myrthe Bruning, Maxime Costalonga, Jacco H. Snoeijer, Alvaro Marin

Cooperations

-

Funded by

European Research Council

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2017

Information

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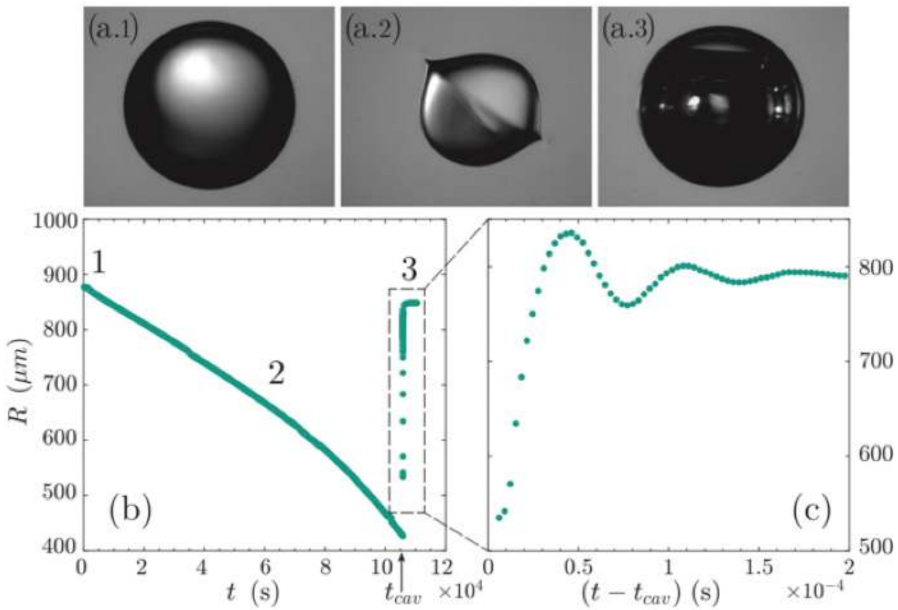

PROJECT LEADERS
Devaraj van der Meer, Detlef Lohse
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Utkarsh Jain
COOPERATIONS
MARIN, NL
FUNDED BY
SLING programme, STW Perspectief
FUNDED %

University	-
FOM	-
STW	65 %
NWO Other	-
Industry	35 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2016
INFORMATION
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PROJECT AIM

To understand the role of free surface instabilities in

- sloshing of liquids close to their boiling temperature.
- hydrodynamic loading on a solid structure.

PROGRESS

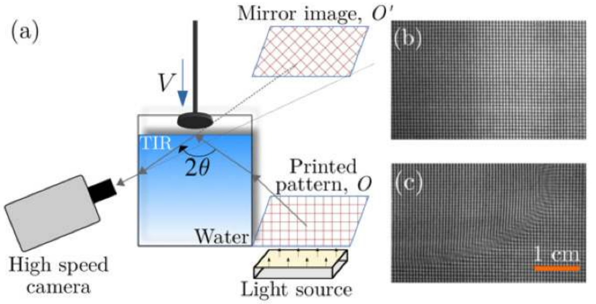
Air cushioning under a disc impacting on water deflects the water surface before any contact is made between the two. We developed a method (total internal reflection - deflectometry) to measure these deflections. The water surface under the disc centre is monotonically pushed down due to stagnation point flow created by the air flow under the disc (figure 2). The process is reproduced using 2-fluid potential flow boundary integral (BI) simulations and analytical modelling. Under the disc's edge, the escaping air velocity assumes its largest velocity and creates a suction on the free surface. We show the suction on the free surface is initiated by a Kelvin-Helmholtz instability. The water surface's behaviour before impact results in air being trapped on the disc at impact. This has consequences on hydrodynamic loading on the disc. Local pressures and forces on the disc due to impact were measured. These were used to calculate the impact impulse and elucidate on the role of added mass effect in being the main contribution to the loading. The force and pressure impulses compared very well with theory.

DISSERTATIONS

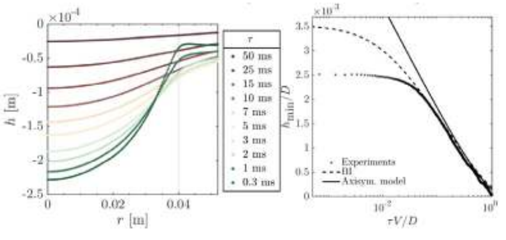
-

SCIENTIFIC PUBLICATIONS

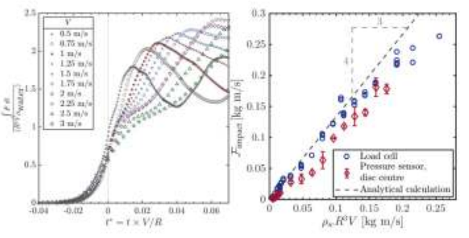
1. U. Jain, M. Jalaal, D. Lohse, D. van der Meer. Deep pool water-impacts of viscous oil drops. Soft Matter 15(23), pp.4629-4638.



Visualisation method using total internal reflection at the water interface



Left panel: Azimuthally averaged free surface profiles of water before impact obtained using an 80 mm wide disc. Right panel: comparisons of the depression of free surface with simulations and theory.



Left panel: force impulses non-dimensionalised by inertial scales. Right: Dimensional comparisons of force and pressure impulses with theory for a disc.

Prof.dr. F Mugele

Mission

The goal of the PCF group is to understand and control the structure and the mechanical properties of liquids and interfaces on length scales ranging from molecular to submillimeter scales. The activities fall in three main categories: i) nanofluidics, ii) (electro)wetting & microfluidics, iii) soft matter mechanics. Our nanofluidics research focuses on understanding the range of validity of macroscopic continuum physics and in its breakdown upon approaching molecular scales, where physico-chemical aspects become increasingly important. In microfluidics, many properties of fluids, in particular drops, are controlled by interfacial effects. By patterning surfaces surfaces and in particular by making use the electrowetting effect we control the shape, the motion, and the generation of microdrops. These processes involve various challenging fundamental issues, such as contact angle hysteresis, the dynamics of contact lines, and hydrodynamic singularities. The soft matter mechanics activities focus on correlations between the internal structure of various types of complex fluids ranging from colloidal suspensions to living cells and their macroscopic viscous and elastic properties.

By improving the physical understanding of fundamental phenomena we contribute to the improvement of various technological processes involving fluid motion on small scales, including oil recovery, immersion lithography, and inkjet printing. This work is frequently carried out in collaboration with industrial partners including BP, Shell, ASML, Océ, Liquavista, sometimes within government sponsored consortia such as FOM-IPPs, sometimes in direct collaboration. A major project on enhanced oil recovery started in late 2009 and became fully operational in 2010. In this context, the group intensified its activities in the area of physical chemistry of liquid-liquid and solid-liquid interfaces. In late 2010, Prof. Mugele obtained a NWO-VICI grant to investigate the properties of superhydrophobic surfaces that are functionalized by electric fields. One major goal of the project is to explore various applications of such smart surfaces for microfluidics, ultrasound detection, and in particular optofluidics.

Hydration forces: A study of interaction forces using Atomic Force Microscopy

Project Aim

To aim of the project is to study the interaction forces at solid-liquid interfaces, where we are interested in the effect of the adsorption of specific ions of different hydration properties. At highly charged, hydrophilic surfaces such as mica, water molecules tend to orientated themselves strongly, resulting in layering of water that we can probe as oscillatory hydration forces. We study how the adsorption of ions, of different hydration properties, affect the structural hydration force.

Progress

We demonstrate that hydration forces consist of a superposition of a monotonically decaying and an oscillatory part, each with a unique dependence on the specific type of cation. The monotonic hydration force gradually decreases in strength with decreasing bulk hydration energy leading to a transition from an overall repulsive (Li+, Na+) to an attractive (Rb+, Cs+) force. The oscillatory part, in contrast, displays a binary character, being hardly affected by the presence of strongly hydrated cations (Li+, Na+), but becoming completely suppressed in presence of weakly hydrated cations (Rb+, Cs+), in agreement with a less pronounced water structure in MD simulations.

Dissertations

-

Scientific Publications

1. Ion-Specific and pH-dependent Hydration of Mica-Electrolyte interface. van Lin, S.R., Grots K.K., Siretanu, I., Mugele, F. Langmuir, 2019 april. doi: 10.1021/acs.langmuir.9b00520.

Project leaders

Frieder Mugele

Research theme

Complex dynamics of fluids

Participants

S.R. van Lin, Dr. I. Siretanu, Prof. Dr. Frieder Mugele

Cooperations

BP

Funded by

NWO, BP

Funded %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

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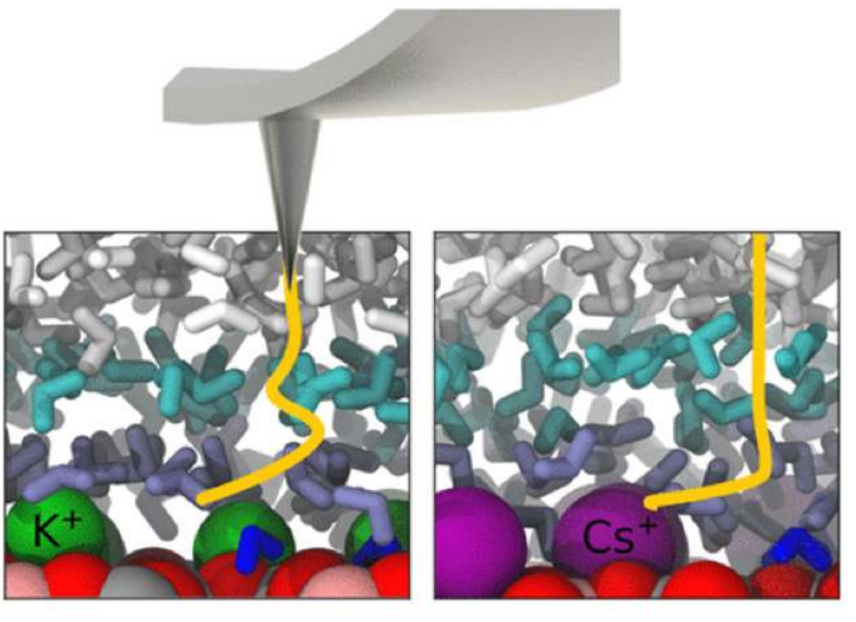

MicroGrease: understanding the relation between the microstructure of lubricating grease and its oil-separation properties

Project leaders
F Mugele

Research theme
Complex structures of fluids

Participants
Q. Zhang, dr. D. van den Ende,
Prof.dr. F. Mugele, Prof.dr.ir. P.M. Lugt

Cooperations
Laboratory of Surface Technology and Tribology

Funded by
NWO, SKF

Funded %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017

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Project Aim

Lubricating grease, the most common lubricant for rolling bearings, consists of a thickener matrix and mobile base oil. This base oil is slowly released from the grease and provides the bearing with a thin film that separates the contacting surfaces, giving the bearing a long operational life. This project aims at understanding the relationship between the material properties/microstructure of the grease, its oil-separation (also called bleeding) properties and the film formation in the bearing contact. A model will be developed to describe the bleeding of grease under static and dynamic conditions.

Progress

A model system is developed to study oil release (i.e. bleeding) of static grease in bearing housings and implemented to test the bleeding properties of different types of commercial greases. This method uses a Washburn-like model to determine the wetting affinity of grease's base oil for the grease thickener network. Using this method, we also look into two major changes that greases undergo in the bearing: oil depletion and mechanical aging. Our preliminary results shows that oil depletion and the very-early-stage mechanical aging changes greases bleeding properties significantly (see Fig. 1 below).

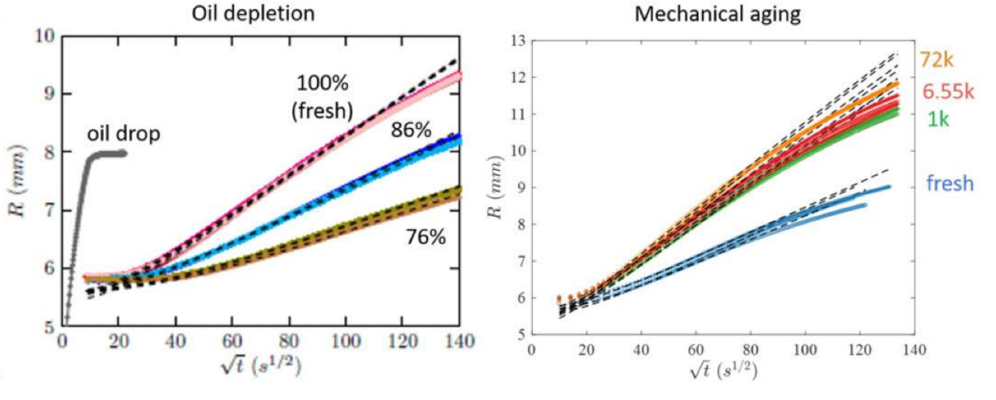
Dissertations

-

Scientific Publications

-

Bleeding of fresh and partially depleted polyurea grease with relative oil contents of 86% and 76% (left panel); and mechanically aged greases in an in-house grease worker for 1, 6.66 and 72 thousand strokes (right panel).



Confocal Raman platform to study the mechanism of enhanced oil recovery

Project Aim

The aim is to develop a confocal Raman imaging platform to study the mechanism of enhanced oil recovery. It has been widely accepted that wettability alteration is a major mechanism. However, the molecule details remain unclear. We need a method that can characterize the wettability alteration, and spontaneously characterize the chemistry that leads to the wettability alteration. vibrational spectroscopy offers unique access to the chemical composition of materials. Confocal spectroscopic microscopy further offers three dimensional (3D) spatial resolution down to submicron scale. These properties suggest that confocal Raman microscopy could be promising platform.

Progress

The potential of Raman microscopy is severely hindered by its low throughput We developed an algorithm improved confocal Raman microscopy that increases the Raman imaging speed by one to two orders of magnitude1. Briefly, we first collect spectra with an electron multiplying CCD at high scanning speed. This results in “noisy” spectra with a signal to noise ratio below one. Then we recover the faint signal with the help of an algorithm named principal component analysis (PCA) (figure below).Building on this technique, we observed the wettability alteration in response to low salinity in the microscopic scale for the first time, supporting the Multi-ion-exchange mechanism.

Dissertations

-

Scientific Publications

1. Nair, S., Gao, J., Yao, Q., Duits, M. H., Otto, C., & Mugele, F. (2019). Algorithm improved high speed and non-invasive confocal Raman imaging of two-dimensional materials. National Science Review. nwz177.
2. Gao, J., Nair, S., Duits, M. H., Otto, C., & Mugele, F. (2019). Combined microfluidics–confocal Raman microscopy platform for studying enhanced oil recovery mechanisms. Journal of Raman spectroscopy 50, 996-1007.

Project leaders

Prof.dr. F. Mugele

Research theme

Complex dynamics of fluids

Participants

Jun Gao, Sachin Nair, Dr. Michael H. G. Duits, Prof.dr. F. Mugele

Cooperations

BP

Funded by

NWO/ BP

Funded %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

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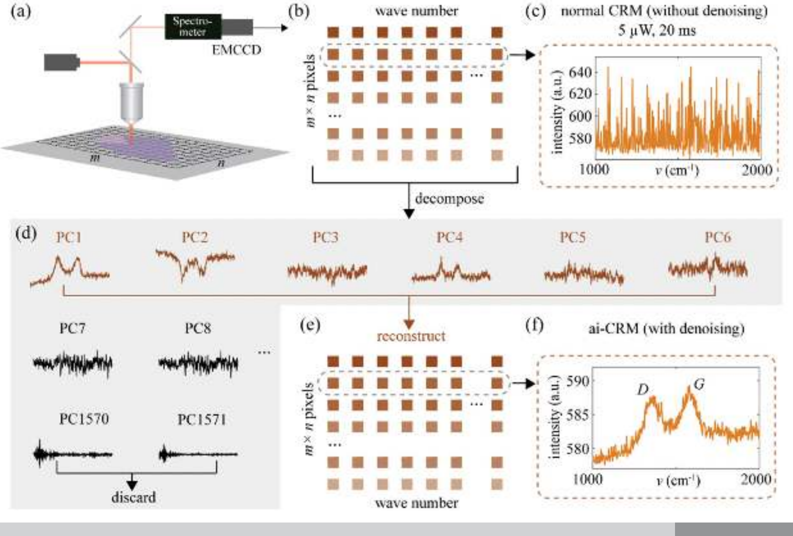

PROJECT LEADERS
Dr. Michael H. G. Duits
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Beybin Ilhan, Prof.dr. F. Mugele, Dr. Michael H. G. Duits, Prof.dr. S. Luding
COOPERATIONS
-
FUNDED BY
NWO
FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017
INFORMATION
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PROJECT AIM

Recently inter-particle roughness has been attributed to be the mechanism behind the discontinuous shear thickening behavior (ie., liquid to solid transition) of dense colloidal systems. Crucial prospect of this project is to observe the effect of roughness on such systems. Particles with tunable surface roughness will be employed to investigate the such effect in macro and micro scale experiments. The macroscopic behavior will be studied via rheology experiments and corresponding computer simulations of particulate systems. Fundamental micro scale mechanisms will be examined by means of the colloidal particle dynamics.

PROGRESS

We have developed a novel approach of using fluorescently labeled raspberry-like colloids with an optical anisotropy to concurrently track translational and rotational dynamics in 3D (Fig.1). The particles are coated by a silica layer of adjustable thickness, which allows tuning the surface roughness. We have validated our method with measurements of Mean Squared (Angular) Displacements (Fig.2.).The research is still ongoing in lines of dense colloidal systems. Particles will be employed in dense systems to observe effect of roughness in translational and rotational dynamics where rotational arrest due to frictional contacts among the particles is believed to become dominant.

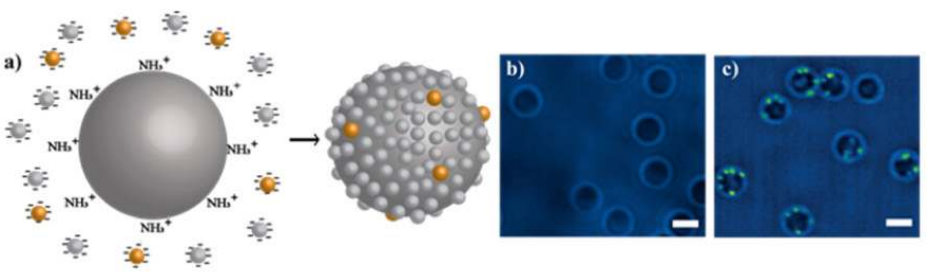
DISSERTATIONS

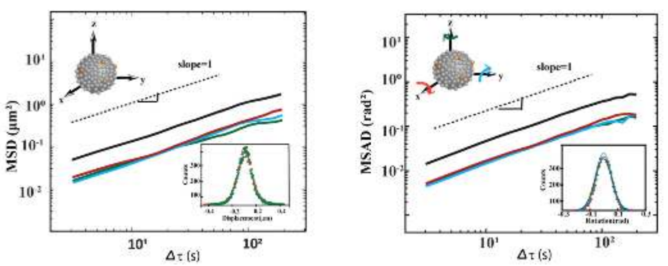
-

SCIENTIFIC PUBLICATIONS

-

a) Illustration of the synthesis of the probe raspberries. b, c) superimposed brightfield and fluorescence image of raspberry probes without/with fluorescent tracers (Scale bars are 2 □m).





MSD and MSAD versus lag time (solid black lines) for probes in water-glycerol solvent. Insets show decompositions along x, y and z for the MS(A)D, and for the displacement histograms. Color coding: red=x, blue=y, green=z.

Mesoscopic Characterization of oil-and-water thin film (de)wetting and adhesion

Project Aim

Understanding the mechanisms underlying low salinity water flooding enhanced oil recovery by using simplified model systems. Demonstrating the connection between macroscopic wettability and salinity-dependent thin film interactions.

Progress

We have looked into ion specific effects in brine/crude oil/mineral on its macroscopic wettability and microscopic mineral surface properties. These experiments are based on simpler systems used previously, where fatty acid-in-alkane solutions were used as the oil phase. We found that most of the ion-specific effects found in these simpler systems did not translated well into the newer crude oil systems, but one important conclusion did still hold: divalent cations, not overall ionic strength, is the most important factor in how the salinity affects macroscopic wettability, and it does so by influencing the adsorption of amphiphilic organic components to the mineral substrate.

Dissertations

1. Salinity-dependent wettability alteration: mimicking low salinity water flooding with model systems of varying complexity.

Scientific Publications

1. Haagh, Martin EJ, Nathalie Schilderink, Frieder Mugele, and Michel HG Duits. "Wetting of Mineral Surfaces by Fatty-Acid-Laden Oil and Brine: Carbonate Effect at Elevated Temperature." Energy & Fuels 33, no. 10 (2019): 9446-9456.

Project leaders

F Mugele

Research theme

Complex dynamics of fluids

Participants

Martin Haagh, Dr. Michael H. G. Duits
Prof.dr. F. Mugele

Cooperations

BP

Funded by

NWO, BP

Funded %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

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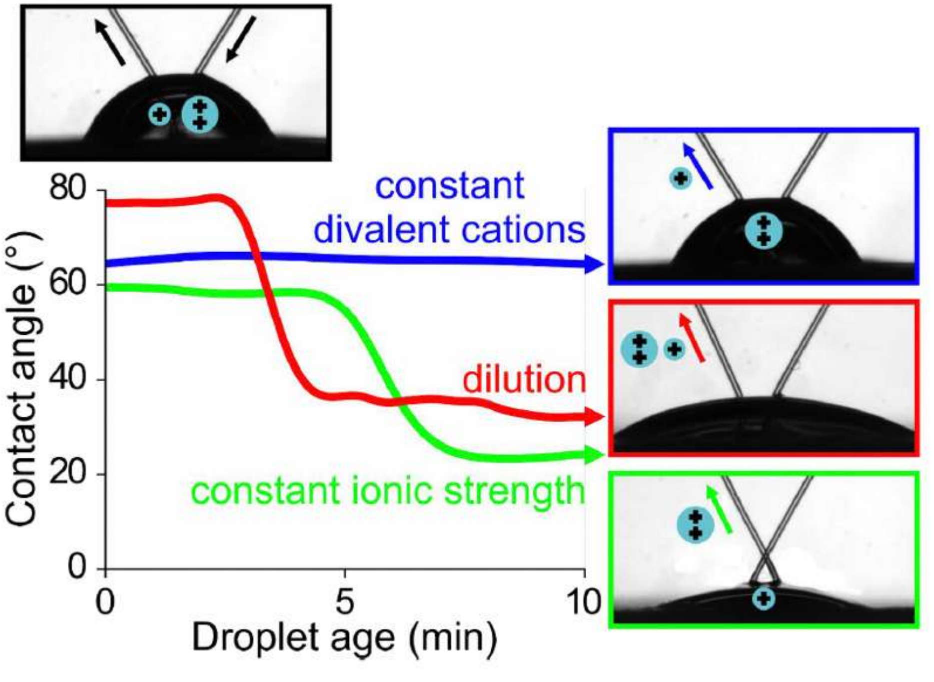

Distribution of inorganic and organic matter at solid-electrolyte interfaces studied by confocal Raman microscopy

Project leaders
Prof. Dr. Frieder Mugele

Research theme
Complex dynamics of fluids

Participants
Sachin Nair, Dr. Michael H. G. Duits, Prof.dr. F. Mugele, Dr. Jun Gao

Cooperations
BP

Funded by
NWO, BP

Funded %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017

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Project Aim

The goal of this project is to provide a chemical distribution map of specific adsorption-desorption phenomena in response to an external stimulus using confocal Raman imaging. Some of the investigated systems include a) investigating the release of oil droplets adhering to mineral substrate in response to lowered ambient brine salinity b) monitoring the release and reorganization of a surfactant coated on a mineral substrate in response to a lowered ambient brine salinity and (c) monitoring the adsorption of analyte molecules on graphene and characterizing their spatial distribution, using Raman imaging.

Progress

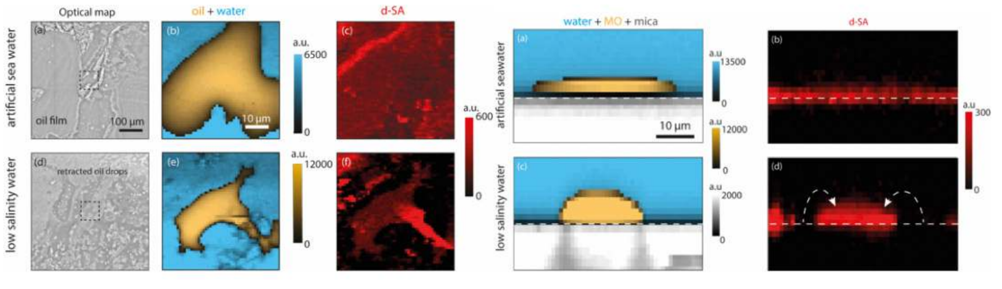
To make volumetric Raman imaging practical within a feasible time-scale, an algorithm-improved confocal Raman imaging (ai-CRM) technique was developed. This facilitated fast volumetric to probe the release and reorganization of a surfactant, and its consequent effect on the wettability alteration of a mineral substrate in response to lowered ambient brine salinity. XY Raman maps showed the retraction of oil films into droplets, reorganizing the underlying surfactant layer in the process, whereas XZ maps allowed for quantification of local microscopic contact angle and mapping the final destination of the released surfactant into the oil phase.

Dissertations

-

Scientific Publications

1. Gao, J.; Nair, S.; Duits, M. H.; Otto, C.; Mugele, F., Combined microfluidics–confocal Raman microscopy platform for studying enhanced oil recovery mechanisms. Journal of raman spectroscopy 2019.
2. Nair, S.; Gao, J.; Yao, Q.; Duits, M. H.; Otto, C.; Mugele, F., Algorithm-improved high speed and non-invasive confocal Raman imaging of two-dimensional materials. National Science Review 2019.



PROJECT AIM

Investigating the charge trapping phenomenon in electrowetting
Exploring the applications based on charge trapping phenomenon.

PROGRESS

1. Figured out the trapped charge distribution on fluoropolymer surface induced by electrowetting.

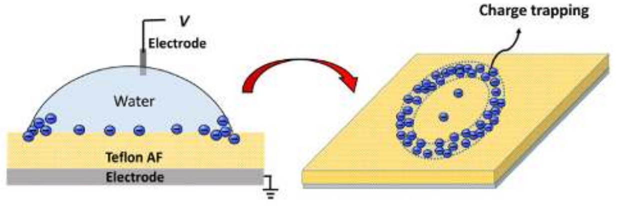
2. Proposed an electricity generator based on charge trapping phenomenon.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



PROJECT LEADERS

Frieder Mugele

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Hao Wu, Niels Mendel, Stijn van der Ham, Prof.dr. Guofu Zhou, Dr. Lingling Shui, dr. D. van den Ende, Prof.dr. F. Mugele

COOPERATIONS

South China Normal University

FUNDED BY

South China Normal University

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT

2017

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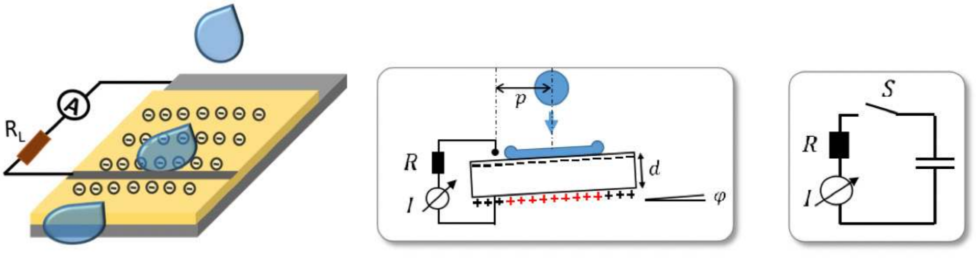

Soft matter, fluidics and interfaces

Prof.dr.ir. RGH Lammertink

Research within the Soft matter, Fluidics and Interfaces group is directed at interfacial phenomena and processes that are relevant for mass and heat transport. We wish to study and exploit fundamental principles where fluid flow encounters structures on a sub-millimeter length scale. Current topics of interest are:

Advanced microreactors

The fabrication and operation of dedicated microreactors, amendable to scaling are investigated. Multiphase reactor systems that incorporate membrane functionality to stabilize interfaces and perform separations are developed.

Soft interfaces

Liquid-liquid and gas-liquid interfaces are crucial in many chemical processes. Interfacial phenomena, including wetting behavior, interfacial tension (gradients), interfacial curvature, are studied to gain understanding in related transport processes near these interfaces.

Micro- and nanofluidics

This topic addresses liquid flow in confined geometries. Its relation to mass and energy transport are studied in both experimental and numerical ways. Special attention is given to boundary layer and concentration polarization phenomena.

Vici - Stirring boundary layer (Adaptive pores in next generation membranes)

Project Aim

In this project the application of a new type of membrane, i.e., slippery liquid-infused membranes (SLIMs) for separation of oil droplets from an oil-in-water (O/W) emulsion was investigated. The challenge was to permeate the dispersed phase (oil droplets) not the continuous phase (water) which required movement of oil droplets towards membrane. This was first studied based on gravity-assisted creaming [1]. To further accelerate the movement of oil droplets, an external field such as acoustic can be applied. Here, the acoustophoretic movement of oil droplets was studied in more details which can shed light on better design of acoustic separation systems [2].

Progress

The acoustophoretic behavior of monodisperse oil droplets (silicone oil and hexadecane) in aqueous surfactant solutions with different concentrations was studied in a microfluidic chip. Upon application of acoustic field, the oil droplets moved towards the pressure anti-nodes at the channel wall (see the following schematic). The acoustophoretic velocity of oil droplets were measured using particle image and tracking velocimetry (PIV and PTV). The results showed no dependency to surfactant concentration and time. Finally, an equation was obtained to relate the acoustic energy density to applied electric field and physical properties of transducer and medium.

Dissertations

-

Scientific Publications

1. Bazyar H., van de Beek N., Lammertink R. G. H., Liquid-infused membranes with oil-in-water (O/W) emulsions, Langmuir 2019, 35, 29, 9513-9520.

Project leaders

Prof.dr.ir. R.G.H. Lammertink

Research theme

Complex dynamics of fluids

Participants

H Bazyar

Cooperations

-

Funded by

NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

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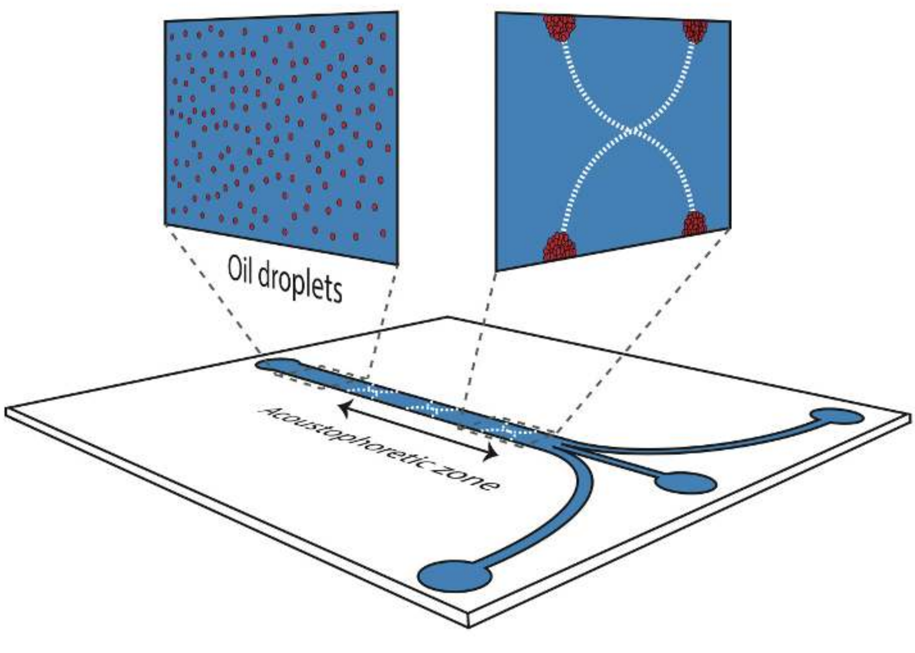

PROJECT LEADERS
Prof.dr.ir. R.G.H. Lammertink
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Abimbola Ashaju
COOPERATIONS
-
FUNDED BY
NWO
FUNDED %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017
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PROJECT AIM

Immobilized catalytic nano/micromotors are capable of generating interfacial driven fluid flow by electrochemical energy conversion having the potential of improving mass transport in areas impacted by boundary layer resistance within nano/microscale applications. A well-known system concerns the Au-Pt bimetallic motor driven by hydrogen peroxide conversion. Despite this advancement, some issues still limit the practical usage of an immobilized nano/micromotor, especially its low energy conversion. Understanding the fundamental parameters that drives the electrocatalytic reaction is necessary to fully exploit the electrocatalytic reaction driven flow for relevant applications.

PROGRESS

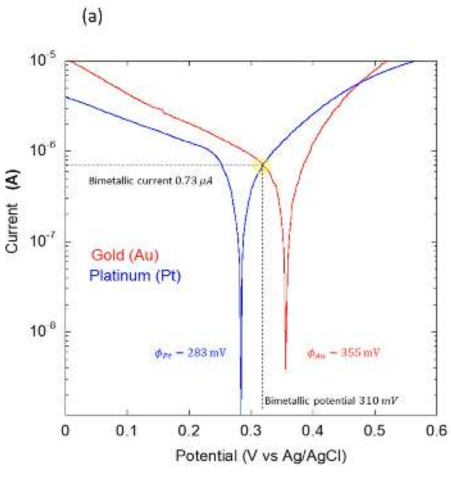
The electrochemical behavior of an immobilized electrocatalytic system was characterized through voltammetric TAFEL analysis (Fig. 1a) and direct potential measurement. Using particle tracking velocimetry we visualized the electro-hydrodynamic response of the system and quantified the induced convective fluid flow, which is influenced by the electrolyte concentration and pH (Fig. 1b). Based on our experimental observations. A 2D numerical model that couples Poisson–Nernst–Planck, and Navier–Stokes equations is formulated to solve for the potential, concentration and velocity field with our experimental electrochemical data as parameter input. Our numerical model advances existing numerical work by the inclusion of electrodes zeta potential that was measured experimentally under varying pH conditions, and electrolyte effects.

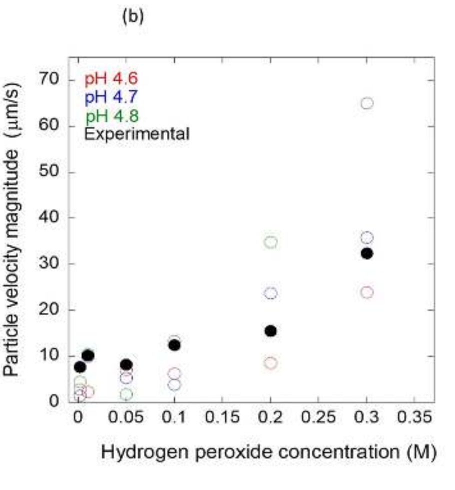
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-





(a) Tafel analysis for Pt and Au electrodes in 0.325 M H_2O_2 (b) Tracer particles velocity driven by the electrocatalytic induced fluid flow

Project Aim

Diffusio-osmotic flow is a surface induced velocity which origins from concentration gradients parallel to an interface. These concentration gradients can be induced by, for example, chemical reactions. The aim of this project is to study the impact and origin of diffusio-osmotic flow. Numerical simulations are used to study a wide variety of parameters, indicating the impact of diffusio-osmosis. Input parameters for the numerical study are determined experimentally.

Progress

In order to study diffusio-osmosis, a more elaborate knowledge about the system is needed. The system consists of a microchannel with titanium dioxide sputtered at the bottom, which functions as photocatalyst and is externally activated by a UV-LED lamp. Kinetics of several compounds is studied in this system in order to use the kinetics in the numerical study. The numerical study confirms that concentration gradients, induced by the catalytic surface reaction, are able to generate flows that enhance the mass transport (see illustration below).

Dissertations

-

Scientific Publications

-

Project leaders

Rob Lammertink

Research theme

Complex dynamics of fluids

Participants

Nicole Timmerhuis

Cooperations

-

Funded by

NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

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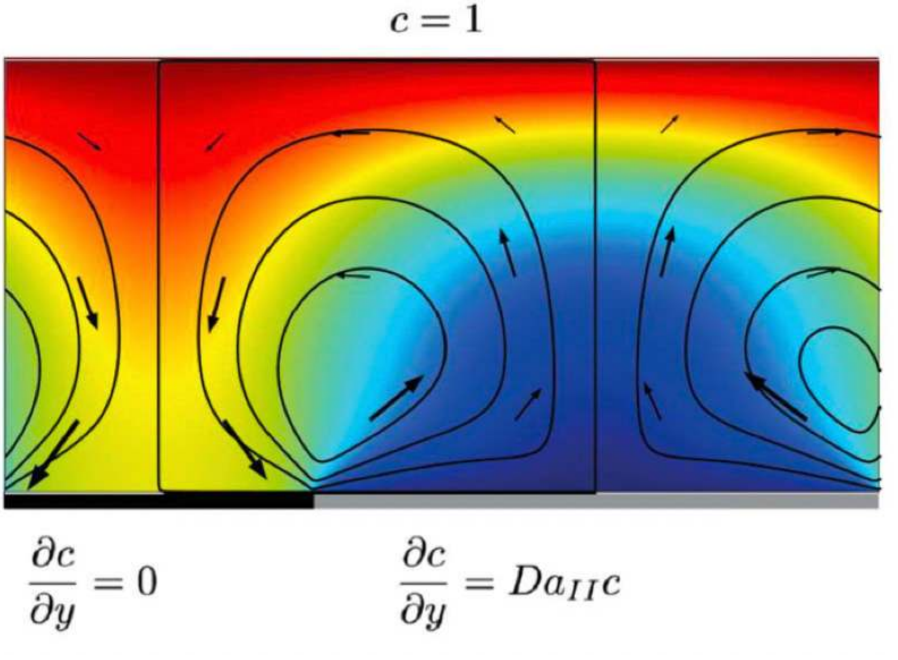

GasDrive

Project leaders
Rob Lammertink, Detlef Lohse
Research theme
Complex dynamics of fluids
Participants
Pim Bullee
Cooperations
-
Funded by
NWO
Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016
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Project Aim

This project aims at achieving high drag reduction by combining superhydrophobic surfaces with bubble injection in fully developed turbulent flows. A practical implementation of this is in the naval industry, where skin friction reduction is of great economic and environmental importance.

When gas bubbles are injected near the hull of a ship, they tend to move away from its surface. This is caused by turbulent velocity fluctuations and near-wall shear. It is therefore highly desirable to have a coating on the ship hull that can 'grab' these bubbles. This will effectively reduce the loss of gas to the surrounding turbulence.

Progress

Measurements of air bubble drag reduction (DR) at Reynolds numbers between 0.5 and 1.8 million with surface roughness similar to heavy marine fouling, showed that the roughness actually has a positive influence of the air bubble drag reduction. Of course, less drag is found for a smooth surface with air bubble DR, but compared to a rough surface without air bubbles, the addition of air bubbles to the flow has a larger effect. A novel design of drag reducing surfaces that are the product of lithographic etching are being studied and show very promising results in terms of gas-liquid interface stability and large slip velocities at the surface.

Dissertations

-

Scientific Publications

1. Bullee, P. A., Verschoof, R. A., Bakhuis, D., Huisman, S. G., Sun, C., Lammertink, R. G. H., & Lohse, D. (2020). Bubbly drag reduction using a hydrophobic inner cylinder in Taylor–Couette turbulence. Journal of Fluid Mechanics, 883, 125. http://doi.org/10.1103/PhysRevLett.105.166104.

Project Aim

This research seeks to elucidate the synergy between membrane separation and photocatalytic oxidation. The aim is to combine membrane and catalyst functionality within a single material. The beneficial synergy expected from having these two functions present at a single location will be studied experimentally and with a transport model. A reactive membrane is expected to reduce the concentration polarization and biofouling layers via the chemical conversion of reactants. Furthermore, photocatalytic degradation of contaminants in water is considered a viable method to remove micropollutants and inactivate viruses.

Progress

Photocatalytically active membranes were fabricated and tested to refine a 1D transport model. The combination of membrane filtration and photocatalytic oxidation showed a remarkable reduction of the concentration polarization. The model contains the membrane function (rejection, □) and the photocatalytic degradation (reaction, Da) including light distribution at different filtration rates (Pe).

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. R.G.H. Lammertink

Research theme

Complex dynamics of fluids

Participants

Shuyana Heredia Deba

Cooperations

-

Funded by

Wetsus

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

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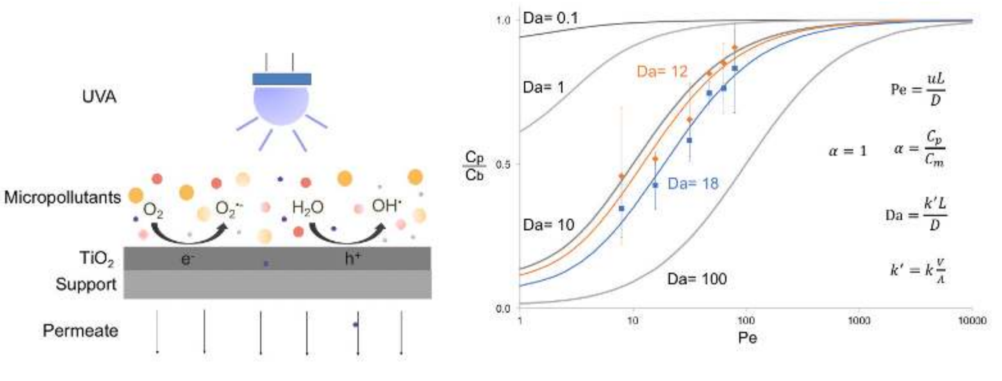
Schematic view of the process in the membrane (left). Filtration rate vs. outlet concentration. Model predictions for permeate concentration and results fitting (right).
When using lower flows, there is more time for the photocatalytic oxidation to take place and therefore the outlet concentration is also lower.



Ion transport through perforated graphene membrane.
FLAG-ERA - (NU-TEGRAM)

Project leaders
Rob Lammertink
Research theme
Complex dynamics of fluids
Participants
Mandakranta Ghosh
Cooperations
-
Funded by
FOM
Funded %

University	-
FOM	100 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016
Information
Rob Lammertink
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Project Aim

In this project we investigate the ion transport mechanism through two dimensional nanoporous interfaces of graphene. Nanopores in graphene are created by ion beam bombardment. Our project aim is to have the fundamental understanding of ion transport through this 2D interface related to the graphene structure and surface properties.

Progress

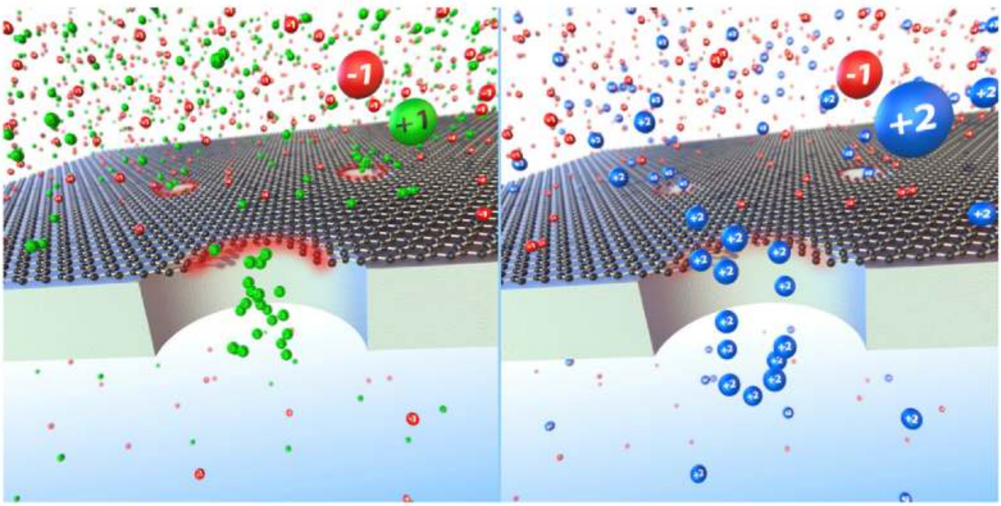
We have studied the transport of ions through the nano-pores in graphene by measuring its membrane potential generated due to diffusion of ions from high to low concentration across the membrane. Our study shows that the membrane is selective to cations. This means that the membrane prefers the cations to pass through and blocks the anions. The membrane potential varies with the concentration which can be explained by charge screening effects. We have explained our experimental result with theoretical analysis and numerical modeling.

Dissertations

-

Scientific Publications

1. Ion transport through perforated graphene. Ghosh, M., Jorissen, K. F. A., Wood, J. A. & Lammertink, R. G. H., 17 Oct 2018, In : Journal of physical chemistry letters. 9, 21, p. 6339-6344 6 p. https://pubs.acs.org/doi/10.1021/acs.jpclett.8b02771



Micro-pollutant Removal by Salt Permeating Polyelectrolyte Multilayer based Nanofiltration Membranes

Project Aim

The aim of this research is to relate material properties and structure of polyelectrolyte multilayers to observed separation properties, to gain a fundamental understanding on transport processes inside these layers. Therefore, detailed structural characterization on nanoscale of PEMs build on model surfaces shall be coupled to macroscopic transport measurements conducted with coated ultrafiltration membranes. The transport will be theoretically described using a transport model based on the extended Nernst-Planck equation. The model shall be used to predict membrane process performance.

Progress

In the initial period of this project a stationary transport model for a hollow fiber nanofiltration membrane was developed based on the extended Nernst-Planck equation, which accounts for convection, diffusion and electromigration. In addition this model allows for the implementation of inhomogeneous charge distributions throughout the separation layer. The model accounts for process parameter variations along the fiber length using a simplified 1D consideration.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. R.G.H. Lammertink

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Moritz Junker

Cooperations

-

Funded by

Oasen, NX Filtration

Funded %

University	-
FOM	-
STW	-
NWO Other	76 %
Industry	24 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

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Project leaders
prof.dr.ir. R.G.H. Lammertink
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Omer Atasi, Ö. (TNW)
Cooperations
-
Funded by
NWO
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019
Information
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Project Aim

A microfluidic concentration device using an ''Electro kinetic trapping'' mechanism is being designed and studied. The characterization and understanding of the physics underlying this electro kinetic trapping mechanism is the first step towards developing new lab on a chip devices making use of similar electro kinetic phenomena. The device consists of a straight glass microchannel containing a liquid with a solute. A thin Nafion patch is inserted inside the channel. When a potential difference is applied along the channel axis, the solute accumulates on the anodic side of the channel.

Progress

The project contains two aspects. The first one consists in designing the microfluidic platform containing the microfluidic channel and various characterization techniques such as fluorence microscopy and micro PIV. The second aspect consists in modelling the ion concentration polarization effects inside the microchannel at the nafion/liquid interface. So far, the microfluidic platform is under design. The modelling we developed so far uses the Nersnt-Planck and Stokes equation assuming electroneutrality in the liquid and Donnan jumps on the membrane/liquid interfaces, gave us insight into the parameters controlling the extent of the depletion layer near the nafion membrane.

Dissertations

-

Scientific Publications

-

Making use of diffusiophoresis for enhanced mass transports off spatially inhomogeneous catalysts

Project Aim

One of the essential component of the chemical industry are the catalytic materials which are mostly suffered from insufficient transport in their bulk. In this project, we propose to improve hydrodynamic transport away from the surface of the inhomogeneous catalysis by making use of diffusiophoretic effect. The main aim of the this project is to (i) quantitative describe this process by comparing controlled experiments and simulations in 2D, (ii) to optimize the pattern of the catalyst to achieve optimal flow with as small catalytic region as possible and (iii) to apply this concept also to 3D catalyst (porous media).

Progress

Experimental setup is in development to observe the diffusiophoretic effect. Specifically, the reaction which we consider concerns the hydrogenation of nitrite, due to its simplicity and fast kinetics. The considered experimental setup to study diffusiophoresis is illustrated below. The migration of catalyst particles can be tracked microscopically. The aims of this experimental setup are to understand the fundamental movement mechanism of the catalyst particles under concentration difference and underline the effect of diffusiophoresis by determining chemical conversion rate.

Dissertations

-

Scientific Publications

-

Project leaders

prof.dr.ir. R.G.H. Lammertink (Rob)
J.A. Wood (Jeffery)

Research theme

Complex dynamics of fluids

Participants

Burak Akdeniz

Cooperations

-

Funded by

Netherlands Center for Multiscale Catalytic Energy Conversion (MCEC)

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

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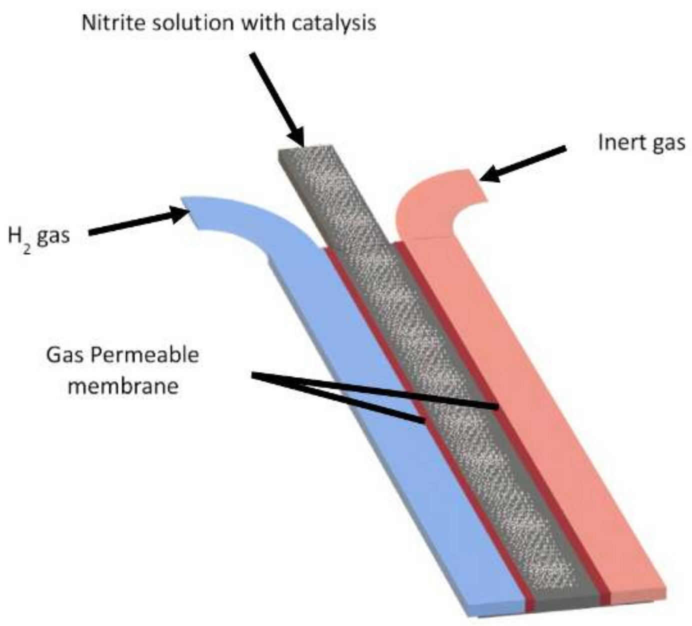

PROJECT LEADERS
Rob Lammertink
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Arputha Paul, Jeffery Wood
COOPERATIONS
-
FUNDED BY
NWO
FUNDED %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017
INFORMATION
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PROJECT AIM

The optimisation of most of the chemical-process technologies involving solid-fluid interfaces, is often limited by the boundary layers that are formed near the interface, since it determines the rate of transport of different species across these interfaces. One innovative way to reduce this boundary layer is by creating a self-induced mixing within the layer i.e. velocities being generated only near the interface, instead of the conventional way of using energy dissipating techniques that stirs the whole bulk fluid. This is possible by creating gradients along the interfaces that induce fluid velocity near the interfaces that might reduce the boundary layer thickness (Figure 1).

Thus, the aim of the project is to control and enhance the transport of chemical species across the boundary layer, externally, using electric fields.

PROGRESS

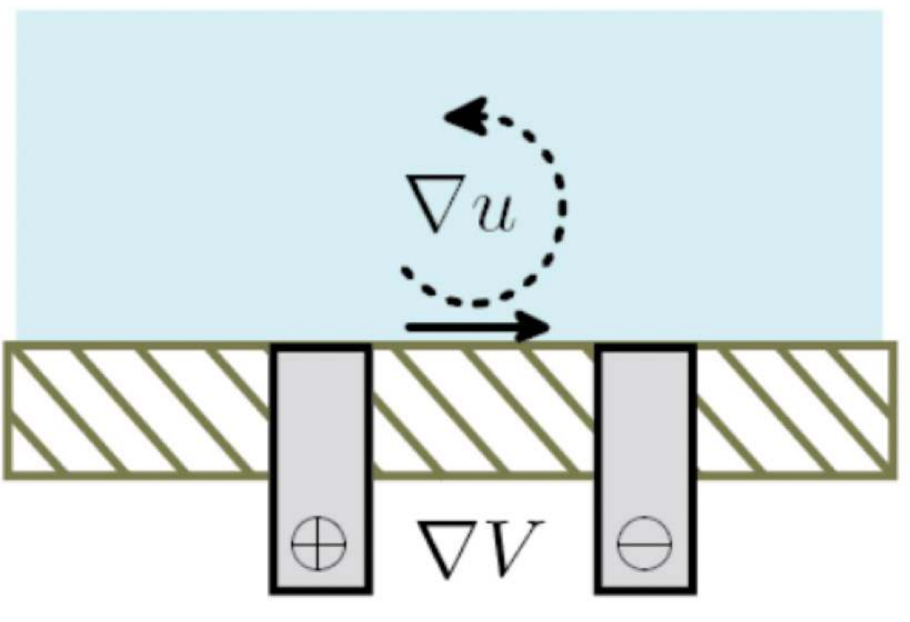
An electrodialysis set-up was chosen to study the effect of the stirring caused by electric fields. Consequently, experiments with surface modified spacers that can bend the electric field are being carried out and results will be compared with the electrodialysis using normal spacers. The experimental and numerical outcomes will be used to understand the different electro-kinetic effects across interfaces. And eventually the effect of the stirring caused by voltage as a gradient, if any, will be quantified and reported.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Engineering fluid dynamics

Prof.dr.ir. CH Venner

Modern engineering challenges concern the design and development of processes and equipment with a high performance and minimal environmental impact, i.e. effective use of resources, energy and minimal generation of waste products and noise. The Engineering Fluid Dynamics group aims to contribute to innovative solutions for practically relevant societal, environmental and industrial challenges by bringing “fundamental” physics to actual applications on many scales, ranging from large size high power such as aircraft parts, compressors, and turbines, to small-scale thin-layer free surface flows in lubrication and bearing applications. The research is both experimental and theoretical, including numerical simulations with in house development of accurate numerical codes and multilevel/multigrid computational methodologies. The research focuses on the following themes:

Fluid Mechanics of Rotating Flow Machines

The flow in centrifugal pumps, compressors, and around wind turbine blades. The research involves optimization of the functional aspects (blade/impeller geometry, cavitation characteristics, efficiency, active flow control) as well as the minimization of non-drag related energy losses in the lubrication and transition layers, and minimization of environmental aspects such as the reduction of vibrational and (aeroacoustic) noise. For this purpose, an aero-acoustic test facility is used: A silent closed circuit wind tunnel with a (0.7x0.9 m2) free-jet test-section (maximum velocity 65 m/s) which is enclosed by a 6x6x4m3 anechoic chamber.

Multi-phase flows and wave phenomena

Flows with phase transition occur in many engineering applications such as flow of oil/water/gas mixtures in hydrocarbon transport lines, ice accretion on aircraft wings in flight, flows with cavitation, separation of mixtures, and dense-phase fluid particle flows in dredging applications. The group develops computational methods for specific applications aimed at actual design and prototyping and also carries out fundamental studies, on the mechanisms of e.g. condensation, in multiphase systems. Research is also carried out aimed at identifying the acoustic signature of the flow.

Computational Aerodynamics Algorithm Design

Practical applications in engineering involve the occurrence of phenomena on largely different scales in almost any application. In such cases both high order accuracy as well as computational efficiency are of the utmost importance. The group develops and tests numerical algorithms for simulation and optimization , and validates predictions for actual applications ranging from Navier Stokes and Euler equations to potential flows, and reduced systems such as lubrication flows with combined elasticity on nano-scale. Aspects of development are high order compact schemes, multigrid/multilevel computational methodologies and gradient based adjoint optimization.

Bio-physical flows

This research deals with the flow in (bio)medical and natural systems, Projects include flow in lungs (aerosol deposition), medical sprays, and separation of specific cell rich flows. Research is aimed at developing new (computational) diagnostic and therapeutic tools. Research in nature-inspired flows is aimed at the development of robot-birds and minimizing the impact of technology on the natural environment.

Project Aim

Natural laminar flow (NLF) technology has been identified as a promising candidate to achieve fuel burn savings on small and mid-sized aircraft in the order of 10%. This PhD project is dedicated to extend the scope of the three-dimensional optimization for wings making use of transition information. Use will be made of existing methods for the aerodynamics (ENSOLV RANS solver), transition modeling (correlation based, stability analysis) and optimization (gradient based in combination with adjoints). The main work of this project is to integrate these methods into a practical design tool that allows for optimization of aircraft wings including transition.

Progress

The coupling between the flow solver (ENSOLV) and the linear stability solver (COSALX) has been finalized and tested extensively for the Sickle wing of the TU Braunschweig and the NASA CRM. The results for these test cases are very encouraging and show the potential of the method. Furthermore, a start has been made with the adjoint version of the coupled solver..

Dissertations

-

Scientific Publications

-

Project leaders

C.H. Venner
E.T.A. van der Weide
B. Soemarwoto (NLR)

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

J.S. Fischer (PhD),
E.T.A. van der Weide
B. Soemarwoto and
C.H. Venner

Cooperations

NLR

Funded by

NLR

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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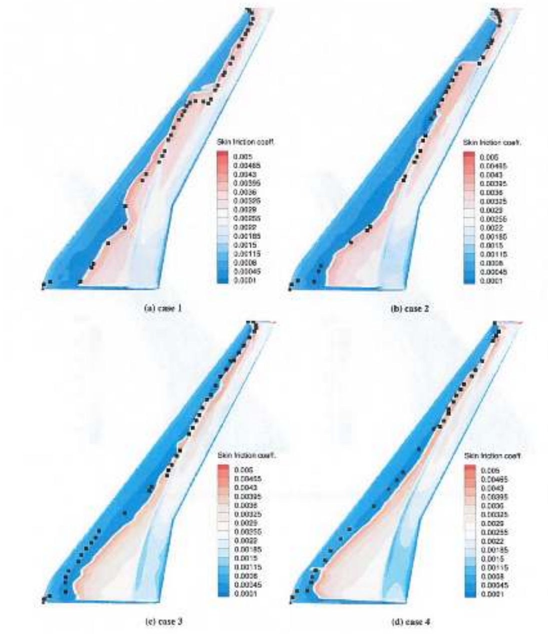

Skin friction coefficient contour on the NASA CRM upper surface for cases 1, 2, 3 and 4 resulting from RANS-LST coupling and indicated transition points from experiment.

PROJECT LEADERS
C.H. Venner, E.T.A. van der Weide, H. Ozdemir (ECN)

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
A. Koodly Ravishankara (PhD), E.T.A. van der Weide, H. Ozdemir and C.H. Venner

COOPERATIONS
ECN

FUNDED BY
ECN

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	100 %
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017

INFORMATION
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PROJECT AIM

Current wind turbines have very large rotors and many use flow enhancement devices like vortex generators. Traditional low-fidelity turbine design and analysis tools are either incapable of handling such complexity or give very inaccurate results. This research focuses on developing high-fidelity tools to design and analyze current and future wind turbines. Additionally, the high fidelity models can also be used to analyze wind farms and tune the lower fidelity tools. The new models will be implemented in the open source CFD code SU2.

PROGRESS

The pressure based incompressible solver of SU2 has been tested for several test cases, including a case with vortex generators. The solver shows the expected results, but more testing is still needed.

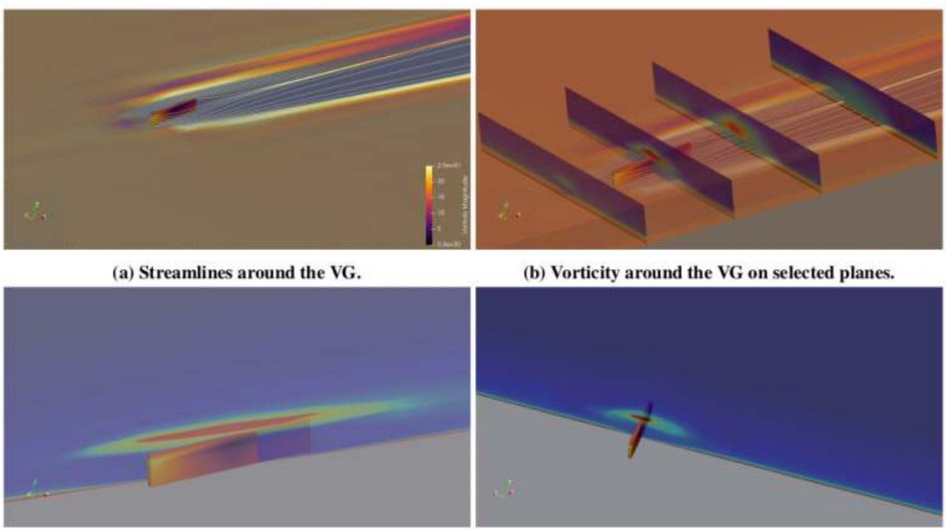
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Implementation of a pressure based incompressible flow solver in SU2 for wind turbine applications. AIAA-paper 2020-0992, January 2020.

Vorticity profiles in a turbulent boundary layer around a vortex generator.



(a) Streamlines around the VG. (b) Vorticity around the VG on selected planes.

(c) Extent of vorticity along $x-$ axis. (d) Extent of vorticity along $y-$ axis.

LES of compressible turbulent flow through combustor liner and dilution holes

Project Aim

The EU project MAGISTER addresses the problem of thermo-acoustic instabilities in combustion chambers of aircraft engines (which occur when cleaner combustion processes are aimed for) by means of machine learning (ML). The role of this PhD project is to deliver simulation data for the turbulent flow through combustor liner and dilution holes that will act as training data for the ML algorithms. For this purpose the high order discretization in the open source code SU2 will be used and this project will focus on non-reflecting boundary conditions using the Perfectly Matched Layer approach, which enables the LES simulation of turbulent flows in the above mentioned geometries.

Progress

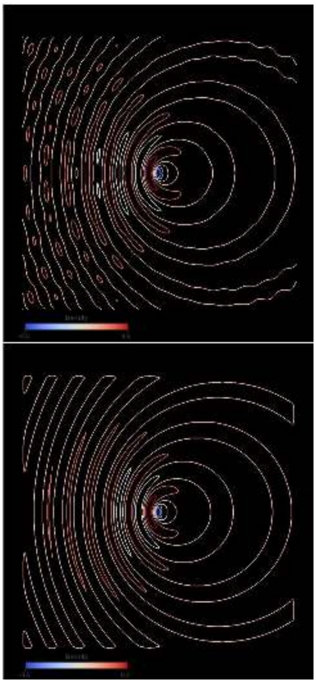
Due to the demanding computational cost in Matlab, prototyping has shifted to raw C++, for high-performance purposes. A two-dimensional multi-zonal structured solver has been developed in C++ from scratch to tackle how effective as well as compare different non-reflective boundary conditions in conjunction with the high-order discontinuous Galerkin method. Non-reflecting methods tested are the perfectly matched layer (PML) and the Navier-Stokes characteristic boundary condition (NSCBC). The discontinuous Galerkin variant used is of a nodal type. The physics studied ranges from the linearized Euler equations to the Navier-Stokes, with the non-linear Euler a special case.

Dissertations

-

Scientific Publications

-



Density contours for the characteristic boundary condition treatment (left) vs. perfectly matched layer approach (right) for a pulsating Gaussian source solved with the Euler equations.

Project leaders

C.H.Venner, E.T.A. van der Weide

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

E. Shehadi (PhD),
E.T.A. van der Weide and
C.H. Venner

Cooperations

GE Germany, Technical University of Munich, Karlsruhe Institute of Technology, University of Cambridge, ARMINES Paris Tech, CERFACS, Safran Tech, Safran Helicopter Engines, ANSYS

Funded by

EU

Funded %

University	25 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	75 %
Scholarships	-

Start of the project

2018

Information

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PROJECT LEADERS
C.H.Venner, H.W.M.Hoeijmakers
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
L. de Santana, L Groot Koerkamp, S. Stramigioli, G.A. Folkertsma
COOPERATIONS
UT Robotics and Mechatronics, Clear Flight Solutions
FUNDED BY
UT
FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2012
INFORMATION
CH Venner
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PROJECT AIM

Investigate experimentally and numerically the flow about nature-inspired configurations, such as Robot Birds. These nature-inspired copies of real birds combine lift and propulsion by flapping wings. The peregrine falcon Robird is a nature and animal friendly means of bird control around airports with many other possible sustainable applications. In the project (scale-models of) this robotic bird, and other flapping flight configurations are investigated in the wind tunnel and numerically to unveil natures secrets.

PROGRESS

Various experimental methods are developed and tested to clearly identify and quantify the vortex structures in the wake of the flapping wing and the net positive jet velocity in the central region. Particle Imaging Velocimetry in the Utwente windtunnel with a flexible model of the wing of the peregrine falcon model carrying out a flapping motion similar to the true motion. The vorticity results observed in the PIV are compared to panel method results for a flapping surface.

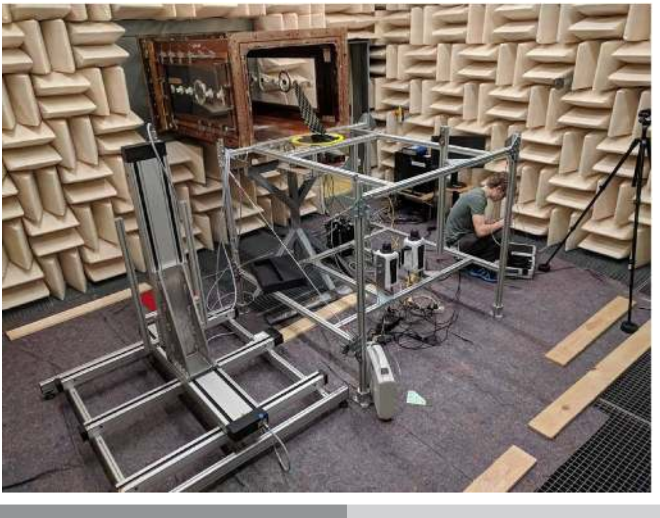
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Groot Koerkamp, L. de Santana, L.D., Hoeijmakers, H.W.M., and Venner, C.H., 2019, Investigation into Wake of Flapping Wing of Robotic Bird, Presented at 2019 AIAA AVIATION AND AERONAUTICS FORUM, Dallas, USA, june 2019. AIAA 2019-3582. https://doi.org/10.2514/6.2019-3582.

Setup of flexible robird flapping wing in windtunnel for PIV measurements



Inverse design and optimisation methods for centrifugal pumps and fans

Project Aim

Using the augmented potential-flow method developed for the prediction of the hydraulic performance of centrifugal and mixed flow pumps, two types of design methods for three-dimensional configurations are investigated: (i) inverse-design methods and (ii) optimization methods. The validation of the computational methods has been carried out in the newly developed Rotating Flow facility, by PIV-measurements of the relative velocity field.

Progress

A three-dimensional inverse-design method for impellers of centrifugal pumps has been developed, by which an impeller geometry is obtained that meets the prescribed hydraulic characteristics (rotational speed, flow rate, head and loading). Optimisation methods have been developed in which the performance of centrifugal pump impellers is optimised with respect to required head, low losses and optimal cavitation characteristics. The relative velocity field has been measured at various operating conditions using PIV, in the newly developed Rotating Flow facility. Publications have been effected. Additional work has been done on the development of a semi-analytical inverse design method.

Dissertations

-

Scientific Publications

-

Project leaders

NP Kruyt, C.H. Venner

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

RW Westra, NP Kruyt, C.H. Venner

Cooperations

Flowserve BV, Urenco Aerospace, Johnson Pump, IHC Parts & Services, NLR, Marin

Funded by

STW, UT

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2003

Information

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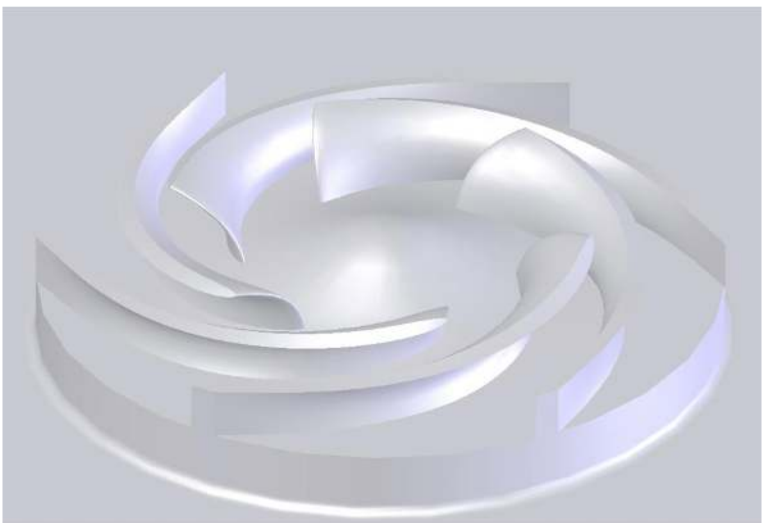

Design for high efficiency of low-pressure axial fans: use of blade sweep and vortex distribution

Project leaders
N.P Kruyt, C.H. Venner

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Jie Wang, N.P Kruyt, C.H. Venner, E.T.A van der Weide, L.D. de Santana

Cooperations
University of Twente and Howden

Funded by
CSC & Howden

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017

Information
N.P Kruyt
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Project Aim

The effects of blade sweep (in axial and circumferential direction) and of the vortex distribution (i.e. the spanwise variation of the “blade loading” or “mean-swirl distribution”) on the aerodynamic performance of low-pressure axial fans are investigated parametrically by using CFD. Based on these results, optimized design methodologies considering blade sweep and vortex distribution will be formulated for obtaining low-pressure axial fans with high efficiency.

Progress

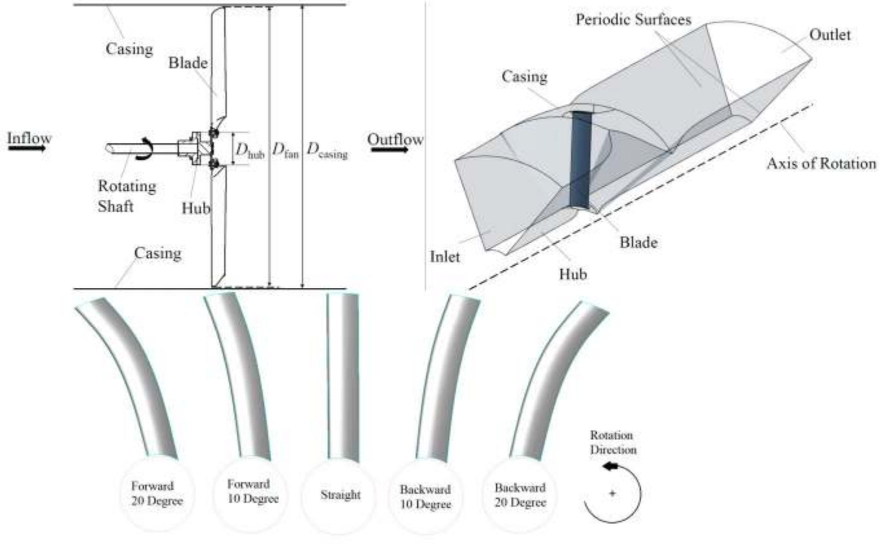
The strategy of CFD simulation of low-pressure axial fans with low hub-to-tip ratio (lower than 0.2) has been reported, good agreements with experimental data are found . Based on the strategy, simulation results of swept blade have been updated and investigated, which is going to be reported. Effects of vortex distribution on the axial fan performance form the next step, as well as the couple of vortex distribution and blade sweep.

Dissertations

-

Scientific Publications

-



The cement response due to a forced expansion load in the structural foundation of a new type of oil well

Project Aim

Identification of the causes of cement compression induced water accumulation and water film annulus formation between casing and cement during compression resulting from casing expansion in a new type (monobore) oil well, and the design of an appropriate experimental setup.

Progress

Developed numerical model has been applied to various cases of expansion tests to validate model predictions. Further development of model, and development of test setup for complete model. Development of test setup to measure specific model parameters such as bonding strength. Experimental tests of bonding strength. Project ended in 2018.

Dissertations

1. van den Berg, M.W., Dynamic Pipe Expansion in a Radial Confined Cemented Oil Well Foundation, PDENG Thesis, University of Twente, Enschede, The Netherlands.

Scientific Publications

-

Project leaders

C.H. Venner

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

M. van den Berg (PDENG)

Cooperations

Shell

Funded by

Shell

Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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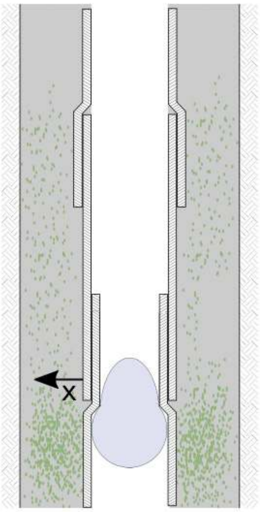
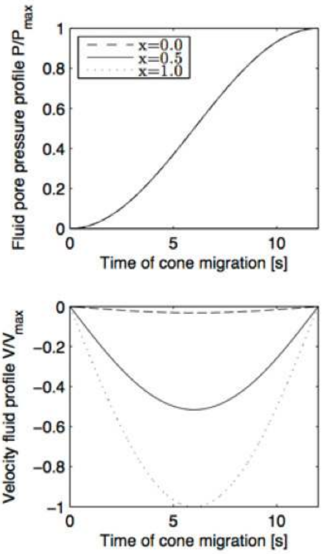
For upward cone migration the cement- and fluid in between the cement along the pipe is compressed. As a result the fluid is displaced towards the interface of cement and oil-pipe, potentially separating the pipeline with its foundation.





PROJECT LEADERS
C.H.Venner

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
C.H.Venner, H.Boffy, P.M.Lugt(SKF), J.Wang (Qingdao), A.A. Lubrecht (INSA), J.H.Snoeijer (UT-PoF)

COOPERATIONS
UT-TNW (PoF), INSA de Lyon, France, Qingdao Technological University, PR. China, SKF ERC, Netherlands, UvA, Leibniz University Hannover, FZG University of Munich.

FUNDED BY
UT/SKF

FUNDED %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2007

INFORMATION
C.H.Venner
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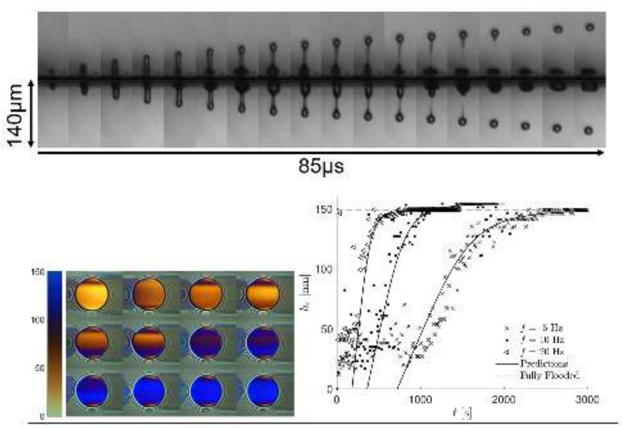
PROJECT AIM
Development of accurate thin film/layer flow models and numerical simulation algorithms for the prediction of lubricant film formation capacity and lubrication life in rolling element bearing contacts in relation to operating conditions, lubricant rheology (oil-grease), supply conditions (starved-flooded), and material properties, and fundamental analysis of physical phenomena.

PROGRESS
Ink jet drop on demand lubrication system developed. Fundamentals studied for small picoliter droplet in single contact setup showing excellent control of lubrication from dry to fully flooded with only nano-liter amounts of lubricatant, see figure below. Realization of lubrication control in a real thrust bearing test setup, Feasibility study in gear setup with FzG. Further development. Continuation of research on fundamental aspects of film formation fundamentals, and friction prediction.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
1. Zhang, Y., Biboulet, N., Venner, C.H., and Lubrecht, A.A., Prediction of the Stribeck Curve under Full-Film Elastohydrodynamic Lubrication, Tribology International, https://doi.org/10/1016/j.triboint.2019.01.028.
2. Van der Kruk, W.M., Smit, S.A., Segers, T.J., Li, X.M., Venner, C.H., Elastohydrodynamic lubrication of a ball-on-disc contact by drop-on-demand printing. Tribology Letters, 67:95 http://doi.org/10.1007/s11248-019-1208-1.
3. Petrova, D., Weber, B., Allain, C., Audeberg, Brouwer, A.M., Venner, C.H., Bonn, D., Fluoresence Microscopy Visualization of Roughness-Induced Transition Between Lubrication Regimes. Science Advances, Sci Adv 5 (12), eaaw4761. DOI: 10.1126/sciadv.aaw4761.
4. Liu, H., Zhang, B., Bader, N., Guo, F., Poll, G. & Yang, P., Venner, C.H., (2019), Crucial role of solid body temperature on elastohydrodynamic film thickness and traction, Tribology international. 131, p. 386-397.



Top: images of droplet generation during ejection. Bottom left: Sequence of optical interferometry images in droplet lubrication. Bottom right: experimentally measured film development as a function of time for different droplet frequencies.

Higher-order constitutive relations for granular materials: a multi-scale approach

Project Aim

This project aims to (i) propose micromechanical expressions for the three-dimensional higher-order strain and stress tensors for granular materials; (ii) investigate free-energy and dissipation potentials from the micromechanical viewpoint; (iii) develop thermodynamically consistent higher-order constitutive relations for rate-independent granular materials; (iv) validate the constructed higher-order constitutive relations, using available data from laboratory tests on granular materials; (v) apply the developed higher-order continuum-mechanical constitutive relations to large-deformation problems in geotechnical engineering.

Progress

An evolution law for fabric anisotropy of granular materials has been developed, that is based on observations from results of experiments and three-dimensional DEM simulations from literature. Current micromechanical expressions for the three-dimensional higher-order strain and strain tensors for granular materials have been analyzed. Skills of DEM simulations of granular materials have been acquired. We are working on improving and proposing new micromechanical expressions for the three-dimensional higher-order strain and stress tensors for granular materials.

Dissertations

-

Scientific Publications

1. Chao-Fa Zhao, Niels P. Kruyt. An evolution law for fabric anisotropy and its application in micromechanical modelling of granular materials, International Journal of Solids and Structures, under review.

Project leaders

N. P. Kruyt

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Chaofa Zhao, Niels P. Kruyt

Cooperations

University of Twente and IRSTEA (France) and Università dell'Aquila (Italy)

Funded by

EU

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2019

Information

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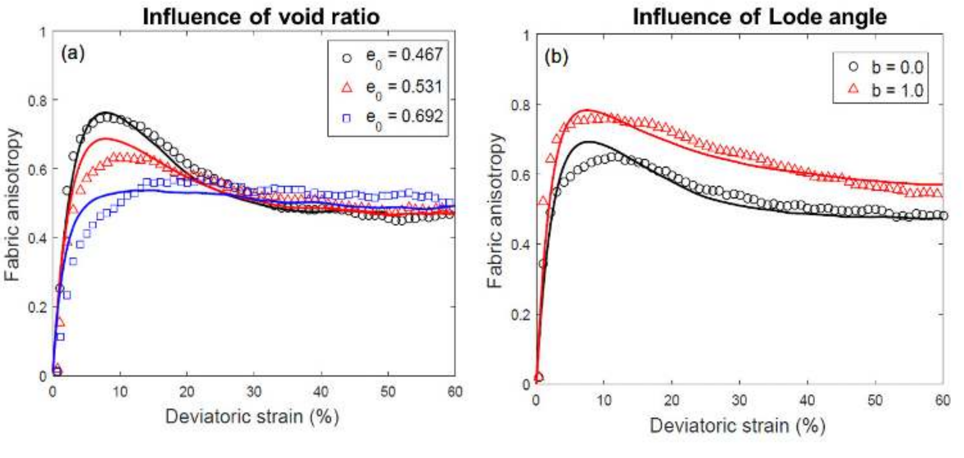

PROJECT LEADERS
C.H. Venner

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Binbin Zhang, Armando Felix

COOPERATIONS
SKF ERC, Nieuwegein, INSA de Lyon, France

FUNDED BY
CSC, SKF

FUNDED %

University	10 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	90 %

START OF THE PROJECT
2016

INFORMATION
.C.H.Venner
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PROJECT AIM

Development of optimally efficient and computational methods for advanced computational diagnostics and optimization of the effect of 3D topology and structural heterogeneity in the subsurface of bearing materials on the service life in contact mechanics and lubrication. The methods will allow "design" of the required local topological mechanical and thermal properties such that fatigue life is maximized, whilst maintaining lubrication life, as well as quick assessment of risk of reduced "lubrication life" from tomographic maps of actual material samples.

PROGRESS

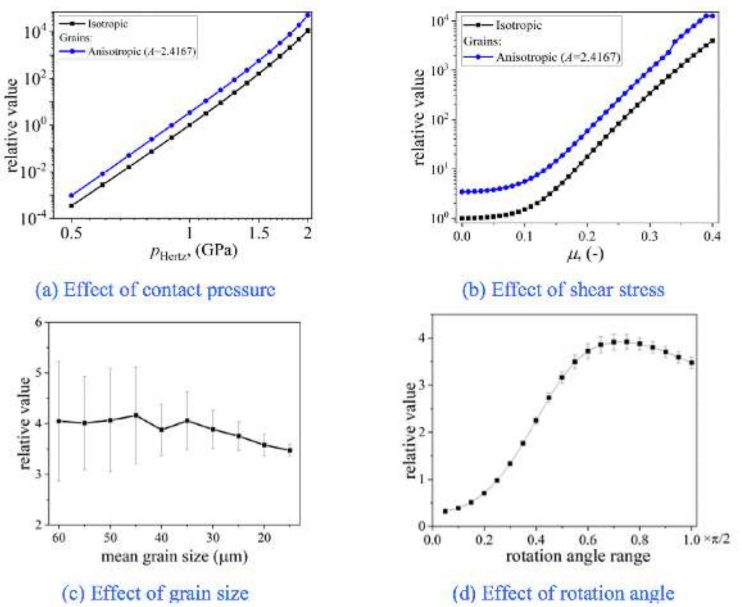
In 2019, the developed multigrid algorithm is applied for the fatigue life analysis of bearing steel considering the influence of heterogeneous anisotropic material. The effect of contact pressure, shear stress, grain size and anisotropy on the predicted fatigue life is analyzed. Results are compared with those of isotropic homogeneous material. From the results, it can be concluded that the heterogeneous anisotropic material leads to a reduction of the predicted fatigue life compared to homogeneous isotropic material. The effect of grain topology and anisotropy should be considered for the fatigue life prediction.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Zhang B B, Boffy H, Venner C H. Multigrid solution of 2D and 3D stress fields in contact mechanics of anisotropic inhomogeneous materials. Tribology International 2019. https://doi.org/10.1016/j.triboint.2019.02.044.



Effect of contact pressure, shear stress, grain size and rotation angle on the relative stress integral value for heterogeneous anisotropic and isotropic material. (ph=1 GPa except 1(a), R=0.02 m, ahertz=138.78 μm, average grain diameter 15 μm except 1(c) rotation angel range 0~π/2 except 1(d))

Project Aim

Development of short time pulse driven methodology, electronical and optical components for e.g. highly time accurate Schlieren imaging, and use of these methods to study fundamental aspects and time varying phenomena and structures in supersonic flows.

Progress

An innovative Power VCSEL driven Schlieren has been developed and used to visualize a system for a cascaded injection in a supersonic cross flow. The flow observed in the supersonic wind tunnel of the University of Twente, is a cascaded dual tandem air in¬ject¬ion transverse to a stream of Mach 1.6, with the upstream injection orifice half the diameter of that of the downstream orifice. The momentum ratio's studied are J=1, J=1,37 and J=2. The VCSEL driven Schlieren system creates excellent spatial and temporal resolution with, potential for multi-angled Schlieren images of high-Mach-number flows. Further extension and parameter variations, jet distance, and J=3 and onwards.

Dissertations

-

Scientific Publications

1. de Maag, S., Segerink, F.B., Hoeijmakers, H.W.M., Venner, C.H., and Offerhaus, H.L., Power VCSEL driven Schlieren visualisation for cascaded injection in supersonic flow. Proceedings 15th International Conference on Fluid Control, Measurements and Visualization 27-30 May 2019, Naples, Italy

Project leaders

C.H.Venner, HWM Hoeijmakers

Research theme

Complex dynamics of fluids

Participants

E.T.A. van der Weide, S. de Maag, F. Segerink, H.L. Offerhaus

Cooperations

UT Optical Sciences

Funded by

UT

Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

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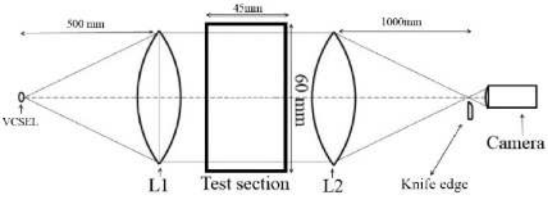
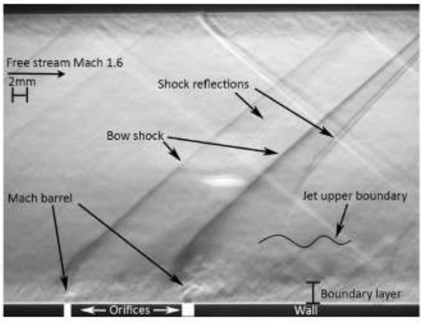
Left: Schematic of Schlieren set-up. Right: Example of Schlieren image obtained for Mach = 1.6, diameter orifices 1 mm (upstream) and 2 mm (downstream). Visualised are the tandem jets 20 mm apart with a momentum ratio of J=1.37, each featuring a Mach barrel, from the orifices, the bow shocks induced by the jets, the boundary layer along the walls and their interaction with the shocks. Also visible are Mach waves originating from small slope discontinuities of the walls.





PROJECT LEADERS
L.de Santana, C.H.Venner
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
F. dos Santos
COOPERATIONS
TNO, MARIN
FUNDED BY
DMO
FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019
INFORMATION
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PROJECT AIM

Modeling the turbulence solid-body interaction is crucial for noise control. The Amiet noise prediction theory considers the noise radiated by a thin flat plate in an isotropic turbulent stream. These conditions are invalid for ship propellers since the inflow is disturbed by the ship hull, and the blades have a more complex geometry and rotational movement. Hence, this research aims to investigate experimentally the near-field phenomena at the leading edge of propeller blades and its relation to the far-field noise production. Based on the experimental results, improvements to the existing noise prediction models and/or new fast turn-around models will be proposed.

PROGRESS

Literature review have been done regarding the aeroacoustic noise sources in propellers and the models used to predict far-field noise production. The next steps of the research are:

- Develop an experimental setup to study the inflow turbulence characteristics and its influence in the far-field noise generation of well-known geometries, such as flat plate and airfoils, and compare the results with the Amiet leading edge noise prediction model;
- Investigate experimentally the influence in the far-field noise of a propeller geometry and its rotation movement in a turbulent stream.

DISSERTATIONS

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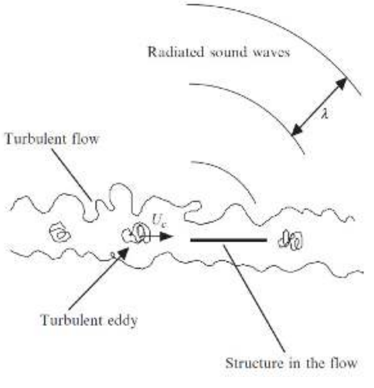
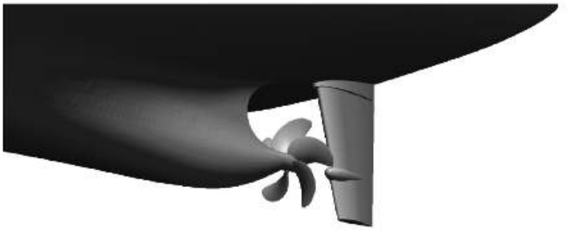
SCIENTIFIC PUBLICATIONS

-



Turbulent flow incident on a structure that radiates sound waves.



Propeller and partial ship hull image

Safe and amplified industrial laser processing (SAILPRO)

Project Aim

In this German-Dutch Interreg multi-partners project knowledge and expertise in on the generation & application of nanoparticles is combined with the knowledge and expertise in machining & application of surface textures. Both fields of application share the benefits of the same laser process: ultra-short laser processing under a water film. Partners: microTEC Gesellschaft für Mikrotechnolo- gie mbH, University of Duisburg-Es- sen (UDE), Veld Laser (VL), PM Bearings (PMB), Laser Appli- cation Cen- ter (LAC), Particle Metrix GmbH (PM).

Progress

The required liquid layer height in under water laser ablation is typically realized by pouring a pre-defined amount of liquid on the surface. Surface tension causes the air-liquid interface at the boundaries of the domain to deviate from a planar interface. An experimental set-up is proposed which circumvents the issues of a curved free surface. Next, a 7 picosecond pulsed laser source at a wavelength of 515nm was used to study the efficiency of laser ablation of stainless steel for a range of liquid layer heights. Our findings provide a more detailed quantification of crater depth as a function of liquid layer height than is available through existing literature.

Dissertations

-

Scientific Publications

1. S. van der Linden, R. Hagmeijer and G.W. Römer, Picosecond pulsed Laser Ablation of Liquid Covered Stainless Steel Effect of Liquid Layer Thickness on Ablation Efficiency. J Laser Micro Nanoen 14 108 (2019).

Project leaders

G.W. Römer, R. Hagmeijer, C.H. Venner

Research theme

Complex dynamics of fluids

Participants

G.W. Römer, S. van der Linden, R. Hagmeijer

Cooperations

EU and industry

Funded by

EU

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	35 %
TNO	-
GTI	-
EU	65 %
Scholarships	-

Start of the project

2016

Information

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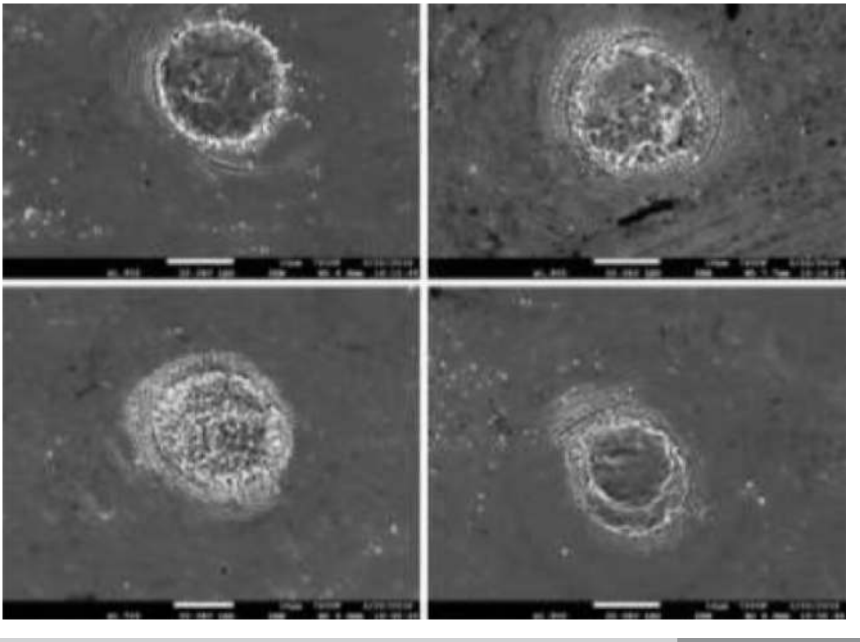

Towards a clinical decision support system in high-flow ventilation therapy: integrated respiration monitoring

Project leaders
R. Hagmeijer, C.H. Venner
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
R. Hagmeijer (UT), H.C. Venner (UT), H.B. ter Woord (UT)
Cooperations
Vrouw-Kind Centrum & Medical School Twente, Medisch Spectrum Twente
Funded by
TKI HTSM, Medisch Spectrum Twente
Funded %

University	15 %
FOM	-
STW	-
NWO Other	70 %
Industry	15 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019
Information
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Project Aim

High flow nasal cannula (HFNC) therapy is widely used to treat critically ill patients with acute, severe respiratory disorders. However, criteria to support clinical decisions with respect to (a) initiation of HFNC therapy, (b) titration of HFNC therapy, and (c) control of airway pressure are lacking. We propose to develop criteria based on using the HFNC-device itself as monitoring device, supported by an optimized and validated theoretical lung model in the background.

Progress

Started with thorough review of the literature on existing pulmonary models. Some work has been done on developing flow in lung tubes and on the current state of the art on alveoli-modeling. Especially the role of surface tension in the alveoli is investigated.

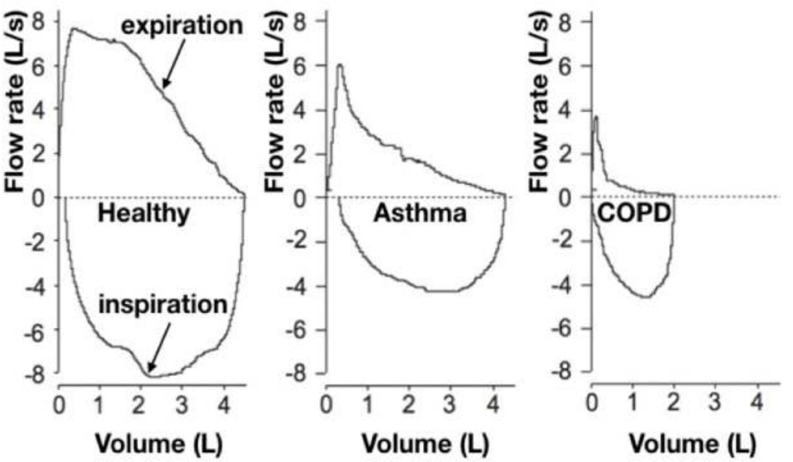
Dissertations

-

Scientific Publications

-

Typical examples of flow-volume loops obtained from spirometry applied to a healthy patient and patients suffering from pulmonary diseases. Miller et al. , Standardisation of spirometry, Eur. Respir. J. 2005, 26: 319–338.



Development of a flat spectrum filter for 3D printed custom-made hearing protection

Project Aim

This PDEng project aims to develop an adaptive hearing protection device. As opposed to hearing aids, which could also be used to attenuate sound instead of amplify sound, the focus is on developing an active component which only increases transmission loss when needed. This increases the users comfort as there is no need to remove the hearing protection device in silent surroundings.

Progress

A mathematical model to simulate sound propagation through the hearing protection device has been implemented and associated hardware has been manufactured. A design has been developed, succesfully tested and validated.

Dissertations

-

Scientific Publications

-

Project leaders

Dr. Ir. Y.H. Wijnant
Prof. C.H. Venner

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Msc. H. Faghanpourgan

Cooperations

Comfoor

Funded by

Comfoor
EFRO PDEng Cluster Smart Industries Oost Nederland

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	50 %
Scholarships	-

Start of the project

2018

Information

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PROJECT LEADERS
L. de Santana, C.H.Venner
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
F. dos Santos
COOPERATIONS
TNO
FUNDED BY
University
FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2019
INFORMATION
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PROJECT AIM

Tripping devices are commonly used in wind tunnel testing to hasten the laminar-turbulent transition to mimic the aerodynamic effects present in the full-scale application. Depending on the tripping device characteristics and flow conditions, the development of a fully developed turbulent boundary layer is challenging. Therefore, this projected aimed to investigate experimentally the effectiveness of two types of tripping devices, e.g., zigzag strips and randomly distributed grits of varied sizes, in hastening the transition and generating a fully developed turbulent boundary layer in a flat plate. Flows of zero and favorable pressure gradients were also considered.

PROGRESS

An experimental setup was developed where hot-wire measurements were performed to quantify the velocity and turbulence intensity profiles in the streamwise direction. The research demonstrates that all trips hastened the transition from laminar to turbulent flow. Zigzag strips introduced stronger disturbances inside the boundary layer compared to grits, consequently, requiring a more significant recovery length. The grits with height of 59% of the boundary layer thickness presented the most consistent results for both pressure gradients since this trip did not overstimulate the boundary layer and developed a turbulent flow faster than the other trips.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. F. L. dos Santos, M. P. Sanders, L. D. de Santana, C. H. Venner, Influence of tripping devices in hastening transition in a flat plate submitted to zero and favorable pressure gradients. AIAA Scitech 2020, AIAA 2020-0046 (2020). DOI: 10.2514/6.2020-0046.

Flat plate with the grits elements distributed near the leading edge.

Top view of the grit particles placed on the flat plate surface.

Prediction of the hydraulic performance of centrifugal pumps and fans

Project Aim

The hydraulic performance of pumps is studied both numerically and experimentally. For the numerical flow simulations, a potential-flow method has been developed for the flow inside centrifugal, mixed-flow pumps as well as axial pumps and fans. This is complemented with RANS-based flow descriptions. The potential-flow based method includes loss models and a cavitation inception model. The method has been extended to include a transpiration-type of model for the effect of sheet cavitation. The experimental work is carried out in the new Rotating Flow facility.

Progress

In 2019 some further work has been carried out. realized. The Rotating Flow facility is being redesigned so that higher rotational speeds become possible. An associated project has been completed that deals with fish-safety of centrifugal pumps.

Dissertations

-

Scientific Publications

-

Project leaders

NP Kruyt, CH Venner

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

RW Westra, NP Kruyt

Cooperations

Flowserve BV

Funded by

Senter, UT

Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

1998

Information

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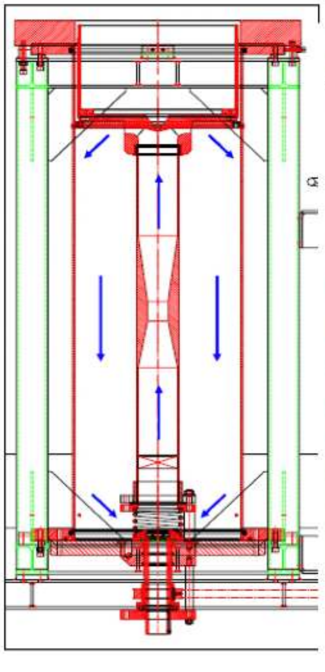

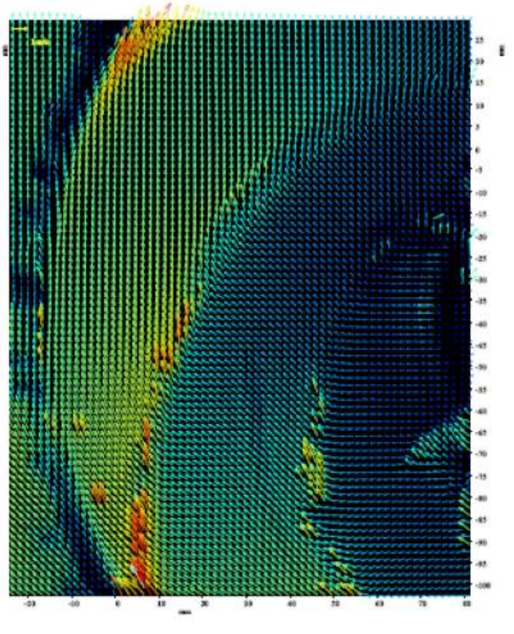

Development of an energy-efficient adaptive hearing protection device

Project leaders
Y.H. Wijnant, C.H. Venner

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Msc. J Mahajan

Cooperations
Comfoor

Funded by
Comfoor
EFRO PDEng Cluster Smart Industries Oost Nederland

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	50 %
Scholarships	-

Start of the project
2018

Information
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Project Aim

This PDEng project aims to develop an adaptive hearing protection device. As opposed to hearing aids, which could also be used to attenuate sound instead of amplify sound, the focus is on developing an active component which only increases transmission loss when needed. This increases the users comfort as there is no need to remove the hearing protection device in silent surroundings.

Progress

A mathematical model to simulate sound propagation through the hearing protection device has been implemented and ways to actively attenuate the sound have been identified. 2019 focussed on actual design and implementation.

Dissertations

-

Scientific Publications

-

Project Aim

The study of the (micro-mechanical) behavior of slowly flowing granular materials, in particular of the relation between microscopic behaviour and the macroscopic, continuum behaviour.

Progress

Dilatancy of granular materials has been studied from the micromechanical viewpoint. Links have been established between the microstructure as characterised by the fabric tensor and macroscopic dilatancy of granular materials.

Dissertations

-

Scientific Publications

1. Xue, L. & Kruyt, N.P. & Wang, R. & Zhang, J.M. (2019). 3D DEM simulation of principal stress rotation in different planes of cross-anisotropic granular materials. International Journal for Numerical and Analytical Methods in Geomechanics 43, 2227–2250.
2. Kruyt, N.P. & Rothenburg, L. (2019). A strain–displacement–fabric relationship for granular materials. International Journal of Solids and Structures 165, 14–22. Pouragha, M. & Kruyt, N.P. & Wan, R.G. (2019).
3. Fabric response to strain probing in granular materials: two-dimensional, isotropic systems. International Journal of Solids and Structures 156–157, 251–262.

Project leaders
NP Kruyt

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
NP Kruyt

Cooperations
University of Waterloo, Canada;
Université de La Rochelle, France;
Irstea, Grenoble, France
University of Calgary, Canada

Funded by
UT

Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2003

Information
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Project leaders
NP Kruyt, C.H. Venner
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
BJ Konijn, NP Kruyt
Cooperations
TUD, IHC
Funded by
Agentschap NL, IHC
Funded %

University	20 %
FOM	-
STW	-
NWO Other	-
Industry	80 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2011
Information
NP Kruyt
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Project Aim

Aim of the project is to develop a CFD method for the modeling of dense-phase fluid-particulate flow. Firstly, experiments have been carried out to determine the dependence of the properties of both liquid and particles on the fluid behavior. With the experimental results, constitutive equations will be constructed. These constitutive relations will be used to develop a CFD method that describes fluid-particulate flow.

Progress

The numerical simulations of mixture flows are continued and expanded. The model is extended with an accurate model for momentum transfer between phases. A specific model has been developed to account for bed formation. The measurements with the rheometer to characterize the behavior of various suspensions, have been continued by an MSc student. It extends the results obtained so far with measurements of suspensions by the use of other particulate materials and fluid viscosities. A study has been completed on the prediction of wear rates of impellers under off-design conditions.

Dissertations

-

Scientific Publications

-

On the measurement of intensity and absorption using a spherical microphone array

Project Aim

The project aims to develop and validate the possibility to measure sound intensity and sound absorption using a spherical array of microphones. It includes the development of a suitable calibration procedure. In addition, the statistically attainable accuracy should be investigated.

Progress

A mathematical model has been implemented and hardware is available to measure sound intensity. A first calibration procedure has been implemented and is investigated using statistical data analysis.

Dissertations

-

Scientific Publications

1. Niels Consten, Theo Campmans, Stéphanie Bertet, Ysbrand Wijnant. ON THE MEASUREMENT OF SOUND POWER USING A CUBICAL ARRANGEMENT OF MICROPHONES IN A SMALL RIGID SPHERE. Conference Proceedings 45th DAGA Rostock.

Project leaders

Y.H. Wijnant, C.H. Venner

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Ir. Niels Consten, Prof. A. de Boer

Cooperations

Soundinsight

Funded by

Soundinsight

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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PROJECT LEADERS
L.D. de Santana, M. Tuinstra, C.H. Venner

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
J.Biesheuvel (PhD), L.D. de Santana, M. Tuinstra, C.H. Venner

COOPERATIONS
Embraer, DNW, NLR

FUNDED BY
TKI

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2018

INFORMATION
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PROJECT AIM

The project aims at reducing uncertainties in noise measurements in wind tunnel experiments, allowing aircraft OEM to reduce their wind tunnel testing costs and decrease design lead times. A key uncertainty is the decorrelation of sound traveling through the shear layer of an open jet wind tunnel. This leads to reduced microphone cross-powers, and lower Sound Pressure Levels when a beamforming algorithm is applied to localize and quantify acoustic sources. The priority is to understand the process that leads to coherence loss and to robustly model the phenomenon. Correction methods will be proposed reducing measurement/design uncertainty.

PROGRESS

A microphone coherence loss model was developed and evaluated using measurements in NLR's Small Anechoic Wind tunnel (KAT). The model was applied to assess the effect on beamforming measurements in closed test-sections on an industrial scale (DNW-LLF, figure on the right). Aerodynamic & acoustic measurements were performed in the Large Low-speed Facility of the German-Dutch Wind tunnels: Noise measurements on a full aircraft model (open-jet), and calibrated speaker tests to study the interaction of the acoustic waves with a turbulent shear layer (figure on the left).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Effect of turbulent boundary layer induced coherence loss on beamforming measurements in industrial scale wind tunnel tests – J. Biesheuvel, M. Tuinstra, L. D. de Santana, C.H. Venner - AIAA 2019 Delft, the Netherlands.

PROJECT AIM

Noise generated by the high-lift devices (i.e. wings) is a major contributor to the sound production of an airplane. The flow mechanisms associated with this noise source are complex and require small-scale wind tunnel testing that enable the measurement and understanding of essential flow quantities related to the noise production. By flow field characterization and coupling with far-field noise measurements, we investigate the restraints and uncertainties encountered in small-scale wind tunnel testing of high-lift devices. Based on these findings, more physics-based modeling of high-lift device noise can be developed which can be used in silent aircraft design.

PROGRESS

The research is initiated with a renovation of the wind tunnel test sections at the University of Twente. The necessary sound localization and quantification tools have been developed in-house and benchmarked. Airfoil noise prediction models have been implemented which form the cornerstone to modeling of the high-lift device noise. Aeroacoustic measurements have been conducted in an open-jet (Figure 2) and hard-wall test section wind tunnel and are compared with LBM simulations (Figure 1). Acoustic corrections still need to be applied to the measurement data. The dataset is used to propose extended high-lift device noise prediction models.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

C.H. Venner, L.D. de Santana

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

M.P.J. Sanders (PhD), J. Biesheuvel (PhD), L.D. de Santana, C.H. Venner

COOPERATIONS

Embraer, DNW, NLR

FUNDED BY

TKI

FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2018

INFORMATION

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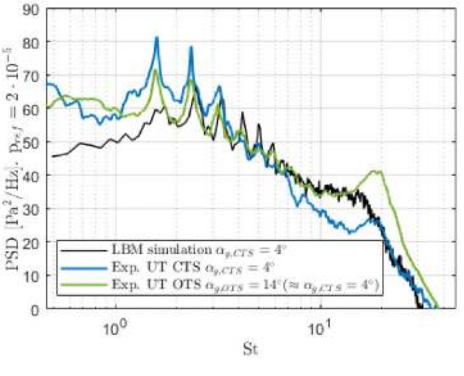
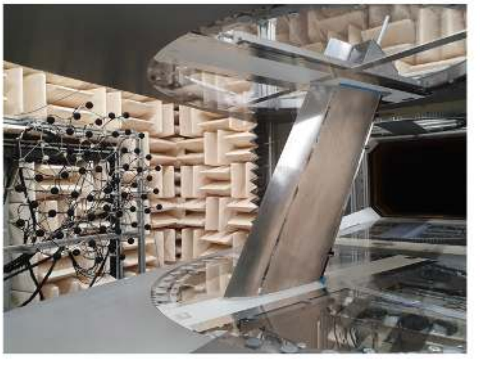


Sound Pressure Level comparison of the noise generated by the high-lift device based on LBM simulations, and open-jet and hard wall test section measurements



Experimental setup at the University of Twente with the high-lift device in swept wing configuration

Viscoelastic layer modeling for contact mechanics with heterogeneous materials and (mixed) lubrication layer islands interface

Project leaders
C.H.Venner

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Yan Zhao, C.H.Venner, G.E. Morales Espejel

Cooperations
SKF

Funded by
SKF/CSC

Funded %

University	10 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	90 %

Start of the project
2018

Information
C.H.Venner
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Project Aim

Develop a new approach in which the lubricant film is replaced by a locally varying viscoelastic layer which can be tuned to mimic a fluid like layer, or a more complex polymer or grease thickener layer, which is combined with a dry contact modeling. Using optical interferometry methods with thin polymer layers on disc to validate the model. The developed model and computational method will be combined with extremely efficient Multigrid/Multilevel computational methods which allow to simulate full 3D heterogeneous, granular, and anisotropic material behavior yielding a novel and efficient way to analyze and optimize lubricated contacts as transitional interfaces.

Progress

Theoretically, the “falling body” dry impact problem, modeled as a ball with mass m and radius R impacting an elastic half-space (Fig.1), was solved based on the Hertzian contact theory (Fig.2). Experimentally, impact test was carried out using a ball-on-disc test rig by loading a ball towards a glass disc, which is covered with a thin viscoelastic PDMS layer. A dent was formed in the contact center (Fig.3).

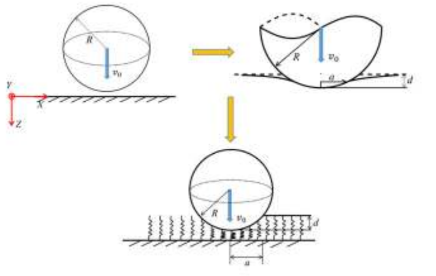
Dissertations

-

Scientific Publications

-

Fig 1 Schematic of the dry impact problem (the gravity of the ball is neglected)



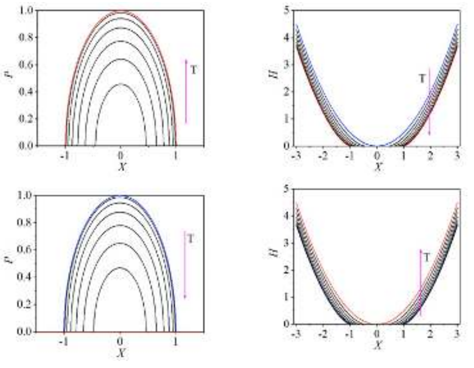


Fig 2 Centerline dimensionless pressure P and film thickness H at different times during impact, arrow indicates increasing time.

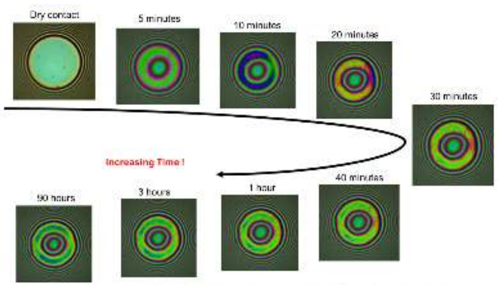


Fig 3 The recorded interferogram showing the variation of the film shape in the impact experiments. (F = 20 N, Ph=0.526 GPa, T = 23 □)

Project Aim

The goal of the EU project TRINIDAT is to optimize and experimentally validate the design of the inlet of the turboprop engines for the Next Generation Civil Tilt Rotor configuration that is being developed by Leonardo. Within this project the University of Twente is responsible for the icing analysis of the inlet, for which the in house code MB-Ice, developed in the EU project HAIC is used.

Progress

The icing analysis of the first inlet design have been carried out using the flow solution from NLR. The water catch has been computed for both Continuous Maximum and Intermittent Maximum conditions. The analysis shows that certain parts of the inlet are rather sensitive for ice accretion, while other parts hardly show any catching of water.

Dissertations

-

Scientific Publications

-

Project leaders

C.H. Venner, E.T.A. van der Weide

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

E.T.A. van der Weide and C.H. Venner

Cooperations

NLR, DNW, DeHarde, ALTRAN, ASDE, Leonardo.

Funded by

EU

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2018

Information

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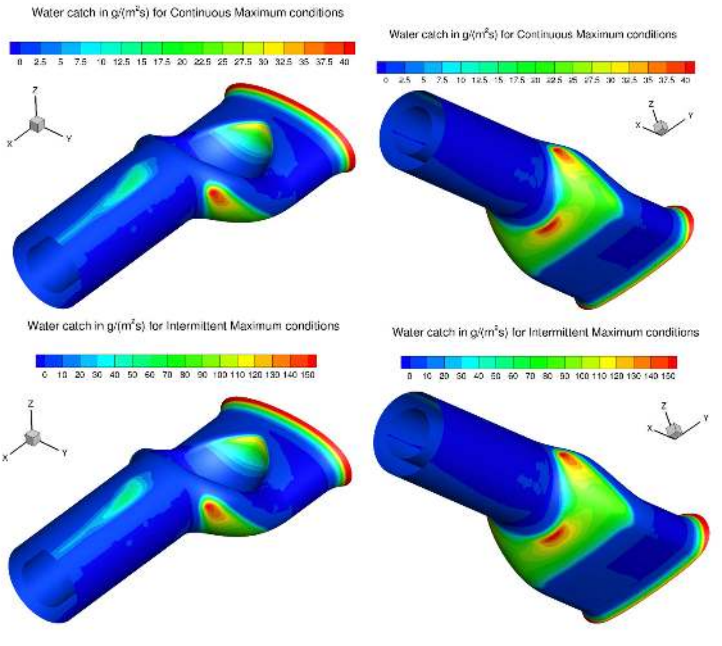

Nasal high-flow therapy to treat COPD exacerbations: a matter of monitoring and controlling settings?

Project leaders
R. Hagmeijer, C.H. Venner
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
R. Hagmeijer (UT), H.C. Venner (UT, M. Duiverman (UMCG), P.Wijkstra (UMCG), R. Hebbink (UT), K. Jain (UT), E. Groot Jebbink (UT)
Cooperations
Universitair Medisch Centrum Groningen
Funded by
TKI Longfonds
Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2018
Information
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Project Aim

COPD is a disease with high morbidity and mortality worldwide. COPD exacerbations are the important contributor to disease deterioration and decrease in health-related quality of life (HRQoL). Therapeutic options to treat exacerbations effectively are limited. Many patients have persistent loss of vital functioning and suffer from frequent re-hospitalisations. Nasal high flow therapy (nHFT) is an innovative therapy that provides humidified and heated air through a nasal cannula. We aim to prove efficacy of nHFT in enhancing recovery exacerbations by developing new technologies to control and monitor the effect of nHFT and by providing background for optimal settings of nHFT.

Progress

We have worked on a new way of monitoring nHFT by using the therapeutic device itself, which seems quite successful. Furthermore we are in the course of doing large-scale Lattice-Boltzmann (LBM) simulations to investigate the refreshment rate ("wash-out") of the nasal cavity, i.e., the removal of CO2-rich air from the nasal cavity by means of the nHFT-jets. In parallel, we are designing and realizing a corresponding particle image velocimetry (PIV) experiment to validate the LBM simulations.

Dissertations

-

Scientific Publications

-

Project Aim

To identify the different materials for microcapsules

To observe the formation of air-shell outside the capsules

To identify how the flow rate will influence the formation of capsules.

Progress

By screening varying combinations of polymers/nanoparticles and solvents, capsules were made from a liquid jet at high speed (>1 ml/min) (figure a); A layer of air formed outside the capsules (figure b); An existing problem is some of the capsules will release the liquid core when contact with water (indicated by arrows in figure c). We will try to solve this problem by adjusting the diameter of liquid jet and the ratio of polymer and nanoparticles.

Dissertations

-

Scientific Publications

-

Project leaders

C.W. Visser, C.H. Venner

Research theme

Complex dynamics of fluids

Participants

Jieke Jiang

Cooperations

IamFluidics, Aquamarijn, Bether Encapsulates

Funded by

European Regional Development Fund

Funded %

University	60 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	40 %
Scholarships	-

Start of the project

2017

Information

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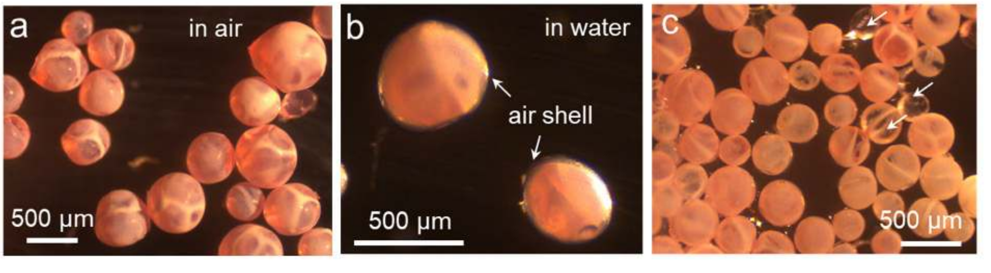

Thermal engineering

Prof.dr.ir. ThH van der Meer

Prof.dr.ir. G Brem

The research activities of the laboratory of Thermal Engineering concentrate on thermal processes for heat and power generation in industrial and domestic applications from the disciplines thermodynamics, fluid mechanics, heat transfer, chemistry and acoustics. The research aims at increasing share of the use of renewable energy, and a more efficient and clean utilization of fossil fuels. The projects are organized around the themes turbulent combustion, thermo-acoustics and transient heat transfer.

The research theme Turbulent Combustion and Thermo-acoustics is related to issues on ignition, extinction, flame stability, pollutant formation (NOx and soot), combustion noise and its interaction with the combustion chamber structure. Numerical models are developed for turbulent combustion including compressibility and heat transfer. These models are implemented in commercially available software (CFX) and in academic code (ALYA). Experimental research is performed in atmospheric and in pressurized combustors using as Laser Induced Fluorescence and Raman/Rayleigh spectroscopy for in-flame measurements of temperature and species concentrations, acoustic measurements applied to Flame Transfer Functions. For particulate emissions (soot) a system is available that can measure particle size distributions of 2-200 nm. Applications are: gas turbine engines, boilers and furnaces.

The research theme Instationary Heat Transfer is related to heat transfer in piston compressors, heat transfer and chemical conversion in pulsed compression reactors and new materials for enhanced heat transfer in regenerators and heat exchangers. Applications are: thermo-acoustic heat pumps and engines and magneto-caloric heat pumps and coolers. Numerical models are developed for the multi-physics phenomena in these systems supported by experimental research.

PROJECT AIM

This project aims to develop a model of flow and heat transfer in a complex 3D heat exchanger in a domestic boiler. This model will be implemented to improve the current pin-fin heat exchanger by a systematic optimization procedure using the adjoint method. The model will then be developed to optimize the heat transfer and pressure drop of a certain section of the heat exchanger.

PROGRESS

Several examples of improved geometries for varied combinations of heat transfer and pressure drop are presented in the dissertation. The design options provide the designer with ample selections to choose from, according to one's requirements and limitations. The flexibility and high number of design choices make the adjoint method a powerful tool for designers. However, the current ANSYS Fluent adjoint optimization procedure is not mature enough for research purposes, therefore suggestions for improvement are discussed in the dissertation. Nevertheless, at the present time this tool is considered to be the most suitable for immediate application in industry.

DISSERTATIONS

1. Modeling and Adjoint Optimization of Heat Exchanger Geometries (submitted 31 October 2019, defended 29 January 2020).

SCIENTIFIC PUBLICATIONS

1. M.C. Vidya, N.A. Beishuizen, D. de Kleine, T.H. van der Meer, Three-Dimensional Multi-Objective Shape Optimization of a Cylinder in a Cross-Flow Using Discrete Adjoint Method, Proceedings of 2nd Pacific Rim Thermal Engineering Conference (2019), 2 24393.

PROJECT LEADERS
T.H. van der Meer

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Mahening Citra Vidya

COOPERATIONS
Bosch Thermotechnology

FUNDED BY
Bosch Thermotechnology

FUNDED %

STW	-
University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2014

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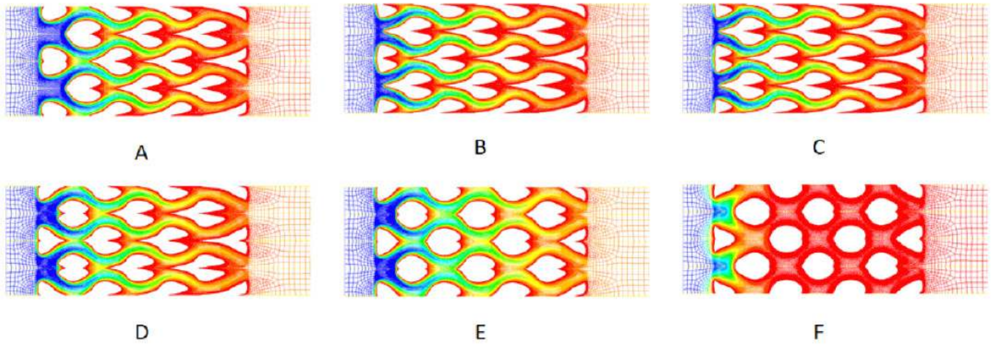

A novel thermosiphon-like cooling system based on magnetocaloric nanofluids

Project leaders
Dr. Mina Shahi
Prof. dr. ir. H.J.M. ter Brake (Marcel)
Research theme
Complex dynamics of fluids
Participants
Prof. dr. ir. Th.H. van der Meer em. (Theo), University of Twente.
Keerthivasan Rajamani, PhD Student.
Cooperations
Prof. dr. E.H. Brück (Ekkes)
Technische Universiteit Delft
Faculteit Technische Natuurwetenschappen
Radiation Science & Technology.
Prof. M.S. Toprak (Muhammet)
Royal Institute of Technology (KTH)
Department of Applied Physics (Albanova).
Dr. ir. B ten Haken (Bennie)
Universiteit Twente
Technical Medical Centre.
Dr. ir. J.F. Burger (Johannes)
Cooll Sustainable Energy Solutions B.V., Netherlands.
Dr. Neil Wilson and Dr. Allesandro Pastore, Camfridge, United Kingdom.
Funded by
TTW
Funded %
STW

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2018
Information
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Project Aim

The use of conventional air conditioning and refrigeration technologies causes global warming through the emissions of greenhouse gases. This research develops an innovative air-conditioning and refrigeration system based on magnetic nanofluids. The proposed system has a great potential to provide enhanced performance properties mainly with respect to heat transfer. This means that the system will be more efficient and environmentally- friendly by avoiding emissions of greenhouse gases. The project cooperates with industry to bring this new type of cooling to the market in future.

Progress

For usage of magnetic pumping in a magneto-caloric fluid based refrigerator, the existing systems in the literature cannot be used due to high frequency (in the range of 1000 Hz) of electric currents used. So a magnetic pumping system that uses current at frequencies less than 1 Hz was designed and its pumping characteristics were experimentally studied. Galinstan, a liquid metal at room temperature, is a preferred base liquid for suspending magneto-caloric materials. As galinstan is reactive in general to many materials, its effect on MnFe(P,Si) and LaFe(Mn,Si)H materials in terms of magnetization change over a month period was investigated.

Dissertations

1. Luca Granelli, Analysis of magnetic pumping for magnetic refrigeration applications, Master Thesis Research 2019, University of Twente.
2. C. F. D. D'Silva, Analysis of thermomagnetic convection of ferrofluid, Master Thesis Research 2019, University of Twente.

Scientific Publications

1. Rajamani, K., Granelli, L., van der Meer, T., Shahi, M., (2019) Experimental Investigation of Magnetic Pumping for Magnetocaloric Refrigerator Application, Delft Days on Magneto Calorics DDMC 2019, November 18-19, the Netherlands.
2. Rajamani, K., Zhang, F., Brück, E., Shahi, M. (2019), Investigation on the effect of Galinstan on the structural and magnetic properties of MnFe(P,Si) and La(Fe,Si)H based compounds for use in a magnetic refrigerator, European Material Research Society, 16-19 September, 2019, Poland.
3. Granelli, L., Rajamani, K., Shahi, M. (2019), Characterization of performance map of magnetic pumping for magnetocaloric refrigerator application, International Conference on Magnetic Fluids (ICMF), July 8-12, 2019, Paris, France.
4. Rajamani, K., Shahi, M., (2019) Investigation of magnetic pumping for magnetocaloric refrigerator application, Burgers Symposium, May 21-22, 2019, Lunteren, The Netherlands.

PROJECT AIM

In the agro and food industry cooling of the meat is essential to provide and keep high quality of the product. Cooling must be rapid to avoid production of the hazardous bacteria but at the same time sufficiently slow and uniform to avoid deterioration of the product and ice crystals formation. This research aims on the development, understanding and intensification of novel meat cooling techniques with application of electrostatic sprays.

PROGRESS

A CFD approach for simulating the behavior of charged, evaporating droplets was developed, based on the Ansys Fluent solver with a series of UDF's. The results were validated against experimental and numerical data from literature, showing a good match. The validation results as well as a simulation of a representative model case were submitted for journal publication. Meanwhile work was started for an experimental campaign to measure the (electrostatic) spray properties. These properties will be used as inputs to future CFD, in which a unit cell of the cooling line will be simulated.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Brentjes, A. , Pozarlik, A. K. , & Brem, G. (2019). CFD Simulation of Evaporating Electrically Charged Sprays in Food Chilling Warehouses. In E. Onate, M. Papadrakakis, & B. Schrefler (Eds.), VIII International Conference on Computational Methods for Coupled Problems in Science and Engineering: COUPLED PROBLEMS 2019 (pp. 634-644). Conference article & presentation.

PROJECT LEADERS

A.K Pozarlik, G. Brem

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

G. Brem, A.K. Pozarlik, A. Brentjes

COOPERATIONS

RBK Holding, CrestCool Concepts, Frontmatec, Aerts, IBK, Graco, Ekro

FUNDED BY

OP oost and EU EFRO

FUNDED %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2017

INFORMATION

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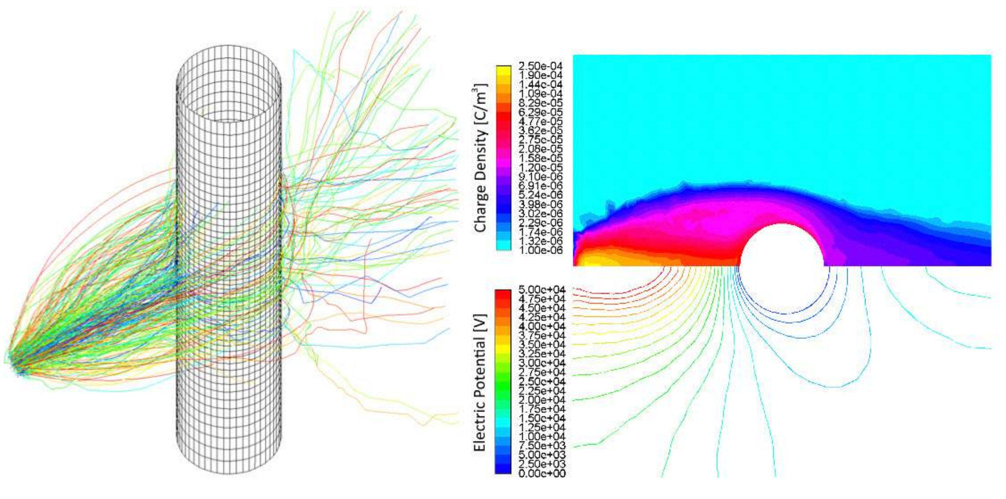
www.utwente.nl/en/et/tfe/research-groups/TE/research/projects/crestcool/#project-information



MAGISTER: Machine learning for advanced gas turbine injection systems to enhance combustor performance

Project leaders
J.B.W. Kok; respective supervisors at each participating organization listed below

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Universiteit Twente (ut), General Electric Deutschland (GEDE), Technische Universitaet Muenchen (TUM), Karlsruher institut fuer Technologie (KIT), University of Cambridge (UCAM), CERFACS, ARMINES Paris Tech, Safran (ST), Safran Helicopter Engines (SHE), ANSYS France SAS (ANSYS)

Cooperations
GE, Rolls Royce, KLM, Stanford University, Georgia Institute of Technology, FDX Fluid Dynamix, SHELL Avaiation

Funded by
Marie Skłodowska-Curie Actions (MSCA)
Innovative Training Networks (ITN)
H2020-MSCA-ITN-2017

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2018

Information
J.B.W. Kok
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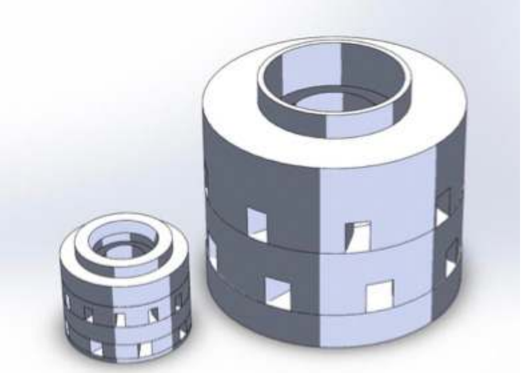
Project Aim
The researchers of the innovative training network (ITN) will study one of the most persistent challenges in aircraft engine development by using a completely new approach: controlling acoustic oscillations in aircraft engine combustors with machine learning methods. This particular ESR deals with CFD simulations of an Airblast atomizer and flame response to acoustic forcing as well as machine learning approach to instability detection.

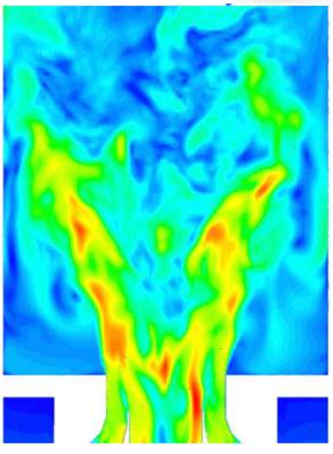
Progress
Design a new Airblast atomizer suited to our experimental requirements.
Generate a hybrid mesh on the geometry.
Perform Cold flow simulations using SU2.
Perform DES complete with combustion scheme using BVM models and FGM libraries.
Perform an acoustically forced simulation.
Extract the relevant data from simulations.

Dissertations
-

Scientific Publications

1. A. Ghasemi and J. B. W. Kok, "Numerical study of a swirl atomized spray response to acoustic perturbations," in Proceedings of the 26th International Congress on Sound and Vibration, ICSV 26, Montreal, 2019.





Enhanced catalytic fast pyrolysis of biomass for maximum production of high-quality biofuels (EnCat)

Project Aim

The EnCat project presents and investigates a new concept for the production of high-quality bio-oil and a high yield. Because of a novel biomass pre-treatment step to be developed the concept is suitable for both woody biomass and biomass residues from agriculture. The pretreated biomass will be pyrolysed in a reactor making use of deoxygenation catalysts.

The aim of the PDEng assignment, which is part of the EnCat project, is to build a CFD model that is capable to mimic a new catalytic pyrolysis oil combustion in a gas turbine. The CFD model will then be used as a tool to design an optimum condition for the combustion.

Progress

A CFD simulations in Open FOAM using diesel, ethanol and surrogates of pyrolysis oil and catalytic pyrolysis oil have been performed and validated with the available experimental data. The CFD results present a qualitatively good agreement with the experiment. Furthermore, an optimization study regarding flow parameters and geometrical dimensions has started, focusing on effect of char content, inlet temperature, primary and secondary air flows, and electrical load on the combustion process and final conversion rate of the char.

Dissertations

-

Scientific Publications

-

Project leaders

G. Brem, A.K Pozarlik, E.A. Bramer

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

G. Brem, A.K. Pozarlik, E.A. Bramer, H. Mysore Prabhakara B.A. Putra

Cooperations

OPRA Turbines, Alucha Management, KTH Royal Institute of Technology, BIOS Bioenergiesysteme

Funded by

Horizon 2020 ERA-NET Bioenergy and RVO

Funded %

University	45 %
FOM	-
STW	-
NWO Other	-
Industry	55 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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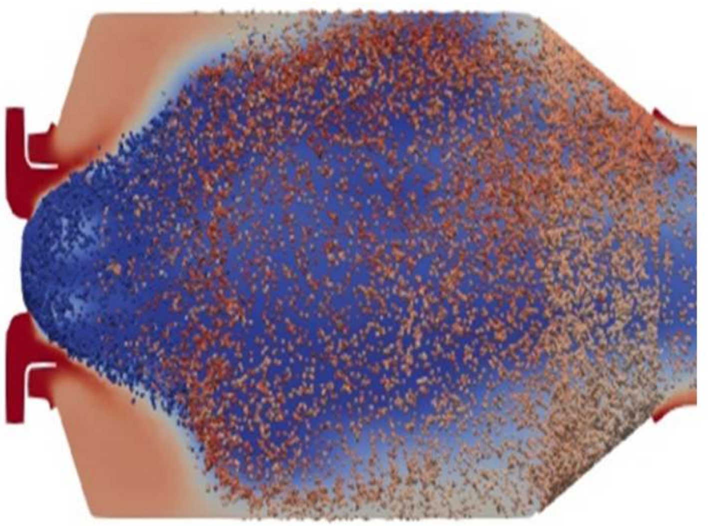
Example of oxygen and particle temperature profiles from combustion of catalytic pyrolysis oil (not optimized case)



PROJECT LEADERS
A. K. Pozarlik
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
G. Brem, A.K. Pozarlik, S. Nagasundaram, H. Norouzi Firouz
COOPERATIONS
Host Bioengineering, Saxion University of Applied Sciences
FUNDED BY
SDE/RVO
FUNDED %

University	20 %
FOM	-
STW	-
NWO Other	-
Industry	80 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2018
INFORMATION
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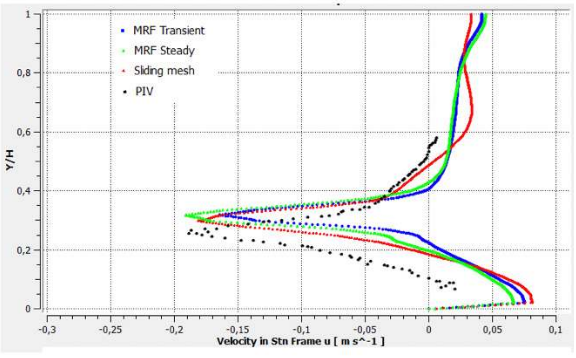
PROJECT AIM
Intensification of the biogas production from the anaerobic digestion process by optimizing turbulence and mixing levels between various organic compounds and bacteria inside a new design of the digester, is the main objective of the research. The work is divided into two PDEng assignments focused on development of a CFD models able to (i) simulate mixing in digesters over the wide range of Re numbers and (ii) predict biogas yield and composition. The models are validated and applied to design an optimized industrial scale digester.

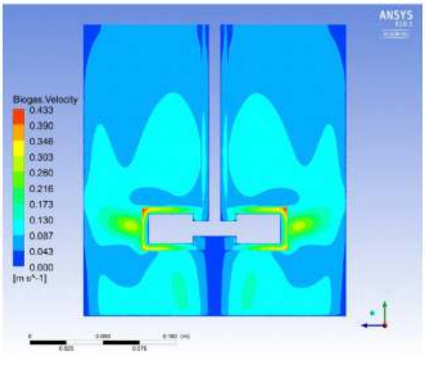
PROGRESS
Validation of the CFD code for digester hydrodynamics was done using tracer and power measurement calculations from lab and full scale digesters. Optimization of the mixing process was achieved by changing the impellers positions and directions. Furthermore, biogas production in industrial scale has been successfully simulated using combination of CFD and ADM1 model.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
1. Norouzi Firouz, H. , Pozarlik, A. K., Nagasundaram, S. , & Brem, G. (2019). Integration of biokinetic and CFD for biogas production. Poster session presented at 16e Anaerobic Digestion Conference 2019, Delft, Netherlands.
2. Nagasundaram, S. , Pozarlik, A. K. , Norouzi Firouz, H. , & Brem, G. (2019). Numerical Modelling and Validation of Shear thinning flows in a lab-scale digester. Paper presented at 16e Anaerobic Digestion Conference 2019, Delft, Netherlands.



Data comparison between CFD and lab-scale experiment



Contours of biogas velocity in lab-scale digester

Characterization of acoustically (un)forced kerosene spray flames at elevated pressure and preheated air

Project Aim

As an strategy to mitigate emission from aero engine combustors is to develop lean premixed combustors operated at very high pressure. A disadvantage is that pressure oscillations in the combustor called thermoacoustics that result critical for the lifetime of engines Traditional engineering methods fall short of predictability during the design of the engines due to a high sensitivity of thermoacoustics with respect to barely known input parameters. MAGISTER project aims to utilize Machine Learning to predict and understand thermoacoustics in aircraft engine combustors, and lead combustion research to a revolutionary new approach in this area.

Progress

Nonlinear analysis treatment of the pressure time series for an atmospheric pressure combustor has been done. At a constant thermal power, given that the noise is not sensitive on this parameter, experiments were realized going from a stable to an instable state and we were able to see a trend from a torus shaped phase portrait to a conglomerate trajectory and a three dimension portrait can reflect the behaviour of the attractors generated by the time series and its delay affected coordinates. These phase portraits and the coordinates where they exist can allow us to create predictive models that can serve as a strategy to detect thermoacoustic instabilities. The progress to make the DESIRE combustor work on liquid fuel are moving forward and new timeline has been proposed to follow.

Dissertations

-

Scientific Publications

1. S. Navarro Arredondo, J.B.W. Kok, A model to study spontaneous oscillations in a lean premixed combustor using non linear analysis, proc ICSV26, Montreal July 2019.

Project leaders

J.B.W. Kok

Research theme

Complex dynamics of fluids

Participants

J.B.W. Kok, S. Navarro Arredondo

Cooperations

General Electric, Karlsruher Institut für Technologie Cambridge University, AMINES, , ANSYS, Technische Universität München,, CERFACS and Safran HE

Funded by

European Union: Marie Curie ITN

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project

2018

Information

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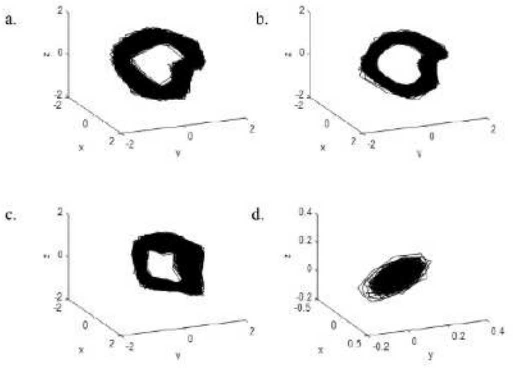
Three dimensional phase portraits for 60 kw: a. λ = 1.2, b. λ = 1.4, c. λ = 1.6 and d. λ = 1.8. Dy-namic time series of the PT3. Space portrait given by [x(t), x(t+Tts), x(t+2Tts], representing coordinates of x, y and z respectively.



New burner for DESIRE combustor

PROJECT LEADERS
A.K. Pozarlik

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
G. Brem, A.K. Pozarlik, U.J.U. Rahman

COOPERATIONS
Institute for Sustainable Process Technology (ISPT)
FrieslandCampina
Energie Centrum Nederland (ECN)
Université Catholique de Louvain (UCL)

FUNDED BY
TKI and ISPT

FUNDED %

University	20 %
FOM	-
STW	-
NWO Other	-
Industry	80 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2018

INFORMATION
A.K. Pozarlik
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www.utwente.nl/en/et/tfe/research-groups/TE/research/projects/Radial%20Multi-Zone%20Dryer/

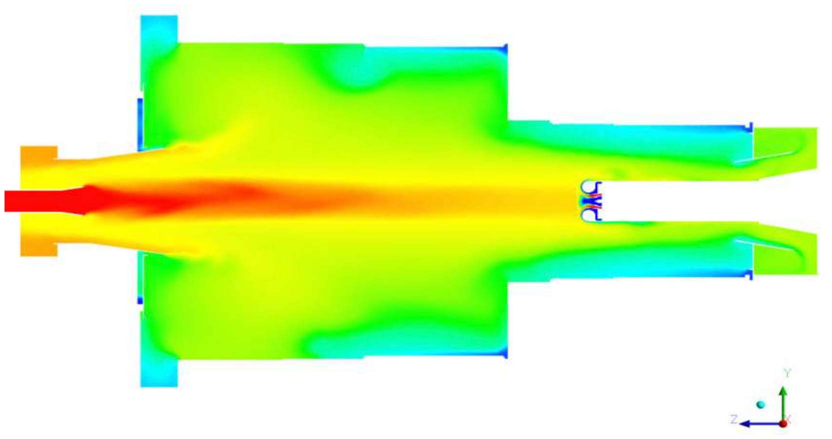
PROJECT AIM
The Radial Multi-zone Dryer is a new type of spray dryer which combines low Capex, low Opex, premium product properties and low specific energy consumption. In this project, experiments and CFD modeling are used to understand the complex multiphase flows inside the RMZD and are applied to optimize the design and derive scale up rules. The type of atomizer, particle size and particle trajectories, as well as hot gas flow are studied in detail to understand the interaction between investigated phenomena and finally to yield the desired drying behavior of RMZD.

PROGRESS
The proof of concept of spray drying in a multi-zone vortex chamber has been extensively studied both experimentally and using numerical CFD tools. A three dimensional steady state and transient CFD multi-phase models were developed to investigate the important parameters influencing drying performance in lab scale RMZD. At present, CFD model RMZD pilot unit is being studied to yield optimum air flow and spray conditions.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
1. Jamil Ur Rahman, U. , Pozarlik, A. K. , Baiazitov, I., de Broqueville, A., De Wilde, J. , & Brem, G. (2019). Stationary and transient aspects of air flow in a novel Radial Multi-Zone Dryer. 40-45. Paper presented at 7th European Drying Conference, EuroDrying' 2019, Torino, Italy.

Temperature profile inside RMZD



Project Aim

This project focuses on the conversion of acoustic power into electric power in thermoacoustic engines. For this purpose, a linear alternator is the most commonly used device. In this work, the use of a bidirectional turbine will be studied as an alternative for the acoustic to electric conversion. A bidirectional turbine rotates in the same direction, independent of the flow direction, and is therefore well suited for converting the oscillatory flow into rotational work and subsequently into electricity. The project aims to identify the operating characteristics (such as efficiency and power output) of the bidirectional turbine and optimize its application in thermoacoustic devices.

Progress

Several prototypes of bidirectional turbines have been 3D printed (see figure for schematic) and experimentally tested in a resonator tube that is connected to a loudspeaker. A fundamental analytical analysis has been done, determining the dimensionless numbers of influence and the scaling rules. Together with the experimentally investigated influence of the tip clearance and axial spacing of the turbine, this is made into a publication. In further research, the turbine design has been experimentally optimized. Finally, the optimized turbine is implemented in a thermoacoustic refrigerator to produce both electricity and cooling in a single thermoacoustic device.

Dissertations

-

Scientific Publications

1. M. Timmer and T. Van Der Meer, “Characterization of bidirectional impulse turbines for thermoacoustic engines,” J. Acoust. Soc. Am. 146(5) (2019), 3524-3535 doi: 10.1121/1.5134450.

Project leaders
TH van der Meer

Research theme
Complex dynamics of fluids

Participants
MAG Timmer

Cooperations
-

Funded by
NWO

Funded %

STW	-
University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

Information
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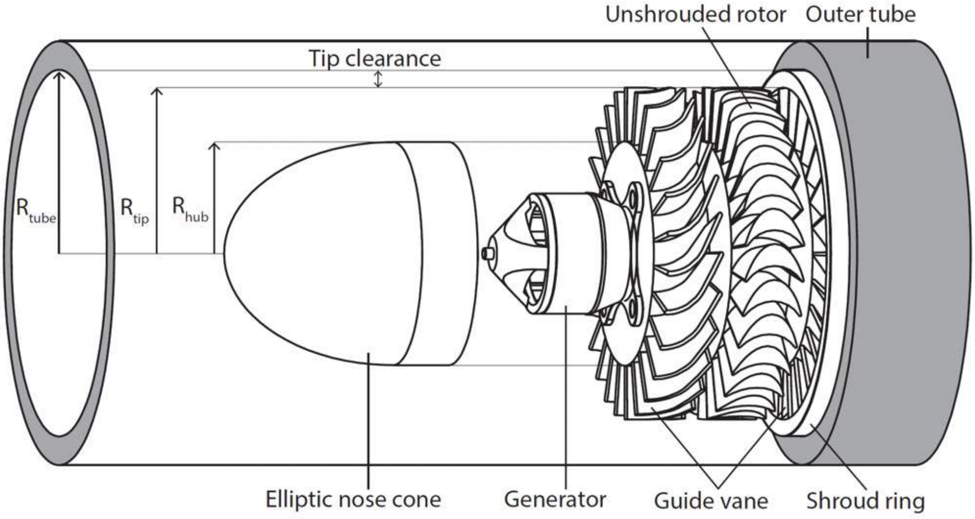

A novel thermosiphon-like cooling system based on Magnetocaloric nanofluids

Project leaders
Dr. Mina Shahi
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Keerthivasan Rajamani
Cooperations
Cooll Sustainable Energy Solutions B.V
Funded by
TTW
Funded %
STW

University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019
Information
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Project Aim

The overall aim of this project is to propose and investigate a new Magnetocaloric cooling system which is superior with respect to heat transfer. The novelty and originality of this proposed system is by using Magnetocaloric nanoparticles suspended into a base liquid in a thermosiphon-like system. Unlike the common Active Magnetic Regenerative systems, this system does not include a separate solid-Magnetocaloric-regenerator and therefore does not need to be coupled to any other secondary fluids.

Progress

A numerical code is successfully compiled and validated in OpenFOAM environment to compute magnetic field distribution produced from a current carrying wire as well as a solenoid. The effect of this distribution on the flow behaviour of ferrofluids is also studied. Additionally, an improved viscosity model is studied for its dependency on strength of magnetic field in the context of Thermomagnetic Convection for ferrofluids. This enhanced our understanding about the flow characteristics at the particle level and how it affects the velocity of magnetic fluid at system level.

Dissertations

-

Scientific Publications

-

Multiscale mechanics

Prof.dr.rer.nat. S Luding

Prof.dr. AR Thornton

The Multi-Scale Mechanics group (MSM) is part of the department Thermal and Fluids Engineering (TFE) in the Faculty of Engineering Technology (ET) at the University of Twente, as well as member of the research institute MESA+. The group studies the static and dynamic properties of dry and wet granular materials, as well as fluids and solids in general.

The main research areas include: flowing particles as well as sticky powders; segregation versus mixing; non-Newtonian fluids and rheology; macro-molecules; self-healing materials; wave-propagation in disordered media like soil; composite solids like concrete or asphalt; and avalanche flows of grains, soil or snow. A wide range of length and time scales characterises the relevant physical processes in these systems. Multi-scale mechanics means that at each length scale, the question arises how the mechanics at that level is determined by the properties of the underlying level, and how, in turn, the current level affects the next level(s).

Generally the above systems are modelled on three levels:

• Microscopic where interactions between individual grains or atoms are considered. Here, the deformation behaviour of the granule/atom/molecule with contact/interaction mechanics and physics on the nano-meter scale determines the dynamics and statics of the many particles.

• Mescoscopic where collections of upscaled grains or coarse-grained atoms with effective properties are modelled. At this level the discrete nature is still retained but 'pseudo-particles' approximate groups of grains or atoms. Mesoscopic models use the small-scale information to formulate effective contact laws. By decreasing the degrees of freedom, larger systems and longer times can be simulated allowing the study or large/slower processes like shear localisation, structure formation, self-assembly of patchy colloidal particles and proteins, or asphalt on the stone-bitumen scale of long-term use to be studied.

• Macroscopic (or bulk) where the materials are approximated by continuum models with an associated rheological model. On this level a discrete, granular material can behave like a complex fluid involving anisotropy and non-Newtonian rheological features.

The group employs a combination of theory, experiments and advanced numerical simulations to understand the multiple scales and their intricate couplings; considerable work is undertaken on accurate micro-macro methods to traverse the different levels of the modelling hierarchy. This powerful combination allows the group to develop a comprehensive fundamental understanding of the studied systems. Finally, the MSM group is a leader in open-source development and leads the open-source code particle solver: mercuryDPM (mercuryDPM.org). Additionally, it uses and contributions to many other packages like the opensource FEM solver oomph-lib. This development work in 2015 led to the foundation of a spin-off company mercuryLab.org whose aim is to put these powerful open-source sohware packages into the hands of industry.

Project Aim

Energy storage is of the utmost importance to stabilize power grids relying on intermittent renewable energy sources. A promising alternative to current commercial energy storage devices is based on a new class of electrolytes, namely ionic liquids. The aim of this project is to explore and optimize ionic liquid energy storage technologies through molecular dynamics (MD) simulations.

Progress

We performed bulk simulations of the ionic liquid [BMIM+][BF4-] and determined the diffusion coefficients of the ions, radial distribution functions, and the 3D distribution of anions around the cations. We also performed simulations for the calculation of the surface tension of the ionic liquid. In addition, we performed simulations of the ionic liquid confined between two copper electrodes on which we imposed both fixed charges and a constant potential. The number densities of these systems were calculated. We are also looking at simpler electrolytes confined between electrodes in order to compare our results with DFT calculations.

Dissertations

-

Scientific Publications

-

Project leaders

A.R. Thornton, W.K. den Otter

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

R.S. Sitlapersad

Cooperations

Utrecht University

Jawaharlal Nehru Centre for Advanced Scientific Research (Bangalore, India)

Funded by

NWO

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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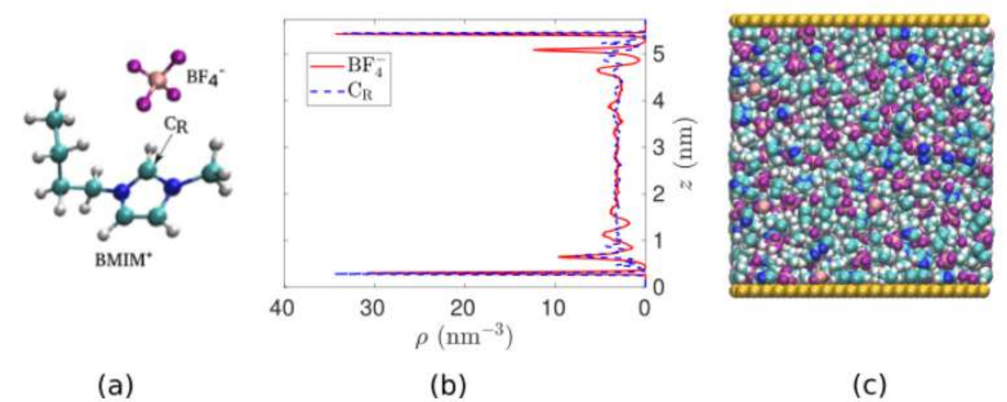
MD simulation of [BMIM+][BF4-] confined between copper electrodes on which a constant potential of 0 V is applied: (a) structure of the ionic liquid, (b) number densities of the ions and (c) snapshot of the simulations



Virtual prototyping of particulate processes (ViPr) – Design and optimization via multiscale modeling and rapid prototyping

Project leaders
T. Weinhart

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
H. Cheng

Cooperations
-

Funded by
STW-NWO-AES VIDI

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019

Information
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Project Aim

Particulate processes are difficult to predict and highly relevant to many fields such as civil, geotechnical and mechanical engineering. Classically the bulk of granular particles are modeled as continua where a material model is essential. Discrete element method provides a bottom-up approach to accurately predicting the constitutive behavior of a material. However, the cost is formidable for large-scale industry applications. In this project, we aim to develop concurrent multi-scale methods by coupling continuum and particle methods either within an overlapping volume or at contact interfaces where the information is mapped between distinctive scales via coarse graining.

Progress

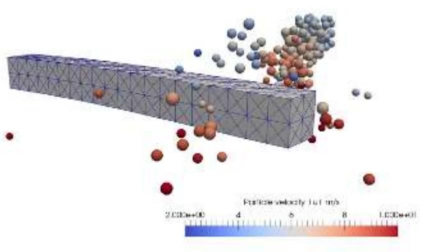
Two FEM-DEM concurrent coupling schemes, namely surface coupling (SC) and volume coupling (VC) have been implemented within a concurrent multi-scale modeling framework. SC is well suited for particle-machinery interaction problems (Fig. 1) where deformation, fatigue, etc. in the structure is important. VC is implemented with the goal to adaptively switch from a discrete particle to a continuum model (Fig. 2), and vice versa, depending on a trade-off between accuracy and efficiency and relevant length/time scales. The method is further developed with the help of coarse graining which allows to map particle scale data to the macro scale while conserving mass and momentum.

Dissertations

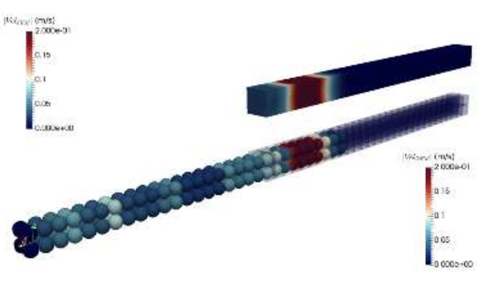
-

Scientific Publications

1. Cheng, H., Luding, S., Saitoh, K. & Magnanimo, V. (2019). Elastic wave propagation in dry granular media: effects of probing characteristics and stress history. International Journal of Solids and Structures.
2. Cheng, H., Luding, S., Rivas, N., Harting, J. & Magnanimo, V. (2018). Hydro-micromechanical modeling of wave propagation in saturated granular media. International Journal for Numerical and Analytical Methods in Geomechanics. 43:1115-1139.
3. Cheng, H._, Shuku, T., Thoeni, K., Tempone, P., Luding, S. & Magnanimo, V. (2018). An iterative Bayesian filtering framework for fast and automated calibration of DEM models. Computer Methods in Applied Mechanics and Engineering. 350: 268-294.



Inflow of particles hitting an elastic body



Wave propagation from DEM to FEM

PROJECT AIM

The aim of this project is to develop numerical tools to simulate polydisperse granular flows, in particular for rotating geometries such as rotating drums. Continuum simulation methods, such as finite volume methods or discontinuous Galerkin finite element methods, are fast but require many assumptions and closure relations. On the other hand, discrete particle simulations are accurate, but computationally very expensive. This project aims to combine both types of simulation methods in order to develop fast and accurate numerical solvers for granular flows.

PROGRESS

Models for shallow bidisperse granular chute flows have been discretized using a discontinuous Galerkin finite element method implemented in hpGEM. Using closure-parameters that were measured in 3D particle simulations of small systems, the one-dimensional continuum simulations show that a structure emerges with the front of the flow being thicker than the inflow, see Figure 1. We developed a traveling wave solution for this structure and have shown that the continuum simulations converge to this traveling wave solution. With the approximations being made, the continuum simulations show remarkable good similarity to discrete particle simulations.

DISSERTATIONS

1. I.F.C. Denissen, On segregation in bidisperse granular flows, University of Twente, 28 November 2019.

SCIENTIFIC PUBLICATIONS

1. I.F.C. Denissen, T. Weinhart, A. te Voortwis, S. Luding, J.M.N.T. Gray and A.R. Thornton, Bulbous head formation in bidispersed shallow granular flow over an inclined plane, J. Fluid Mech. 866, 263 (2019).
2. A.R Thornton, M. Post, L. Orefice, P. Rapino, S. Roy, H. Polman, M.Y. Shaheen, J.E. Alvarez Naranjo, H. Cheng, L. Jing, H. Shi, J. Mbaziira, R. Roeplal and T. Weinhart, Faster, more flexible, particle simulations: the future of MercuryDPM, Proceedings of the 8th International Conference on Discreet Element Methods (DEM8), Enschede (2019).

PROJECT LEADERS
A.R. Thornton

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
I.F.C. Denissen

COOPERATIONS
T. Weinhart, S. Luding, D.R. Tunuguntla, N. Gray (Univ. of Manchester, U.K.)

FUNDED BY
STW-NWO VIDI

FUNDED %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2015

INFORMATION
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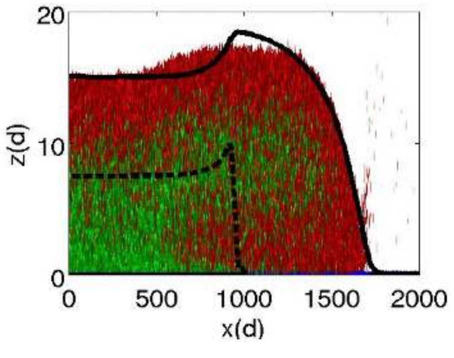

Comparison of a discrete particle simulation of a bidisperse flow down an inclined plane (with large particles in red and small particles in green) with species boundaries by the bidisperse shallow granular continuum model (black lines). Note that the x-axis is 100-fold compressed

Project leaders
W. K. den Otter, S. Luding
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
T. Hulikal Chakrapani, A. Jarray
Cooperations
Océ Industry B.V.
(Canon Production Printing as of 1st January 2020), TU/e
Funded by
NWO/Océ
Funded %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
Information
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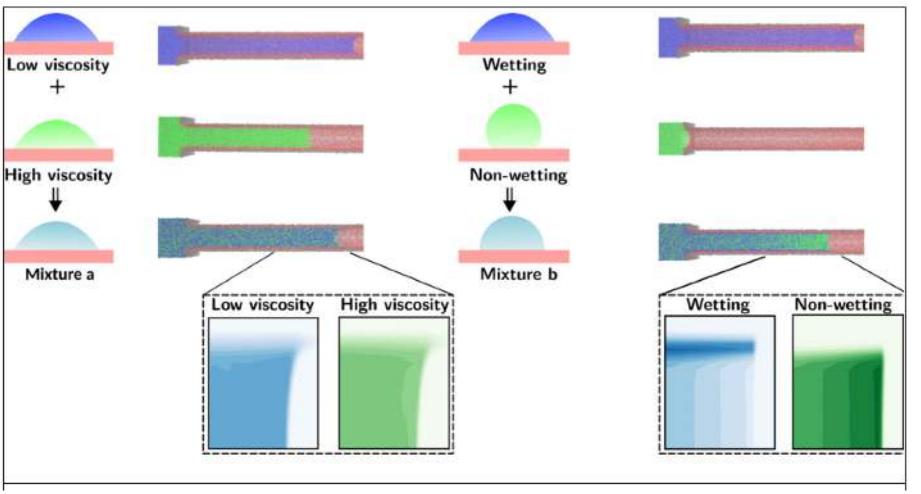
Project Aim
Water-based ink for ink-jet printing on paper contains several components in addition to pigment particles. With the water content of the droplet gradually decreasing through evaporation and imbibition into the paper, a solidifying deposit is left at the surface of (and partly inside) the paper. A good ink produces a well-defined and lasting deposition of pigment particles. The aim of the project is to study the evolution of ink droplets deposited on paper at the mesoscopic level. The project entails modeling both the ink, a complex liquid, and the paper, a complex solid.

Progress
Binary liquid mixtures are used as solvents in jetting inks, and they can significantly affect the ink-paper interaction. Hence, we first studied the capillary imbibition of binary mixtures into cylindrical nanopores. For pairs of fluids differing in their viscosities only the less viscous fluid is slightly enriched at the imbibition front. Surprisingly, for mixtures differing in their wettability only, the less wettable component is significantly enriched at the imbibition front. This effect is attributed to the more wetting fluid forming a monolayer covering the walls, acting as a lubrication layer for the less wetting fluid (see right column of Figure 1).

Dissertations
-

Scientific Publications
-



Schematic of the capillary imbibition of binary mixtures into a nanopore. (Left) Pairs of fluids varying in their viscosity only. The concentrations of the two fluids are almost equal near the wetting front. (Right) Pairs of fluids varying in their wettabilities only. The concentration of the non-wetting fluid at the wetting front is significantly higher than its wetting counterpart

PROJECT AIM

Wettability and imbibition of ink in paper are key phenomena underlying the inkjet printing process. The goal of this project is to investigate the complex multiphase ink-substrate interactions at the microscopic scale using molecular dynamics simulations. The research is subdivided into two work packages: developing an approach to formulating an optimal water-based ink, and exploring the imbibition of ink in a porous medium.

PROGRESS

When a drop of water-based ink is deposited on a porous substrate, the imbibition of the droplet is strongly affected by the ink composition and the pore's physicochemical properties. Molecular dynamics simulations are used to take into account the multitude of interactions between the ink components and the substrate. We find that surfactants enhance the imbibition of the fluid mixture into a capillary, see Figure. The chemical properties of the porous structure also markedly affect the imbibition rate. These findings, and the exploration of their molecular origins, enable the formulation of guidelines for the efficient design of more optimized inks and paper coatings.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

S. Luding, W.K. den Otter,
H. Wijshoff, T. Nicolae, A.A. Darhuber

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

J. Ahmed, T. Hulikal Chakrapani

COOPERATIONS

Océ, TU/e

FUNDED BY

STW - NWO

FUNDED %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2017

INFORMATION

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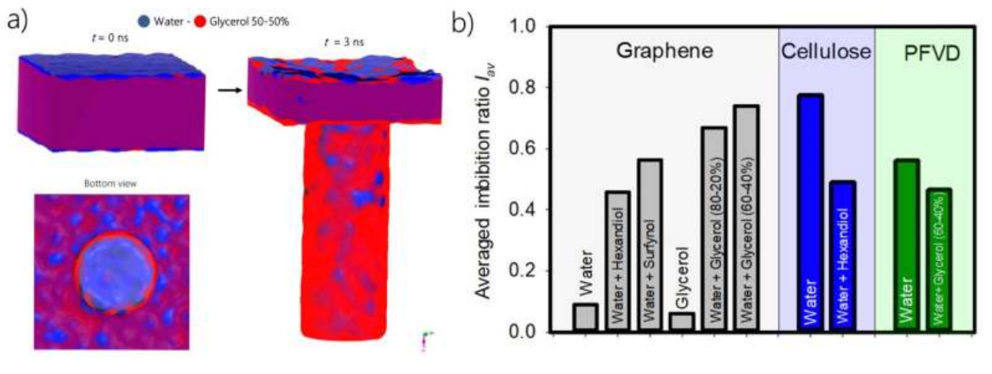

a) Molecular dynamics simulation of imbibition into a nanopore by a water-glycerol mixture. b) Imbibition ratios of various liquids into pores in various materials

Systematic approach to predicting wettability using molecular dynamics simulation

Project leaders
S. Luding, W.K. den Otter, H. Wijshoff, T. Nicolae, A. A. Darhuber, J. Luiken

Research theme
Complex dynamics of fluids

Participants
J. Ahmed

Cooperations
Océ, TU/e.

Funded by
STW-NWO

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017

Information
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Project Aim
Wettability of ink on paper is a key phenomenon underlying the inkjet printing process. The goal of this project is to establish a fast and reliable method to predict the degree of wettability of liquids on substrates.

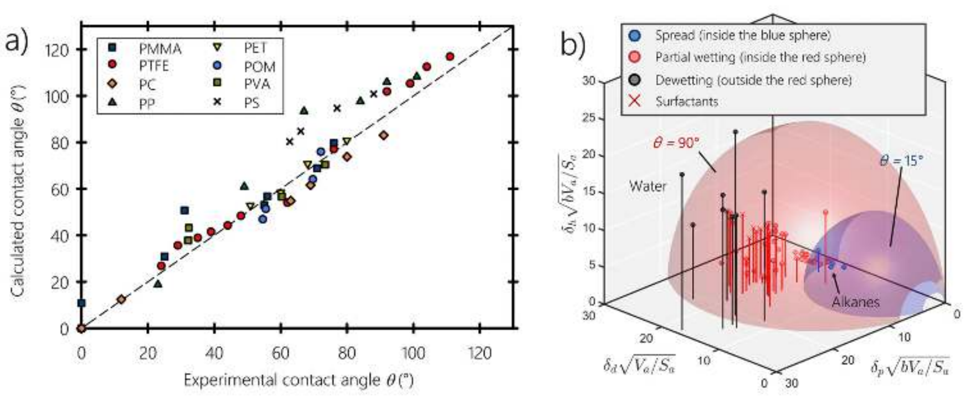
Progress
We developed a method whereby the contact angle of a liquid droplet deposited on a substrate is extracted from simulations of the bulk liquid and the bulk substrate, without the two ever coming into contact in the simulations. The figure shows the excellent agreement between simulation results and experimental data. We also proposed a 3D wettability space, inspired by the Hansen solubility parameter space, to generate the wetting spheres of substrates, see Figure. This permits a fast prediction of the wettability properties of liquids and liquid mixtures on these substrates, facilitating the design of suitable inks for specific substrates.

Dissertations
-

Scientific Publications

1. Jarray A., V. Magnanimo, S. Luding. Wet granular flow control through liquid induced cohesion, Powder. Tech. 341, 126-139 (2019).

a) Simulation-based versus experimental contact angle of several liquids on various polymeric substrates. PMMA: polymethyl methacrylate, PTFE: polytetrafluoroethylene, PP: polypropylene, PC: polycarbonate, PET: polyethylene terephthalate, POM: polyoxymethylene, PS: polystyrene and PVA: polyvinyl alcohol.
b) Wettability spheres with liquids, represented by dots, inside the blue (red) sphere forming contact angles of less than 15° (90°) on PTFE.



Shaping segregation: advanced modeling of segregation and its application to industrial processes – parallel particle simulation (mercuryDPM.org)

Project Aim

Granular segregation is a major problem to numerous industries, which often rely on empirical rules of thumb to predict non-segregating operating conditions. The aim of this project is to understand the fundamental cause(s) of segregation, particularly in rotating drums, which are investigated using particle simulation tools (MercuryDPM) and particle analysis tools (MercuryCG).

Progress

To investigate segregation, we performed particle simulations of chute flows of similar-sized particles containing one 'intruder' particle of deviant size. The intruder particle is kept at a fixed height normal to the planar chute, to determine the average segregation force acting on the particle. Analysis of the macroscopic field data (density, flow/strain, stress tensor, etc) is currently in progress, using the open source coarse graining tool MercuryCG. Furthermore, MercuryDPM has been adapted to parallel computing. This enables investigation of the extremely slow axial segregation process of bidispere granular beds in rotating long drums.

Dissertations

1. M.P. van Schrojenstein Lantman, A study on fundamental segregation mechanisms in dense granular flows, University of Twente, 25 April 2019.

Scientific Publications

-

Project leaders
A.R. Thornton

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
I.F.C. Denissen

Cooperations
T. Weinhart (UT)
S. Luding (UT)
K. van der Vaart (UT and EPFL, Lausanne, CH)

Funded by
STW-NWO VIDI

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

Information
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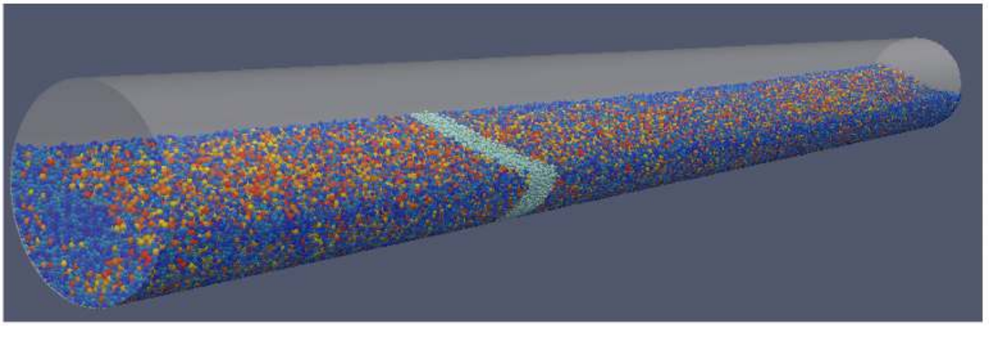

Snapshot of a bed of large (yellow/red) and small (blue) granules in a rotating drum. The simulation runs in parallel, with the white band indicating the workload of one core.

Project leaders
W.K. den Otter

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Duraivelan Palanisamy

Cooperations
-

Funded by
NWO/FOM – Shell CSER project

Funded %

University	-
FOM	100 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2014

Information
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Project Aim

With the increasing number of non-dispatchable sustainable energy sources, electrical energy storage is crucial to maintaining a stable power grid. The recently proposed 'semi-solid rechargeable flow battery' offers a promising new technique for such energy storage. The aim of this PhD project is to develop a simulation model for the complex physical processes taking place in the (dis)charge cell, in particular i) the flow behavior of sticky colloidal suspensions, ii) the flow of charge between the colloidal aggregates and the walls of the cell, and iii) the interplay between both flows.

Progress

We have developed an efficient general method to simulate, in the Stokesian limit, the coupled translational and rotational dynamics of arbitrarily shaped colloids subject to external potential forces, linear flow fields and Brownian motion. The colloid's surface is represented by a collection of spherical primary particles, see figure, whose hydrodynamic interactions are condensed into a single (11 × 11) grand mobility matrix for the entire colloid. Methods have been developed to determine the viscosity of a dilute solution of these colloids, both under linear shear flow and by a Green-Kubo analysis of the thermal fluctuations of the stress in a quiescent solution.

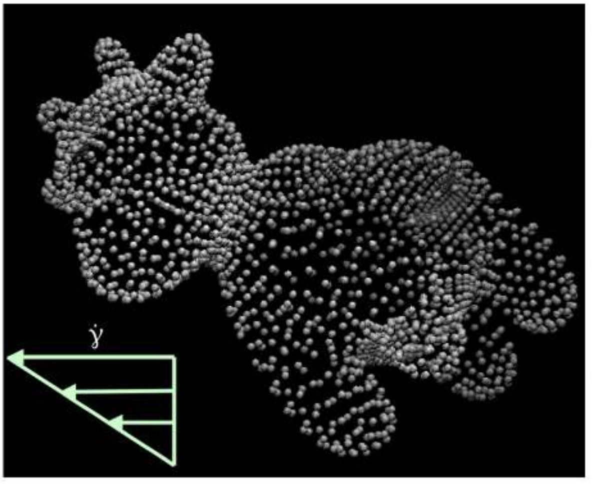
Dissertations

1. D. Palanisamy, Micro-hydrodynamics of non-spherical colloids: a Brownian Dynamics study, University of Twente, 16 May 2019.

Scientific Publications

1. D. Palanisamy and W.K. den Otter, Intrinsic viscosities of non-spherical colloids by Brownian Dynamics simulations, J. Chem. Phys. 151, 184902 (2019).

Snapshot of an arbitrarily shaped colloid tumbling in a linear shear flow (as indicated by the arrows).



PROJECT AIM

• Identify the non-cohesive and cohesive regimes of granular systems;

• Develop DEM contact models for dry and cohesive systems, and calibration thereof by laboratory experiments;

• Apply the adhesive contact model to describe industrial-scale tableting.

PROGRESS

The work is at the closure stage in line with the objectives described above. We have achieved the first objective by conducting material characterization tests on limestone powders with a wide distribution of sizes, and thus cohesivity, with various shear testers. The results are currently being explored in more detail for the particle and continuum model calibrations of the second objective. For the third objective, we have conducted the high stress tableting study on the same limestone powders and the results will be published soon. In addition, an investigation of dilute to dense granular rheology has being conducted, culminating in the development of an extended generally valid model involving the dependence of density and macroscopic friction on dimensionless numbers that characterize shear rate, softness, friction, and cohesivity.

DISSERTATIONS

1. Shi, H. (2019). Deformation of Cohesive Granular Materials: Micro influences Macro. Enschede: Ipskamp Printing. DOI: 10.3990/1.9789036547420. ISBN: 978-90-365-4742-0.

SCIENTIFIC PUBLICATIONS

1. García-Triñanes, P., Luding, S., & Shi, H. (2019). Tensile strength of cohesive powders. Advanced Power Technology, 30(12), 2868-2880.
2. Jarray, A., Shi, H., Scheper, B., Habibi, M., & Luding, S. (2019). Cohesion-driven mixing and segregation of dry granular media. Scientific Reports, 9(1), 1-12.
3. Weinhart, T., Orefice, L., Post, M., van Schrojenstein Lantman, M.P., Denissen, I.F., Tunuguntla, D.R., Tsang, J.M.F., Cheng, H., Shaheen, M.Y., Shi, H. and Rapino, P. (2019). Fast, flexible particle simulations—An introduction to MercuryDPM. Computer Physics Communications, (249), p.107129.

PROJECT LEADERS

V. Magnanimo, S. Luding

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

H. Shi (UT), A. Jarray (UT)

COOPERATIONS

Tech. Univ. Braunschweig, Univ. of Edinburgh, Univ. of Greenwich, Univ. of Liége

FUNDED BY

EU ITN T-MAPPP

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

START OF THE PROJECT

2014

INFORMATION

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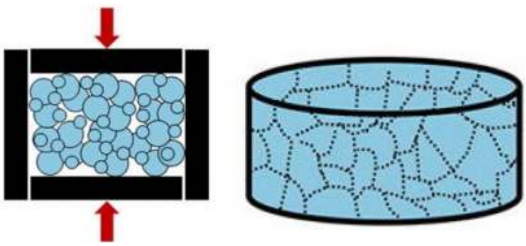
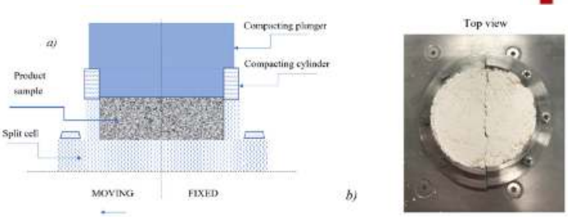
Schematic representation of the tableting process





(a) Ajax Equipment full volume cell illustrated.
(b) Eskal300 sample springing apart.

PROJECT LEADERS
A.R. Thornton, T. Weinhart, S. Luding
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
M.J. Post
COOPERATIONS
-
FUNDED BY
NWO-STW
FUNDED %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017
INFORMATION
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PROJECT AIM

Powder agglomeration is a widely encountered phenomenon in many industries such as pharmaceutics, additive manufacturing, food processing and so forth. A fast and accurate numerical model of agglomeration is therefore highly desired. We have developed a multiscale approach to extract the macroscopic bulk behavior of powders from the microscopic particle-particle interactions. The aim of this project is to extend this model to also include particle-fluid interactions. The extended model will specifically be used for applications that involve high pressure powder agglomeration, a.k.a. tableting.

PROGRESS

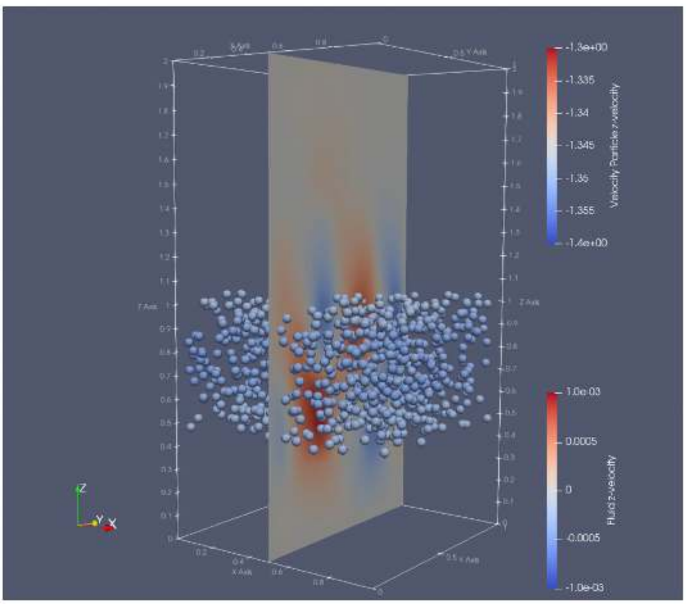
The particle-fluid coupling is incorporated using two open-source codes: MercuryDPM as the particle solver and oomph-lib as the finite element method (FEM) fluid solver. The current work focusses on under-resolved coupling, using the Anderson-Jackson formulation, with the particle volume fraction extracted from discrete particle simulation. This will then be applied to the die filling process and powder compaction to study the tableting process. In the current state of the code, 3D two-way coupled, the behavior of a particle-fluid system can be studied for example in particle settling (see Figure).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Two-way coupled simulation of particles settling in a fluid.

PROJECT AIM

The aim of this project is to quantitatively predict agglomeration of fine-grained material through compression and/or heating. This requires the development and calibration of new multi-scale particle models for fine powders and their subsequent application to processes in, among others, additive manufacturing and the production of pharmaceutics. Selective laser sintering (SLS) and tableting are chosen as the prototype processes to which the new techniques are applied first. Especially challenging and novel aspects are the process dynamics, both the kinetics and rate-dependence, as well as the coupling between the macro and micro scales.

PROGRESS

Selective Laser Sintering (SLS) is an additive manufacturing process consisting of various stages, each requiring different process parameters. Typically, the optimization of those parameters to achieve the desired final properties is done by performing costly experimental trials. We are developing a computational model that will help reduce the number of trials, thereby reducing the manufacturing costs. In addition, allowing processability predictions for new materials. This is achieved by comparing numerical results obtained through simulation of individual production steps against experimental data on the same processes, as illustrated by the figures below, as for example, spreading (Fig. 1), contact melting (Fig. 3), and AM-product testing (Fig. 2), to advance the development of accurate predictive models.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. M.Y. Shaheen et al., Discrete particle simulation of the spreading process in additive manufacturing, Int. Conf. Discrete Element Methods (DEM8) (2019).

PROJECT LEADERS
T. Weinhart, S. Luding, A. Thornton

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
M.Y. Shaheen, M. J. Post

COOPERATIONS
-

FUNDED BY
STW

FUNDED %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2017

INFORMATION
M.Y. Shaheen
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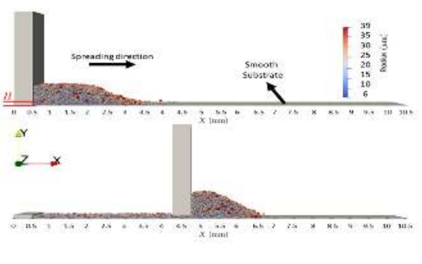
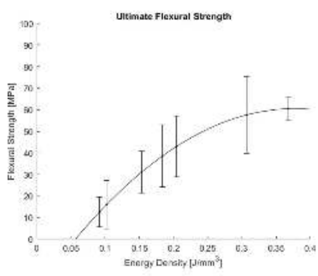
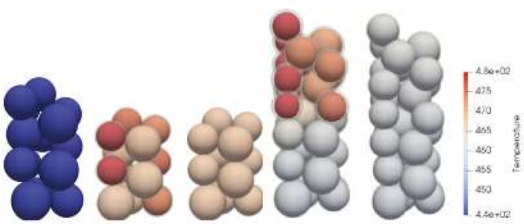
Powder spreading process



Flexural strength of SLS parts



Simulation snapshots, from left to right: (1) add layer of particles, (2) partial melting during heating, (3) forming bonds during cooling, (4) add second layer of particles, heating it and (5) allow it to cool down



Prof.dr. SJMH Hulscher

The work of the Water Engineering and Management (WEM) group was originally mainly devoted to the modelling of sand waves on the seabed. First it was shown, that the seabed patterns in the North Sea can be explained as free instabilities of the seabed. Subsequently, the modelling of sand waves was extended and refined. The group has worked on a scientific and practical tool for fully nonlinear modelling of sand waves. Over the last five years, the offshore morphodynamic work has broadened to rivers, coasts and blue-ice. Alternate bars in a flume were compared with (Ginzburg-)Landau-type models. The group was the first to explore data assimilation for morphodynamic predictions. Further work concentrated on using data assimilation to combine field data with sand wave amplitude models for maintenance dredging management of navigation channels and sand wave-related pipeline problems. Also, North Sea data were analysed and a new bed mode, called long bedwaves, was discovered. The origin of nearshore bars was addressed. A method was developed for modelling human interferences in a morphodynamic setting. This has opened perspectives for a new approach towards modelling large-scale sand mining in shallow seas. A project for developing tools for evaluation of human interference in the North Sea for optimal management of the seabed started recently and sediment transport concerning near-shore sand pits is being investigated. Since 2000 the group has studied the use of morphodynamical models in a societal context. Recently, a method for decision making based on quantitative information including uncertainties was developed in the multidisciplinary project Flyland, which opens the field of designing an assessment framework for appropriate modelling.

RiverCare project F: River governance: uncertainties, participation and collaboration

Project Aim

In recent years the Room for the River policy programme was implemented in the Dutch river system. This programme consisted of numerous interventions in the river system. RiverCare aims to learn from such large programmes to fundamentally improve the understanding of adaptation in river systems. In subproject F1 we study the validity and uncertainty of models used to quantify the effects of such projects. Our aim is to develop a method for efficient uncertainty estimation for models applied in river engineering.
In subproject F2 we study public perceptions of such interventions and stakeholder participation in monitoring the effects.

Progress

In F1, we developed a method to significantly decrease the computational burden of uncertainty quantification and we quantified the uncertainty of archetypical spatial interventions and demonstrated that the uncertainty is between 20% to 40% of the mean effect. Finally we compare model simulations with thirty years of hydraulic observations. In F2, surveys were used to measure public perceptions of the river landscape, attachment to the area, trust and perceptions of the intervention. Based on the results we designed a pilot for participatory monitoring with local anglers. This method to engage local stakeholders in adaptive monitoring is now being tested.

Dissertations

-

Scientific Publications

1. Berends, K.D., Scheel, F., Warmink, J.J., de Boer, W.P., Ranasinghe, R., Hulscher, S.J.M.H. (2019), Towards efficient uncertainty quantification with high-resolution morphodynamic models: A multifidelity approach applied to channel sedimentation. Coastal Engineering 152, 103520. https://doi.org/10.1016/j.coastaleng.2019.103520.
2. Berends, K.D., Straatsma, M.S., Warmink, J.J., Hulscher, S.J.M.H., (2019), Uncertainty quantification of flood mitigation predictions and implications for interventions. Nat. Hazards Earth Syst. Sci. 19, 1737-1753, https://doi.org/10.5194/nhess-19-1737-2019.
3. Cortes Arevalo, V.J. Verbrugge, L.N.H., den Haan, R.J., Baart, F., van der Voort, M.C., Hulscher, S.J.M.H. (2019) Users' Perspectives About the Potential Usefulness of Online Storylines to Communicate River Research to a Multi-disciplinary Audience, Environmental Communication, 13:7, 909-925, DOI: 10.1080/17524032.2018.1504098.

Project leaders

prof. dr. S.J.M.H. Hulscher
dr. J.J. Warmink
dr. D. Augustijn

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

ir. K.D. Berends
dr. L.N.H. Verbrugge

Cooperations

Deltares, Rijkswaterstaat, Witteveen+Bos, HKV, Waterbouwkundig Laboratorium (Flanders Hydraulics Research)

Funded by

NWO STW (Perspectief)

Funded %

STW	-
University	-
FOM	-
STW	75 %
NWO Other	-
Industry	20 %
TNO	-
GTI	5 %
EU	-
Scholarships	-

Start of the project

2015

Information

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Longitudinal training dam as a river intervention along the river Waal, The Netherlands (source: Rijkswaterstaat).

All-Risk: Modeling the effects of transitions on wave overtopping flow and dike cover erosion

Project leaders
prof. dr. S.J.M.H. Hulscher
dr. J.J. Warmink

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
V.M. van Bergeijk, MSc

Cooperations
Rijkswaterstaat, Ministerie van Infrastructuur en Water, Deltares, HKV, Royal Haskoning DHV, Arcadis, Witteveen + Bos, HillBlocks, Vechtstromen

Funded by
NWO TTW (Perspectief)

Funded %
STW

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017

Information
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Project Aim

During storms, waves overtop the dikes and cause erosion at the landward side of the dike. The erosion due to wave overtopping can lead to a dike breach. Wave overtopping is one of the main cause of dike failure and transitions are potential weak spots in the dike cover. However, there is still a lot unknown about the wave overtopping process and its erosional effects. The goal of the project is to quantify and model the effect of transitions on overtopping flow and dike cover erosion.

Progress

A paper was published on an analytical model for the wave overtopping flow velocities on the crest and landward slope. Two master students coupled this analytical model to an erosion model and applied it to the Afsluitdijk and to different transitions to show the applicability of the model.

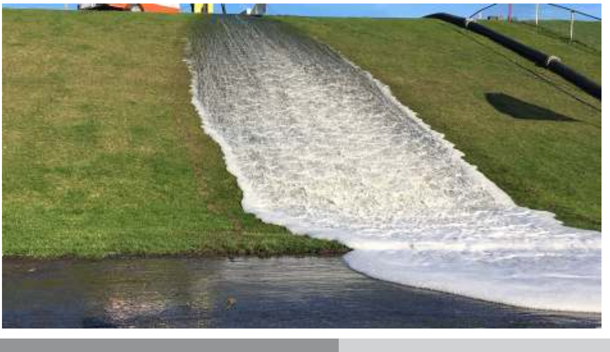
A detailed hydrodynamic model was developed in the open-source software OpenFOAM. The model results are validated with field tests on grass-covered dikes in the Netherlands. The hydraulic forces along a dike profile are studied to find the dominant hydrodynamic process during overtopping.

Dissertations

-

Scientific Publications

1. Van Bergeijk, V., Kriebel, M., & Warmink, J. (2019). Wave overtopping on the reinforced green Afsluitdijk: A case study on the grass cover. ConcepTueel, (4), 16-19.
2. Van Bergeijk, V. M., Warmink, J. J., Frankena, M., & Hulscher, S. J. M. H. (2019). Modelling Dike Cover Erosion by Overtopping Waves: The Effects of Transitions. In N. Goseberg, & T. Schlurmann (Eds.), Coastal Structures 2019. Bundesanstalt für Wasserbau. https://doi.org/10.18451/978-3-939230-64-9_110.
3. Van Bergeijk, V. M., Warmink, J. J., & Hulscher, S. J. M. H. (2019). Dike cover erosion by overtopping waves: an analytical model. 32-32. Abstract from NCR Days 2019: Land of Rivers, Utrecht, Netherlands.
4. Van Bergeijk, V. M., Warmink, J. J., van Gent, M. R. A., & Hulscher, S. J. M. H. (2019). An analytical model of wave overtopping flow velocities on dike crests and landward slopes. Coastal engineering, 149, 28-38. https://doi.org/10.1016/j.coastaleng.2019.03.001.
5. Van Bergeijk, V. M., Warmink, J. J., & Hulscher, S. J. M. H. (2019). An analytical model for dike cover erosion by overtopping waves. 27-27. Abstract from NCK-DAYS 2019, Enkhuizen, Netherlands.



Project Aim

We aim to contribute to improvement of the current estimates of discharge-frequency relationships for the Lower Rhine, which is the primary tool for flood risk management in the lower Rhine delta and directly contributes to the first layer of protection. This study focusses on the parametrization of hydraulic characteristics of the river and floodplains of the various historical years and use this as input for the hydraulic models to reconstruct past flood magnitudes and hence extent the historic time series of measured discharges.

Progress

In the last year, a method was developed to study how dike breaches may influence downstream discharge partitioning. A manuscript has been submitted to Natural Hazards. Furthermore, a method was set up that enables the inclusion of historic flood events in flood-frequency analysis, reducing the uncertainty intervals of flood-frequency relations. Finally, a surrogate model (ANN) was set up with which it is possible to determine the maximum discharge during the 1809 flood event of the Rhine river.

Dissertations

-

Scientific Publications

1. Bomers, A. , Schielen, R. M. J. , & Hulscher, S. J. M. H. (2019). Application of a lower-fidelity surrogate hydraulic model for historic flood reconstruction. Environmental modelling & software, 117, 223-236. https://doi.org/10.1016/j.envsoft.2019.03.019.
2. Bomers, A. , Schielen, R. M. J. , & Hulscher, S. J. M. H. (2019). Consequences of dike breaches and dike overflow in a bifurcating river system. Natural hazards, 97(1), 309-334. https://doi.org/10.1007/s11069-019-03643-y.
3. Bomers, A. , Schielen, R. M. J. , & Hulscher, S. J. M. H. (2019). Decreasing uncertainty in flood frequency analyses by including historic flood events in an efficient bootstrap approach. Natural hazards and earth system sciences, 19(8), 1895-1908. https://doi.org/10.5194/nhess-19-1895-2019.
4. Bomers, A., Meulen, B. , Schielen, R. M. J. , & Hulscher, S. J. M. H. (2019). Historic Flood Reconstruction With the Use of an Artificial Neural Network. Water resources research, 55(11), 9673-9688. https://doi.org/10.1029/2019WR025656.
5. Bomers, A. , Schielen, R. M. J. , & Hulscher, S. J. M. H. (2019). The effect of dike breaches on downstream discharge partitioning. 28-28. Abstract from NCR Days 2019: Land of Rivers, Utrecht, Netherlands.
6. Bomers, A. , Schielen, R. M. J. , & Hulscher, S. J. M. H. (2019). The influence of grid shape and grid size on hydraulic river modelling performance. Environmental fluid mechanics, 19(5), 1273-1294. https://doi.org/10.1007/s10652-019-09670-4.
7. Bomers, A. , Schielen, R. M. J. , & Hulscher, S. J. M. H. (2019). The severe 1374 Rhine river flood event in present times. In 38th IAHR World Congress: Panama City 2019, Water connecting the World (pp. 1764-1773). (IAHR World Congress Proceedings series). IAHR. https://doi.org/10.3850/38WC092019-0501.
8. Bomers, A. , Schielen, R. M. J. , & Hulscher, S. J. M. H. (2019). Verkleinen van de onzekerheid in huidig waterbeleid met historische overstromingen. H2O.

Project leaders

S.J.M.H. Hulscher

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

R.M.J. Schielen

A. Bomers

Cooperations

University of Utrecht, Rijkswaterstaat, Deltares

Funded by

Rijkswaterstaat, Deltares

Funded %

STW	-
University	-
FOM	-
STW	83 %
NWO Other	-
Industry	17 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

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PROJECT LEADERS
BW Borsje
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
Dr. Ir. B.W. Borsje
COOPERATIONS
MIT, University of Cambridge, Antwerp University
FUNDED BY
STW, VENI
FUNDED %
STW

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2015
INFORMATION
B.W. Borsje
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PROJECT AIM

In the ForeShore project, the aim is to understand and apply wetlands in front of dikes in order to dissipate wave energy. These wetlands are able to grow with sea level rise and at the same time strengthen ecosystem functioning. Recent laboratory experiments demonstrated surprisingly high stability of coastal wetlands, even during such extreme events. However, the physical processes responsible for the stability of the bed are not yet understood. Therefore, the safety level of these measures is not certain and consequently hampers the implementation of wetlands as innovative coastal protection measure worldwide.

PROGRESS

Field studies in the Western Scheldt are ongoing, Flume experimnts at NIOZ Yerseke are ongoging and models are developed at Twente University and Deltares to quantify the wave-vegetation interaction.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Zhenlu Wang, Bingchen Liang, Guoxiang Wu, Borsje, B.W., 2019, Modeling the formation and migration of sand waves: The role of tidal forcing, sediment size and bed slope effects. Continental Shelf Research.
2. Damveld, J. H., Roos, P. C., Borsje, B. W., & Hulscher, S. J. M. H., 2019. Modelling the two-way coupling of tidal sand waves and benthic organisms a linear stability approach. Environmental Fluid Mechanics.
3. Vuik, V., Borsje, B. W., Willemsen, P. W. J. M., Jonkman, S. N., 2019. Salt marshes for flood risk reduction: Quantifying long-term effectiveness and life-cycle costs. Ocean & Coastal Management, 171, 96-110.

SMARTSEA - Safe navigation by optimizing sea bed monitoring and waterway maintenance using fundamental knowledge of sea bed dynamics

Project Aim

We aim to devise an optimized policy of sea bed monitoring and waterway maintenance in shallow seas, based on knowledge of sea bed dynamics, in order to warrant both nautical safety and port access. To this end, we define three subprojects: P1 on the influence of storm events and wind waves on sand wave dynamics; P2 on the feedback among waterways, waterway maintenance (e.g., dredging) and the surrounding seabed environment; and P3 on how to translate/combine knowledge of marine systems into a national survey and maintenance policy for the Netherlands Continental Shelf and waterways?

Progress

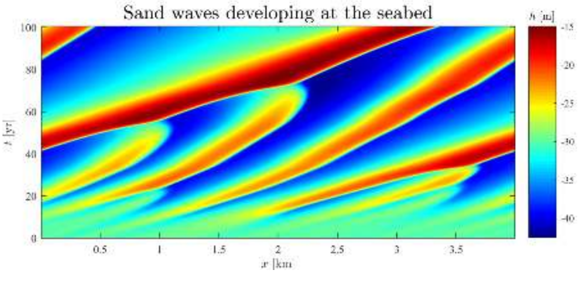
Subproject 2 (G.H.P. Campmans): Using the earlier developed nonlinear sand wave model the effects of dredging on sand wave dynamics have been investigated. This resulted in a conference abstract and a submitted (2020) journal paper. The SMARTSEA project was finalized this year with a closure workshop.

Dissertations

-

Scientific Publications

1. Campmans, G.H.P., Roos, P.C., & Hulscher, S.J.M.H. (2019). Storm influences on sand wave dynamics: an idealized modelling approach. 33-38. Abstract from MARID VI, Marine and River Dune Dynamics 2019, Bremen, Germany.
2. Campmans, G.H.P., van Dijk, T.A.G.P., van der Sleen, N.R., Stolk, A., Roos, P.C., & Hulscher, S.J.M.H. (2019). Nonlinear process-based sand wave model: a comparison with North Sea field observations. In H. Friedrich, & K. Bryan (Eds.), RCEM 2019: the 11th Symposium on River, Coastal and Estuarine Morphodynamics: Book of abstracts (pp. 154-154).



Project leaders

Dr.ir. P.C. Roos

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Dr.ir. G.H.P. Campmans
Ir. J.M. Damen
R. Toodesh, MSc
Dr. T.A.G.P. van Dijk
Dr.ir. P.C. Roos
Dr.ir. A.A. Verhagen
Prof.dr. S.J.M.H Hulscher
Prof.dr.ir. R.F. Hanssen
Prof.dr.ir. H.J. de Vriend
Ir. T. Ligteringen
Dr.ir. N.A. Kinneging

Cooperations

Rijkswaterstaat
Netherlands Hydrographic Service
Advanced Consultancy Romke Bijker
MOW Vlaamse Hydrografie
Deltares
Delft University of Technology
Van Oord

Funded by

NWO/TTW(STW) (TKI Maritime Call)
Co-funders: Rijkswaterstaat, Netherlands Hydrographic Service, Deltares, Advanced Consultancy Romke Bijker (ACRB)

Funded %

STW	-
University	-
FOM	-
STW	63 %
NWO Other	-
Industry	33 %
TNO	-
GTI	4 %
EU	-
Scholarships	-

Start of the project

2014

Information

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SANDBOX – Smart and sustainable design for offshore operations in a sandy seabed

Project leaders
Prof. dr. ir. S.J.M.H. Hulscher
Dr. ir. P.C. Roos
Dr. ir. B.W. Borsje

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Ir. J.H. Damveld

Cooperations
Delft University of Technology, NIOZ Yerseke, Boskalis, IMARES, RBINS OD Nature, Dienst der Hydrografie, ACRB, Deltares, Rijkswaterstaat
Dr. F. Heins (independent)

Funded by
NWO-ALW, Boskalis Westminster N.V.

Funded %

STW	
University	-
FOM	-
STW	-
NWO Other	89,5 %
Industry	10,5 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

Information
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Project Aim

We aim to develop a coupled biogeomorphologic model to increase the understanding of the effects of benthic organisms on the behaviour of coastal bedforms. Using this model we intend to study the spatiotemporal evolution after anthropogenic interventions in shallow coastal seas, together with implementing the concept of ecological landscaping in offshore engineering. This requires integration of knowledge from ecology (collaboration with NIOZ Yerseke), fine sediment dynamics (collaboration with TU Delft) and geomorphology (this subproject).

Progress

An idealized process-based model has been used to study the two-way coupled interactions between benthic organisms and sand waves; paper published in Environmental Fluid Mechanics.

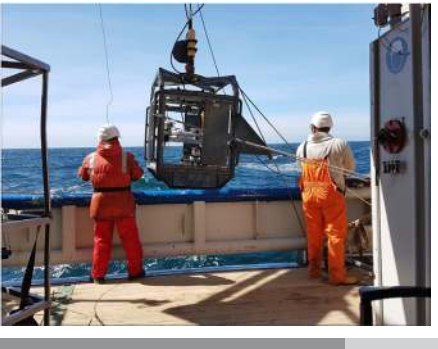
Using Delft3D, the coupled feedbacks between sand waves and patches of the tube-building worm Lanice conchilega were studied. Also using Delft3D, sediment sorting processes over sand waves were studied. It turns out that both the organisms and fine sediments are more abundantly present in sand wave troughs, compared to the crests. These model results agree qualitatively with field observations.

Dissertations

-

Scientific Publications

1. Damveld, J. H., Roos, P. C., Borsje, B. W. & Hulscher, S. J. M. H. (2019). Modelling the two-way coupling of tidal sand waves and benthic organisms: a linear stability approach. Environmental Fluid Mechanics, 19(5), 1073-1103. doi:10.1007/s10652-019-09673-1.
2. Damveld, J. H., van der Reijden, K. J., Cheng, C., Koop, L., Haaksma, L. R., Walsh, C. A. J., Soetaert, K., Borsje, B. W., Govers, L. L., Roos, P. C., Olff, H. & Hulscher, S. J. M. H. (2019). The spatial distribution of benthic organisms and sand ripples over tidal sand waves: insights from a submerged camera system. Paper presented at NAEM 2019, Lunteren.
3. Damveld, J. H., Roos, P. C., Borsje, B. W. & Hulscher, S. J. M. H. (2019). Phase-related patterns of tidal sand waves and benthic organisms: field observations and idealised modelling. Lefebvre, A., Garlan, T. & Winter, C. (Eds.), Proceedings Marine and River Dune Dynamics VI, Bremen.
4. van den Broek, J., Damveld, J. H., Cheng, C. H., Soetaert, K., Borsje, B. W. & Hulscher, S. J. M. H. (2019) Modelling the transport of organic matter in offshore sand wave fields. Paper presented at the NCK-Days 2019, Enkhuizen.



Project Aim

This PhD project focuses on the hydrodynamics and sand transport processes on the swash zone through series of laboratory experiments in a large-scale wave flume, and on developing a new practical model for sand transport in the swash zone. This research aims to improve the understanding of swash zone sand transport processes and on quantifying sediment fluxes for a variety of swash conditions. These experiments will shed new insights in detailed bedload and suspended sand transport processes in the swash, and also in net sand transport rates for a wide range of swash conditions.

Progress

The PhD student passed the qualifier. The first experimental campaign in the large-scale flume in UPC (Barcelona) with a slope of 1:15 was completed. Data is still being processed and analysed. The second experimental campaign with a slope of 1:25 is underway.

Dissertations

1. den Haan, R.J. (Draft). Games to Collaboratively Explore Environmental Complexity: Designing the Virtual River Game. Defense date: 17th of April, 2020, University of Twente.

Scientific Publications

1. Dionisio Antonio, S., van der Werf, J. J., van der Zanden, J., Vermeulen, B., Ribberink, J. S., & Hulscher, S. J. M. H. (2019). Large-scale sediment transport experiments in the swash zone. 39-39. Abstract from NCK-DAYS 2019, Enkhuizen, Netherlands.
2. van der Werf, J., Dionisio Antonio, S., Kranenborg, J., Vermeulen, B., Campmans, G., van der Zanden, J., ... Hulscher, S. (2019). Shaping The Beach: Cross-Shore Sand Transport in the Swash Zone. In N. Goseberg, & T. Schlurmann (Eds.), Coastal Structures 2019 Bundesanstalt für Wasserbau. https://doi.org/10.18451/978-3-939230-64-9_080.

Project leaders
Prof.dr. S.J.M.H. Hulscher

Research theme
Complex dynamics of fluids

Participants
MSc. S. Dionísio António
prof. dr. S.J.M.H. Hulscher
dr. ir. J.L van der Werf
dr. ir. B. Vermeulen

Cooperations
Deltares, Arcadis, Royal HaskoningDHV, Svasek Hydraulics, Rijkswaterstaat, Hoogheemraadschap Hollands, Nooorderkwartier

Funded by
NWO TTW, Deltares

Funded %

University	-
FOM	-
STW	-
NWO Other	89 %
Industry	11 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2018

Information
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Biogeomorphological responses of mangrove forests to variations in hydrodynamic forcing

Project leaders
Prof. dr. K.M. Wijnberg
Dr. ir. E.M. Horstman

Research theme
Complex dynamics of fluids

Participants
Ir. R. Gijsman

Cooperations
NIWA New Zealand
NUS Singapore
USGS United States

Funded by
University of Twente

Funded %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2019

Information
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Project Aim

We aim to measure, analyze and model sedimentation/erosion and tree growth/decline in mangrove forest fringes in response to yearly variations in hydrodynamic forcing, to assess mangrove forests as an adaptive coastal protection measure. Field measurements will be conducted in three contrasting mangrove forest fringes in New Zealand (collaboration with NIWA), Singapore (collaboration with NUS) and the United States (collaboration with USGS).

Progress

A literature review has been conducted, which resulted in the abovementioned aim. In collaboration with NIWA, measurement frames have been installed in a mangrove forest fringe in the Firth of Thames estuary in New Zealand. In collaboration with NUS, measurement frames have been installed in a mangrove forest fringe in the Sungei Buloh Wetland Reserve in Singapore.

Dissertations

-

Scientific Publications

-

Linking Building-with-Nature type interventions in channel-shoal systems to sub-aerial impacts on the beach-dune system

Project Aim

The aim of this project is to link Building-with-nature interventions in channel-shoal systems in tidal inlets to impacts in the adjacent beach-dune system, in a convenient time-scale for stakeholders. Therefore, it is necessary to understand which scenarios of beach-dune system response can be expected to occur under various shoreline development conditions and make the insights accessible to the stakeholder community.

Progress

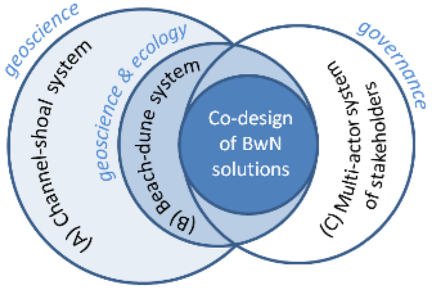
Numerical modelling using the cellular automata model DUBEVEG has been used to assess different characteristics regarding beach-dune systems near inlets. Two papers on the topic have been published. Moreover, long-term data of inlet morphodynamics have been performed and, together with numerical simulation with DUBEVEG, have been used to submit a paper on shoal attachment effects on dune development. Numerical modelling using the model XBeach has also been performed, with results leading to one submitted manuscript. A manuscript integrating all results in a coastal management scheme is currently in preparation. The PhD thesis has also been submitted and will be defended in April 25th.

Dissertations

1. Galiforni Silva, F. (2019). Beach-dune systems near inlets: Linking subtidal and subaerial morphodynamics. Enschede: University of Twente. https://doi.org/10.3990/1.9789036547598.

Scientific Publications

1. Galiforni Silva, F.; Wijnberg, K. M. ; Groot, A. V. ; Hulscher, S. J. H. M. (2019). The effects of beach variability on coastal dune development at decadal scales. Geomorphology. v. 329, p. 58-69.
2. Galiforni Silva, F., Wijnberg, K. M., & Hulscher, S. J. M. H. (2019). Modelling the effects of storm surges on sand flats: case study in Texel (NL). 44-44. Abstract from NCK-DAYS 2019, Enkhuizen, Netherlands.
3. Galiforni Silva, F.; Wijnberg, K. M. ; Groot, A. V. ; Hulscher, S. J. H. M. (2019). Modelling the effects of shoal attachment on dune growth. Coastal Sediments 2019. Presented at the International Conference on Coastal Sediments 2019. https://doi.org/10.1142/9789811204487_0110.
4. Galiforni Silva, F.; Wijnberg, K. M.; Hulscher, S. J. H. M.. (Subm.). Storm-induced sediment supply to coastal dunes on sand flats.
5. Galiforni Silva, F.; Wijnberg, K. M.; Hulscher, S. J. H. M. (Subm.). The effects of shoal attachment on coastal dune development: case study in Terschelling (NL).



Project leaders

Dr. K.M. Wijnberg
Prof. Dr. S.J.M.H. Hulscher

Research theme

Complex dynamics of fluids

Participants

MSc. F. G. Silva
Dr. A. V. de Groot
Dr. J.P.M. Mulder

Cooperations

IMARES.
Deltares.
UNESCO-IHE.
Delft University of Technology.
Arcadis.
Rijkswaterstaat Waterdienst.
Arens Bureau voor strand en duinonderzoek.
Hoogheemraadschap Hollands NoorderKwartier.

Funded by

NWO, Hoogheemraadschap Hollands NoorderKwartier.

Funded %

University	-
FOM	-
STW	-
NWO Other	92,3 %
Industry	-
TNO	-
GTI	-
EU	7,7 %
Scholarships	-

Start of the project

2014

Information

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Project leaders
prof. dr. S.J.M.H. Hulscher
dr. J.J. Warmink

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
M.R.A. Gensen, MSc

Cooperations
Rijkswaterstaat, STOWA, Deltares, HKV Lijn in Water, Natuurmonumenten, Hollands Noorderkwartier, Noorderzijlvest, It Fryske Gea, Vechtstromen

Funded by
NWO-TTW

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017

Information
Matthijs Gensen
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Project Aim

The goal of this project is to quantify and possibly reduce river water level uncertainties in a bifurcating river system. In this very complex and interactive system uncertainties are propagated throughout the entire system. Dominant sources of water level uncertainties are regulation structures at bifurcation points, river bed forms and large-scale river interventions. In this project these uncertainty sources are studied in a model with dimensions similar to the river Rhine. This work will give insight into the combined effect of natural processes and human river interventions to improve river maintenance strategies.

Progress

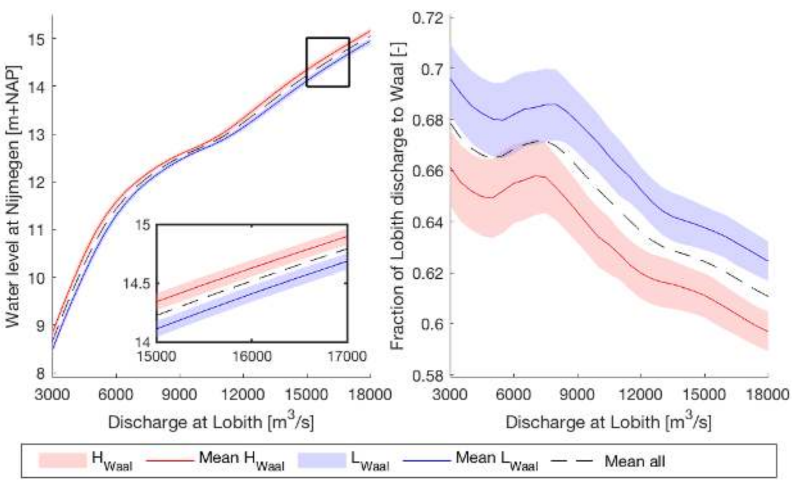
A one-dimensional hydraulic SOBEK model of the Dutch Rhine branches was used to propagate main channel roughness uncertainties towards water level uncertainties. The results show that the bifurcation points of the Dutch Rhine branches provide a self-regulating mechanisms for system-wide water levels. Disturbances, e.g. high water levels due to high roughness, are partly offset by changes in discharge distribution.

Dissertations

-

Scientific Publications

1. Gensen, M.R.A., Warmink, J.J., & Hulscher, S.J.M.H. (2019). Propagating main channel roughness uncertainty in the bifurcating Dutch Rhine system. 28-29. Abstract from NCR Days 2019: Land of Rivers, Utrecht, Netherlands.
2. Gensen, M.R.A., Warmink, J.J., & Hulscher, S.J.M.H. (2019). River dune based roughness uncertainty for the Dutch Rhine branches. 101-106. Abstract from MARID VI, Marine and River Dune Dynamics 2019, Bremen, Germany.
3. Gensen, M.R.A., Warmink, J.J., & Hulscher, S.J.M.H. (2019). Water level uncertainties due to uncertain bedform dynamics in the Dutch Rhine system. Abstract from XXXVIII International School of Hydraulics 2019, Łaçk, Poland



PROJECT AIM

To prevent floodplain vegetation to cause water safety issues during high water discharges, measures are taken to limit the development of floodplain forests. However, measures must be taken cautiously, as many of the Dutch floodplains are assigned as nature area. The difficulty here is that the effects those measures have on water safety and nature values as well as their efficiency are not well understood. Therefore, the aim of this study is to develop a spatially explicit, trait based model that provides insight in the dominant steering processes of floodplain vegetation development, thereby aiding well-founded floodplain management.

PROGRESS

Working on second and third paper.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS
SJMH Hulscher, DCM Augustijn

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
V. Harezlak, G Geerling

COOPERATIONS
Deltares, Rijkswaterstaat, RIVM, Bureau Waardenburg, Arcadis

FUNDED BY
STW Perspectief

FUNDED %

University	-
FOM	-
STW	60 %
NWO Other	-
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2015

INFORMATION
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SEAWAD: SEDIMENT SUPPLY AT THE WADDEN SEA EBB-TIDAL DELTA. FROM SYSTEM KNOWLEDGE TO MEGA-NOURISHMENTS

PROJECT LEADERS
Prof dr. K.M. Wijnberg
Drs. Ir. B.W. Borsje

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
dr. ir. B.W. Borsje
prof. dr. P.M.J. Herman
prof. dr. ir. K.M. Wijnberg
Ir. H.Holzhauer

COOPERATIONS
Delft University of Technology, Deltares, Utrecht University

FUNDED BY
STW

FUNDED %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2016

INFORMATION
H. Holzhauer
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PROJECT AIM

To ensure ecological sustainability of the Dutch coast, human activities in the coastal zone need to be managed. This requires knowledge and models to assess and predict changes in the coastal ecosystem in response to changes in environmental conditions. Within this research we focus on the environmental processes steering the distribution of benthic species in the ebb tidal delta and the shore face. In order to understand the relationships of benthic species and their underlying environmental processes which are disturbed by human impacts (e.g. nourishments) and natural impacts (e.g. storm event, severe winter, calm periods).

PROGRESS

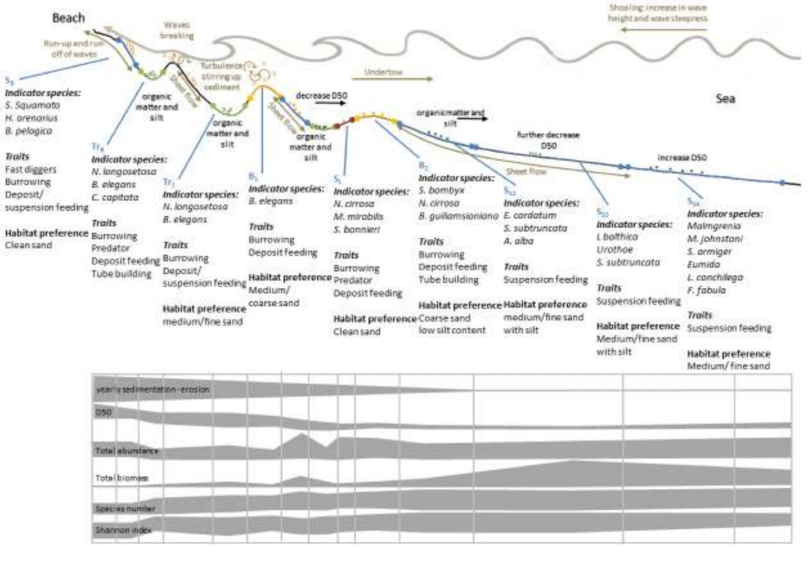
Article published (2019) on the relationship between morphological features in the near shore, such as bar crests, troughs and slopes, and the distribution of benthic species is investigated with the help of mixed-effect-models and partial redundancy analysis. Writing the results of the multivariate analysis of the species abundance data retrieved at the Ameland ebb tidal delta.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Harriëtte Holzhauer, Bas W. Borsje, Jan A. van Dalfsen, Kathelijne M. Wijnberg,Suzanne J.M.H. Hulscher and Peter M.J. Herman (2019). Benthic Species Distribution Linked to Morphological Features of a Barred Coast. J. Mar. Sci. Eng. 2020, 8(1), 16.
2. S.G. Pearson, B.C. van Prooijen, F.P. de Wit, H. Holzhauer, A.P. de Looff, Z.B. Wang (2019). Observations of suspended particle size distribution on an energetic ebb-tidal delta. Coastal sediments, Tampa/St. Petersburg, Florida, USA, 27 – 31 May 2019.



Conceptual drawing of the cross-shore wave related processes, environmental parameters measured and the macrobenthic species identified as indicator species for the morphological features

BE SAFE: Bio-Engineering for Safety using vegetated foreshores: long-term biogeomorphology

Project Aim

We aim to develop new methods to assess how, and how much vegetated foreshores can contribute to flood risk reduction. The project will lead to a better understanding of (uncertainties in) the functioning and stability of these ecosystems and the development of novel governance arrangements. This requires integration of knowledge from ecology, biogeomorphology, hydraulic engineering, and governance.

Progress

Several achievements have been obtained in 2019:

- Contributing to three peer-reviewed journal papers (see below).
- Writing a manuscript on "Field-based decadal wave attenuating capacity of combined tidal flats and salt marshes", which is accepted in 2019 by the journal Coastal Engineering (but published in 2020).
- Presenting (oral presentation) the results of the previously mentioned achievement at the AGU conference in San Francisco.
- Contributing to the technical development of a 2D model for modelling hydrodynamics, morphodynamics and vegetation development to simulate the development of the intertidal area.
- Setting up collaborative fieldwork in Singapore to measure hydrodynamics, morphodynamics and vegetation growth in mangroves. Measurements are continuously conducted.

Dissertations

-

Scientific Publications

1. Vincent Vuik, Bas W. Borsje, Pim W.J.M. Willemsen, Sebastiaan N. Jonkman (2019). Salt marshes for flood risk reduction: Quantifying long-term effectiveness and life-cycle costs. Ocean and Coastal Management 171, 96-110. DOI: 10.1016/j.ocecoaman.2019.01.010.
2. Martin J. Baptist, T. Gerkema, B.C. van Prooijen, D.S. van Maren, M. van Regteren, K. Schulz, I. Colosimo, J. Vroom, T. van Kessel, B. Grasmeijer, P. Willemsen, K. Elschot, A.V. de Groot, J. Cleveringa, E.M.M. van Eekelen, F. Schuurman, H.J. de Lange, M.E.B. van Puijenbroek (2019). Beneficial use of dredged sediment to enhance salt marsh development by applying a 'Mud Motor'. Ecological Engineering, 127, 312-323.DOI: 10.1016/j.ecoleng.2018.11.019.
3. Poppema, D. W., Willemsen, P. W. J. M., de Vries, M. B., Zhu, Z., Borsje, B. W., & Hulscher, S. J. (2019). Experiment-supported modelling of salt marsh establishment. Ocean & Coastal Management, 168, 238-250.

Project leaders

Prof. dr. S.J.M.H. Hulscher,
Prof. dr. T.J. Bouma

Research theme

Complex dynamics of fluids

Participants

Ir. P.W.J.M. Willemsen (PhD candidate),
Dr. ir. B.W. Borsje (Daily supervisor)

Cooperations

NIOZ Yerseke, TuDelft

Funded by

Deltares, Rijkswaterstaat, Van Oord, Boskalis, WNF, Hogeschool Zeeland, NWO-ALW, NIOZ, University of Twente.

Funded %

University	40 %
FOM	-
STW	-
NWO Other	60 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

Information

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Optimizing Water Availability with Sentinel-1 Satellites (OWAS1S)/

Project leaders
Prof. dr. S.J.M.H. Hulscher
Dr. ir. D.C.M. Augustijn
Dr. D.M.D. Hendriks

Research theme
Complex dynamics of fluids

Participants
Dr. Ir. M. Pezij

Cooperations
University of Twente, Wageningen University, Deltares, Province of Overijssel, Waterschap Aa en Maas Waterschap Vechtstromen, Waterschap Groot Salland, Hoogheemraadschap De Stichtse Rijnlanden, ZLTO, HKV, HydroLogic, Rijkswaterstaat, STOWA, Vienna University of Technology

Funded by
NWO-TTW, Regional water authorities, Province of Overijssel, Deltares

Funded %

University	-
FOM	-
STW	-
NWO Other	85 %
Industry	15 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

Information
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Project Aim

This project is part of the OWAS1S-project to optimize water availability with Sentinel-1 satellites. The focus of this project is the optimization of operational water management using soil moisture data. Newly developed remotely sensed soil moisture maps will be used to improve the performance of existing hydrological models (e.g. LHM). The improved model will be applied to historic cases to optimize for example crop water availability based on pre-defined criteria. Based on these results, it will be possible to develop new operational/strategic water management strategies in cooperation with users.

Progress

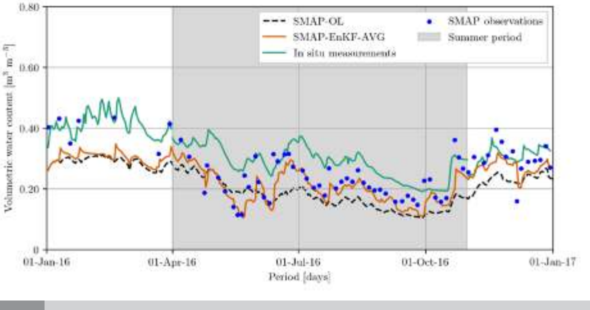
Two papers have been published. The first paper focuses on the use of information by Dutch operational water managers. The second paper introduces a data-assimilation approach for the unsaturated zone model MetaSWAP to update soil moisture simulations using satellite data. Furthermore, a manuscript has been finished in which a novel machine-learning method to describe soil moisture conditions is introduced. In addition, the PhD thesis is finished. The PhD defense was on January 30 2020.

Dissertations

1. Pezij, M. (2020). Application of soil moisture information for operational water management. Enschede: University of Twente. https://doi.org/10.3990/1.9789036549486.

Scientific Publications

1. Pezij, M., Augustijn, D.C.M., Hendriks, D.M.D., and Hulscher, S.J.M.H. 2019. The role of evidence-based information in regional operational water management in the Netherlands. Environmental Science&Policy 93. 75-82. doi:10.1016/j.envsci.2018.12.025.
2. Pezij, M., Augustijn, D.C.M., Hendriks, D.M.D., Weerts, A.H., Hummel, S., Van der Velde, R., Hulscher, S.J.M.H. 2019. State updating of root zone soil moisture estimates of an unsaturated zone metamodel for operational water resources management. Journal of Hydrology X, 4, 10040. doi:10.1016/j.hydroa.2019.100040.
3. Pezij, M., Augustijn, D.C.M., Hendriks, D.M.D., Hulscher, S.J.M.H. 2019. Transfer Function-Noise Modeling Using Remote Sensing Data to Characterize Soil Moisture Dynamics: a Data-driven Approach. AGU Fall Meeting 2019.
4. Pezij, M., Augustijn, D.C.M., Hendriks, D.M.D., Hulscher, S.J.M.H. 2019. Data underlying the publication: Applying transfer function-noise modelling to characterize soil moisture dynamics: a data-driven approach using remote sensing data. Dataset. doi:10.4121/uuid:ba33fc56-e07b-4547-9630-9b1565d18040.



WADSnext! Morphodynamic modelling tools for the sustainable management of barrier coasts

Project Aim

We aim to to explain the long-term morphodynamic development of the inlets and back-barrier basins in a mesotidal barrier coast subject to both environmental and anthropogenic changes. Specifically, this project aims to study the stability of multiple tidal inlets and the effects on these systems by storms, back basin geometry, back basin topography, and back basin dynamics.

Progress

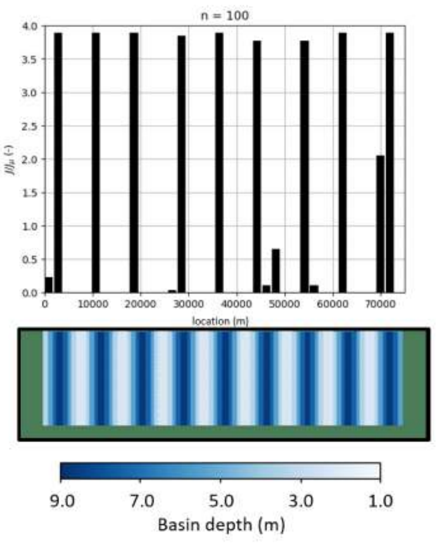
Last year a new model was developed to study the effect of a non-uniform basin topography on the long-term morphological evolution of barrier coasts. This allows us to study the effect of basin topography on the size and spacing of tidal inlets, see Fig. 1.

Dissertations

-

Scientific Publications

1. Reef, K. R. G. , Roos, P. C., Schuttelaars, H. M. , & Hulscher, S. J. M. H. (2019). The influence on basin geometry on the long-term morphological evolution of barrier coasts. 76-76. Abstract from NCK-DAYS 2019, Enkhuizen, Netherlands.
2. Reef, K. R. G. , Roos, P. C., Schuttelaars, H. M. , & Hulscher, S. J. M. H. (2019). The impact of basin geometry on the long-term morphological evolution of barrier coasts: an exploratory modelling study. In H. Friedrich, & K. Bryan (Eds.), RCEM 2019: the 11th Symposium on River, Coastal and Estuarine Morphodynamics: Book of abstracts (pp. 6-6).
3. Reef, K. R. G. , Roos, P. C., Andringa, T. E., Dastgheib, A. , & Hulscher, S. J. M. H. (2019). The effect of stochastically simulated storm-induced breaches on the long-term morphological evolution of barrier coasts. In P. Wang, J. D. Rosati, & M. Vallee (Eds.), Coastal Sediments 2019: Proceedings of the 9th International Conference (pp. 139-148) https://doi.org/10.1142/9789811204487_0013.



Results of an ensemble of 100 simulations. Top: histogram with the ratio of open inlets J over the mean Jµ per km barrier coast. Bottom: topography of the backbarrier basin.

Project leaders
P.C. Roos

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
P.C. Roos
H.M. Schuttelaars
S.J.M.H. Hulscher
K.R.G. Reef

Cooperations
Deltares

Funded by
NWO
University of Twente
Deltares
4TU

Funded %

University	25 %
FOM	-
STW	-
NWO Other	50 %
Industry	25 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016

Information

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PROJECT LEADERS
Dr. R.M.J. Schielen
Dr.ir. D.C.M. Augustijn

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Dr.ir. R.P. van Denderen, MSc

COOPERATIONS
Rijkswaterstaat
LievenseCSO
RoyalhaskoningDHV
HKV consultants

FUNDED BY
STW (Perspective programme P12-14)
Rijkswaterstaat
LievenseCSO
RoyalhaskoningDHV
HKV consultants

FUNDED %

University	-
FOM	-
STW	60 %
NWO Other	-
Industry	15 %
TNO	-
GTI	-
EU	25 %
Scholarships	-

START OF THE PROJECT
2014

INFORMATION
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PROJECT AIM

The construction of a side channel is a popular method to restore the river's ecology and to lower the water level during floods. However, side channels can cause aggradation within the main channel that can cause problems for the navigational function of the river. The aim is to quantify the aggradation based on measurements.

PROGRESS

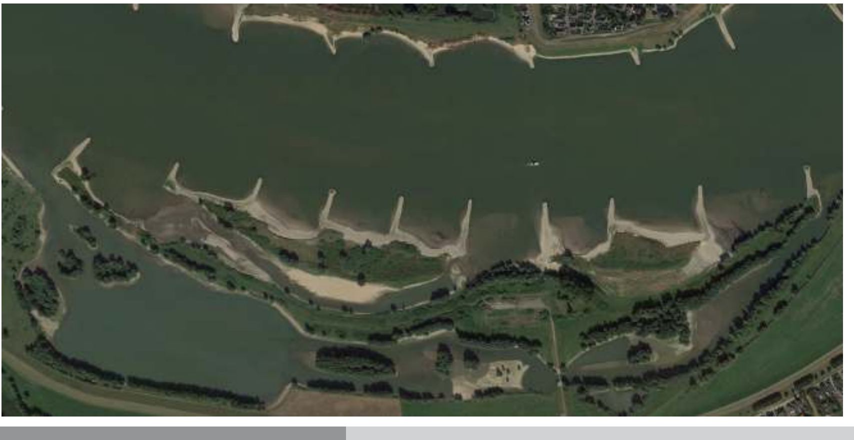
We use a large dataset and apply a sophisticated method to estimate the bed level changes that occur with various causes. This allows us to isolate the effect from river interventions from the large scale and small scale bed level variations.

DISSERTATIONS

1. Van Denderen, R. P. (2019). Side channel dynamics. Enschede: University of Twente. https://doi.org/10.3990/1.9789036547437.

SCIENTIFIC PUBLICATIONS

1. Van Denderen, R. P., Schielen, R. M. J., Straatsma, M., Kleinhans, M. G., & Hulscher, S. J. M. H. (2019). A characterization of side channel development. River research and applications, 35(9), 1597-1603. https://doi.org/10.1002/rra.3462.
2. Van Denderen, R. P., Schielen, R. M. J., & Hulscher, S. J. M. H. (2019). A framework to better understand river side channel development. In H. Friedrich, & K. Bryan (Eds.), RCEM 2019: the 11th Symposium on River, Coastal and Estuarine Morphodynamics: Book of abstracts (pp. 25-25).
3. Van Denderen, R. P., Schielen, R. M. J., Westerhof, S. G., Quartel, S., & Hulscher, S. J. M. H. (2019). Explaining artificial side channel dynamics using data analysis and model calculations. Geomorphology, 327, 93-110. https://doi.org/10.1016/j.geomorph.2018.10.016.
4. Van Denderen, R. P., Schielen, R. M. J., & Hulscher, S. J. M. H. (2019). Measuring and modeling the development of side channels. 44-44. Abstract from NCR Days 2019: Land of Rivers, Utrecht, Netherlands.
5. Cortes Arevalo, V. J., Verbrugge, L. N. H., Brugnach, M. F., Sools, A. A. M., Wolterink, R., Van Denderen, R. P., ... Hulscher, S. J. M. H. (2019). Storylines to improve science communication to practitioners in rivermanagement. Abstract from EGU General Assembly 2019, Vienna, Austria.



Idealized modeling of estuarine sand dunes: understanding natural and human-induced dynamics

Project Aim

We will develop a process-based morphodynamic model of large-scale bedforms in estuaries to explain their formation and dynamic equilibrium configuration as a function of environmental parameters.

Progress

Development of process-based idealized model which aims to show the effect of the gravitational circulation on estuarine bedforms.

Dissertations

-

Scientific Publications

1. van der Sande, W.M., Roos, P.C., Hulscher, S.J.M.H., 2019. Investigating idealised modelling of estuarine sand waves. Presentation at Marine and River Dune Dynamics (MARID VI) in Bremen, Germany, April 1-3.

Project leaders

Prof. dr. ir. S.J.M.H. Hulscher
Dr. ir. P.C. Roos

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Ir. W.M. van der Sande

Cooperations

University of Twente, Rijkswaterstaat Van Oord, Boskalis, Deltares, Wageningen University & Research

Funded by

NWO

Funded %

University	5 %
FOM	-
STW	60 %
NWO Other	-
Industry	35 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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PROJECT LEADERS
Prof. Dr. S.J.M.H. Hulscher
Dr. J.J. Warmink

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Weiqiu Chen

COOPERATIONS
Deltares, Rijkswaterstaat, Ministerie van Infrastructuur en Water, HKV, Royal Haskoning DHV, Arcadis, Witteveen + Bos, HillBlocks, Vechtstromen

FUNDED BY
China Scholarship Council
University of Twente

FUNDED %

University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

START OF THE PROJECT
2017

INFORMATION
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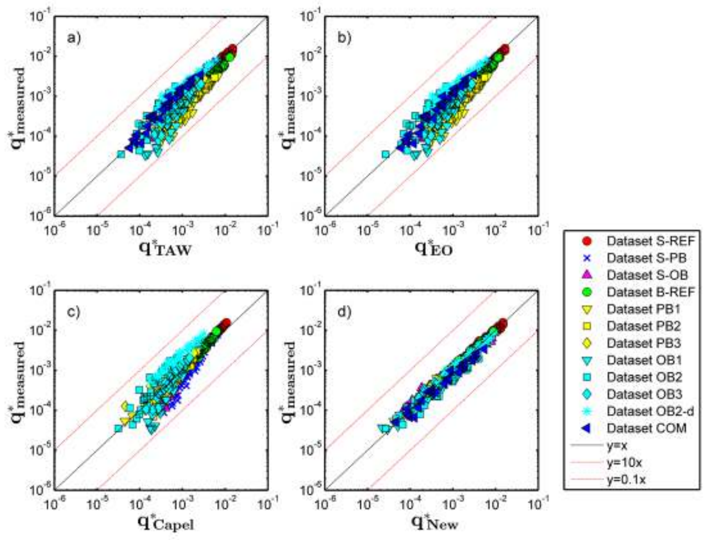
PROJECT AIM
Due to climate change and sea level rise, the possibility of wave overtopping at dikes increases significantly and large overtopping discharge might cause dike breaching. Thus, a reliable estimation of average overtopping is essential for dike design and safety assessment. Berms and roughness elements are widely used to decrease overtopping discharge at dikes. Therefore, this project aims to develop new methods of estimating berm and roughness influence on wave overtopping thereby improving predictive accuracy of average overtopping discharge at dikes.

PROGRESS
- Physical model tests on the influence of berms and roughness on wave overtopping discharge have been finished.
- Data analysis of experiments have been finished and new empirical equations for berm and roughness influence factors were developed. One journal paper on these experimental results was accepted by Coastal Engineering.
- A numerical model was built by using OpenFOAM to predict the overtopping discharge at dikes.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
1. Chen, W., Warmink, J. J., van Gent, M. R., & Hulscher, S. J. (2019). Experimental study on the influence of berms and roughness on wave overtopping over dikes. Coastal Structures 2019, 1086-1096. https://doi.org/10.18451/978-3-939230-64-9_109.
2. Chen, W. (2019). Study of wave overtopping of flood defences: Literature report. Enschede.



Project Aim

Numerical models are an important tool to study the nearshore environment. However, these tools still have difficulty predicting the dynamics on the boundary between the dry part of the beach and the surf zone, called the swash zone. In this project, a new type of model will be applied to study swash zone processes that affect sediment transport and morphodynamics. These new insights in swash processes will be used to build novel parametrizations that can be used by coastal engineers to better predict the evolution of the coastal environment.

Progress

During the year the focus has been on developing a depth-resolving model for swash hydrodynamics and sediment transport. The hydrodynamics have been validated with dambreak experiments (see Kranenborg et al., 2019 below). The sediment model is still begin developed and validated, but initial results can be seen in figure 1.

Dissertations

-

Scientific Publications

1. Kranenborg, J., Campmans, G., van der Werf, J., Reniers, A., & Hulscher, S. (2019). Depth-Resolving vs Depth-Averaged Modelling of Swash Zone Hydrodynamics. In N. Goseberg, & T. Schlurmann (Eds.), Coastal Structures 2019 Bundesanstalt für Wasserbau. https://doi.org/10.18451/978-3-939230-64-9_083.
2. van der Werf, J., Dionisio Antonio, S., Kranenborg, J., Vermeulen, B., Campmans, G., van der Zanden, J., ... Hulscher, S. (2019). Shaping The Beach: Cross-Shore Sand Transport in the Swash Zone. In N. Goseberg, & T. Schlurmann (Eds.), Coastal Structures 2019 Bundesanstalt für Wasserbau. https://doi.org/10.18451/978-3-939230-64-9_080.
3. Kranenborg, J., Campmans, G., van der Werf, J., Jacobsen, NG.& McCall, R., Reniers, A., & Hulscher, S., (2019). Numerical modelling of the swash zone. NCK-DAYS 2019, Enkhuizen, Netherlands, 20/03/19-23/03/19, pp. 61-61.

Project leaders

prof. dr. S.J.M.H. Hulscher
dr. J.J. van der Werf

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

ir. J.W.M. Kranenborg

Cooperations

Delft University of Technology
Deltares
Arcadis
Royal HaskoningDHV
Svašek Hydraulics
Rijkswaterstaat
Hoogheemraadschap Hollands
-Noorderkwartier, Marin

Funded by

NWO-TTW, Deltares

Funded %

University	-
FOM	-
STW	-
NWO Other	89 %
Industry	11 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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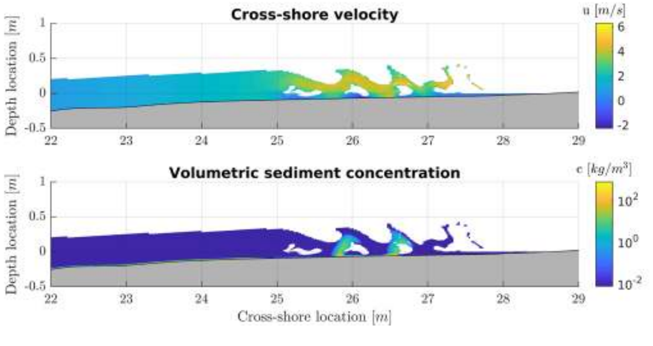

Cross-shore velocity and sediment concentrations in the swash. The sediment plumes generated by the vortices from the broken bore are clearly visible.

Experiment-supported modelling of beach-dune evolution in interaction with the built environment

Project leaders
Prof. dr. K.M. Wijnberg
Prof. dr. S.J.M.H. Hulscher

Research theme
Complex dynamics of fluids

Participants
Ir. D.W. Poppema

Cooperations
University of Delft

Funded by
NWO, Hoogheemraadschap Hollands Noorderkwartier, Rijkswaterstaat, Deltares, Witeveen&Bos, H+N+S

Funded %

University	-
FOM	-
STW	-
NWO Other	78 %
Industry	22 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017

Information
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Project Aim

Dunes protect the Netherlands and many other places against flooding. Simultaneously, the beach-dune area is very attractive for recreation, resulting in the development of buildings like beach pavilions and holiday homes. These buildings influence Aeolian sediment transport patterns and thereby shape dune development. Therefore, this research aims to understand and model how (configurations of) buildings at the beach-dune interface affect Aeolian sediment flows and long-term dune development. It is part of the ShoreScape project.

Progress

I have conducted field experiments to answer the first two research questions and have presented my first results at the Coastal Sediments conference. I have published a conference paper for Coastal Sediments. Currently I am writing a journal paper on the experimental results.

Dissertations

-

Scientific Publications

1. Poppema, D., Wijnberg, K. M., Mulder, J. P., & Hulscher, S. J. (2019, May). Scale experiments on Aeolian depositon and erosion patterns created by buildings on the beach. In 9th International Conference on Coastal Sediments 2019 (pp. 1693-1707).
2. Poppema D.W., Wijnberg K.M., Mulder J.P.M. & Hulscher S.J.M.H (2019). Scale experiments on Aeolian deposition patterns around buildings on the beach. 73. Abstract from NCK-days 2019, Enkhuizen, Netherlands.

The impact of buildings at beaches on airflow and aeolian sediment transport patterns across beach-dune topography, using CFD modeling

Project Aim

Coastal zones have always attracted a large number of people because of the resources and the recreations that they provide. This highly increasing population living along the coastline, increases the demands for construction of restaurants, beach houses and pavilions at the beach-dune interface. These structures block the wind flow and change the airflow patterns which in turn alter the sediment transport pathways and influence the aeolian sand dunes. In this project, we will investigate the impacts that the buildings' characteristics and their positioning at beaches can have on wind flow patterns and consequently on aeolian sediment transport and coastal dunes.

Progress

The PhD student finished her literature review and research proposal. The candidate passed her proposal defense in July 2019. Then, she started modelling with OpenFOAM and developed the basic airflow model around an isolated building. Currently she is working on validating her model and then she is planning to study the impact of different buildings' characteristics and positioning on airflow patterns and aeolian sediment transport.

Dissertations

-

Scientific Publications

1. Pourteimouri, P., Campmans, G. H. P., Poppema, D. W., Wijnberg, K. M., & Hulscher, S. J. M. H. (2019). CFD modeling of airflow over urbanized beaches and the impact of built environment on aeolian sediment transport. 74-74. Abstract from NCK-DAYS 2019, Enkhuizen, Netherlands.

Project leaders

prof. dr. S.J.M.H. Hulscher
prof. dr. K.W. Wijnberg
dr. G.H.P Campmans

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

P. Pourteimouri, MSc

Cooperations

NWO
Delft University of Technology

Funded by

NWO and co-funded by RWS and HHNK

Funded %

University	15 %
FOM	-
STW	-
NWO Other	85 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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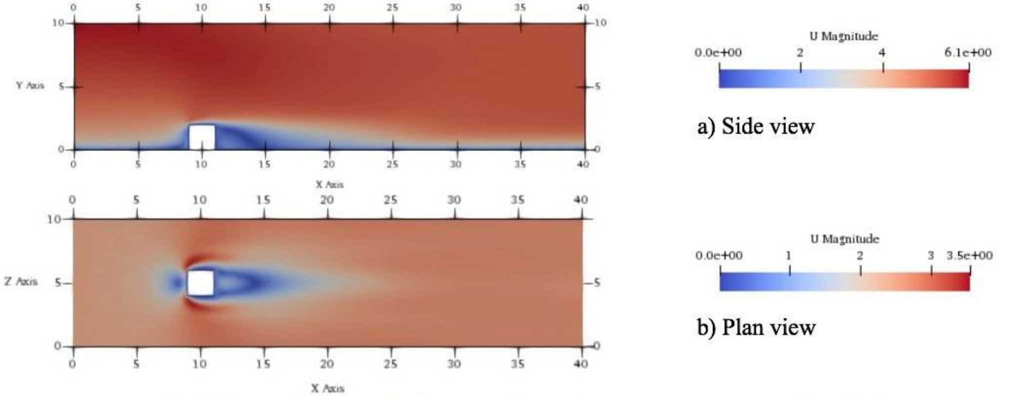

OpenFOAM model predictions of wind velocity (m/s) around an isolated cubic building.
a) side view (half plane) b) plan view (at the elevation of 0.3 meter from surface)

RiverCare towards self-sustaining multifunctional rivers
Communication programma outcome: knowledge base, visualisation and Virtual River

Project leaders
Prof.dr. S.J.M.H. Hulscher
Prof.dr.ir. Mascha C. van der Voort

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Robert-Jan den Haan (G1)
Juliette Cortes Arevalo (G2)

Cooperations
Rijkswaterstaat, Deltares, Arcadis, RoyalHaskoningDHV, Witteveen+Bos HKV, T-Xchange, Tygron

Funded by
STW (Perspectief: co-funded)

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
Subproject G1: Oct 2014
Subproject G2: May 2015

Information
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Juliette Cortes Arevalo
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Project Aim

Subproject G1: “A serious gaming environment to support collaborative decision-making in river management” (den Haan)

Subproject G2: “The potencial of knowledge-base website to give an overview of the RiverCare projects and outputs to practitioners interested in more sustainable river management” (Cortes Arevalo)

Progress

For subproject G1, a working prototype of a tangible user interface, an interface that uses physical objects to interact and manipulate digital information, was developed. The interface uses physical game pieces that contain information on both elevation and land use to represent a river stretch. Players move game pieces to design and apply river management interventions, which are processed by the interface’s software as input for a hydrodynamic, ecological and cost model. The interface enables players to collaboratively work with these models in the Virtual River Game. A full conference paper on design and development of the tangible user interface was written and presented at the Human-Computer Interaction (HCI) in Games conference. Based on the working prototype, a number of game sessions have been held. Five sessions were used to analyse how and to what extent the game stimulates social learning. A journal paper manuscript on the game’s design, game sessions and subsequent analysis was written and submitted to Environmental Modelling and Software. Furthermore, a draft thesis of the PhD research was written and approved by the promotors and is with the graduation committee at the time of writing.

For subproject G2, the RiverCare website was actively shared to invite interested professionals from partner organizations to the RiverCare Symposium. About 60 participants evaluated the website during the event. Results higlighted the attractiveness of the website. the ease of use and the simple and clear way to present the information. Although Symposium participants are willing to visit the website again they are not equally inclined to share it with colleagues. Future reseach should identify most effective ways to engage end-users of the RiverCare program in populating the wbesite content and motivate them to actively share it. Furthermore, three RiverCare storylines were prepared one of which was fully lead by the reseaercher who poduced the results. Overall, we explored the benefits of open-source tools to preare the storylines (see the river inervention explorer), a content that is more focused in the application (see the social network analysis in maintanint Dutch floodplains) and points out the researcher as a main character (see ecological benefits of a sheltered channel parallel to the main river).

Dissertations

-

Scientific Publications

-

Prof.dr.ir. EWC van Groesen

In our group AAMP we study natural phenomena or help to design and improve technical apparatus or processes. We investigate the propagation of surface waves on a layer of fluid, the shock propagation caused by volcano eruptions through the earth, and the way how light gets reflected and transmitted through different materials.

We study these aspects with a set of suitable mathematical techniques that we extend and improve constantly. Our understanding of the phenomena is reflected in the mathematical models, which are updated and improved with increased understanding from theoretical investigations and simulations. Except for their mathematical structure with intrinsic beauty, our investigations are often 'useful': for hydrodynamic laboratories we advise how to generate the wave fields that they want to produce in their tanks to test ships in realistic situations, the calculations of seismic events may lead to an understanding which earth quakes give rise to large tsunamis, the design of optical devices with nano-scale structures helps to advance telecommunication, etc.

The topics mentioned above are very diverse in their appearance, and cover length scales ranging from 10^-9 till 10^7 meter. The beauty of the mathematical descriptions is that they are actually quite similar: the major physical process is the evolution of waves, or an abstraction of it. Special properties that depend on the application are reflected in the mathematical structure of the wave equations that are at the basis of the models. For instance, energy or momentum conservation corresponds to symmetries in the mathematical formulations. Specific methods that we use include variational methods, which exploit the remarkable fact that often a certain optimality property can be found in the phenomenon. Except for theoretical methods, often supported with computer algebraic calculations, regularly we design larger or smaller simulation tools of a numerical nature.

For the design of these numerical schemes we aim to keep the special properties of our theoretical models as well, leading to consistent finite dimensional version of the infinite dimensional models.

The research in water waves contains various topics. Characteristic is that for irrotational flows we approach the problems in a unified consistent modelling way. This is based on the fact that upon neglecting dissipation, the full free surface equations have a basic variational structure (Luke, 1967), with the free surface equations described by a Hamiltonian system (Zakharov 1968, Broer 1974). In our modelling of specific wave fields, we exploit this structure by finding approximations of the kinetic energy part of the Hamiltonian. This is used for approximate models described by pde's like the shallow water equations, Boussinesq-, KdV and NLS-type of equations.

For numerical simulations, this structure is exploited to find consistent discretizations by variational restriction: the functionals defined on infinite dimensional spaces are restricted to finite dimensional subspaces, which may be high dimensional but may also be much more restricted by including essential properties of the phenomenon in the description, depending on the specific cases.

Within the basic approach, we include various active or passive boundary conditions, depending on the application (to generate waves by wave flaps for hydrodynamic laboratories, or bottom motions for seismic applications), or to allow a reflection-free description for calculations on numerical artificial windows. Locally, the activities are grouped in the projects Math Modelling and consistent Numerical Simulations, Free flows and Extreme Waves, Coastal Waves, and Seismic generation of waves.

PROJECT AIM

In various subprojects the variational structure of inviscid fluid dynamics is used to derive accurate and efficient numerical implementations of Boussinesq-type of equations. Hamiltonian variational wave models with exact dispersion are obtained with a spatial-spectral implementation (AB), and with a problem-dependent optimal dispersive FEM implementation (VBM). Applications deal with laboratory, coastal and oceanic waves, including harbour waves. Extension to radar image reconstructions and wave prediction, and fully dynamic, nonlinear Hamiltonian wave-ship interaction.

PROGRESS

Extended with user-friendly GUI's, the software developed over the past years is available as HAWASSI (www.hawassi.labmath-indonesia.org) under license of LabMath-Indonesia for wave simulations. The main emphasis in 2019 has been on accurate simulation of infra-gravity waves generated from ocean waves run-up the coast. The nonlinear 2HD pseudo-spectral AB-code, is being extended with fully nonlinear wave-ship interactions, including force calculations on fixed and moving ships. Methods for wave reconstruction and future prediction from radar images of (multi-modal) seas have been extended, and tested.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. R. Kurnia, P. Turnip & E. van Groesen, Spectral AB Simulations for Coastal and Ocean Engineering Applications, ICOE 2018, Chennai,pp 207-217, in Springer Proceedings of the Fourth International Conference in Ocean Engineering (ICOE2018).

PROJECT LEADERS

E. van Groesen

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

R. Kurnia (PD-TUD, LMI)
A. Latifah (LMI/LIPI)
A. P. Wijaya (LMI)
Dr. Andonowati (LMI);

COOPERATIONS

LabMath-Indonesia, Bandung Indonesia (LMI)
TUD Ship hydromechanics & structures
Technip FMC

FUNDED BY

Labmath-Indonesia

FUNDED %

University	-
FOM	-
STW	10 %
NWO Other	-
Industry	90 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2012

INFORMATION

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Mathematics of computational science

Prof.dr.ir. JWW van der Vegt

The research in the Mathematics of Computational Science group in the Department of Applied Mathematics of the University of Twente concentrates on two main topics:

- The development, analysis and application of numerical algorithms for the (adaptive) solution of partial differential equations for problems originating from the physical and technical sciences, in particular (discontinuous Galerkin) finite element methods.
- Mathematical modeling of complex physical problems to make them accessible for computation, in particular for turbulence and geophysical problems. In order to support these activities a significant research effort is directed towards the development of hpGEM, an object oriented toolkit for finite element methods, written in C++, and suitable for high performance parallel computers. Important applications are in the fields of gas dynamics, wet chemical etching of microstructures, fluid structure interaction, two phase flows both dispersed and with free surfaces, water waves, large eddy simulation of turbulent flows, geophysical flows and computational electromagnetics. Many of these projects are conducted in close collaboration with groups in physics and chemical technology, large technological research institutes (NLR, MARIN, WL Delft Hydraulics, KNMI), and industry (DSM, AKZO and Shell).

The research is conducted in the research institute IMPACT and the research in two-phase flows is part of the UT spearhead program “Dispersed multiphase flows”. The NACM group participates in the 3TU Center of Excellence for Multiscale Phenomena.

Multiscale modeling & simulation

Prof.dr.ir. BJ Geurts

The research of this group focusses on computational modeling of multiscale problems in multiphase flows, environmental flows and flows in complex domains. Applications are selected from the field of energy and bio-fluid mechanics. Novel algorithms, their parallel implementation and analysis are at the core of the research, with an emphasis on error quantification, immersed boundary methods and time-parallel integration.

Predicting atmospheric boundary layer characteristics in nested LES models

Project Aim

The objective of this research is to develop a WRF application with which atmospheric boundary layer flow over rough terrain can be predicted accurately. A nested approach is followed to cover a wide area of our planet in the computational model, at acceptable costs. The finest embedded grid centers on the region of interest and aims to predict day-night changes of weather features and compare these with field data.

Progress

A random perturbation model was developed with which small scale turbulence that is missing at an inflow boundary coupling a RaNS model to an LES model in the next finer grid in the nest. The area needed to reach developed turbulence could be significantly reduced while keeping the correspondence with field data intact. This was assessed for the Perdigao test location in the context of an EU collaborative research project.

Dissertations

-

Scientific Publications

-

Project leaders

Prof. B.J. Geurts, Prof. F. Chow

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

M. Wendels, L. van Veen

Cooperations

UC Berkeley

Funded by

STW, Industry

Funded %

University	-
FOM	-
STW	90 %
NWO Other	-
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

Bernard Geurts
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Project leaders
Prof. B.J. Geurts
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
M. Koenrades, C Slump
Cooperations
-
Funded by
UT, Vascutek Ltd.
Funded %

University	-
FOM	-
STW	90 %
NWO Other	-
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016
Information
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Project Aim

The objective of this research is to validate motion estimation algorithms applied to dynamic CT scans and to investigate motion and conformational changes of aortic vessels and implanted stent grafts during patient follow-up. With this research, we aim to identify parameters that aid the prediction of stent graft failure. This would allow for patient specific follow-up schemes and early identification of problems. In addition, stent graft manufacturers may optimize their designs based on this knowledge.

Progress

The results of research in the past years was laid down in a PhD thesis and defended successfully in 2019.

Dissertations

1. On evaluating stent-artery interaction in abdominal aortic stent grafting: an in-depth analysis of longitudinal and pulsatility related behavior, Maaike Anne Koenrades, 978-90-365-4875-5.

Scientific Publications

-

Project Aim

Flow in the upper ocean and the lower atmosphere requires solving the equations of fluid dynamics. However, our incomplete understanding of turbulence, the chaotic nature of these equations as well as the changing climate are several factors that make solving these equations incredibly difficult. By means of introducing stochastic transport noise in the shallow water equations under rotation we arrive at qualitative models with which we may study the structures in the flow and mathematical properties of geophysical fluid dynamics. This is aimed at contributing to improved weather and ocean mixing forecasting and provide an estimate of the uncertainty in the forecasts.

Progress

A detailed investigation of stochastic dynamics in the Lorenz 63 framework was undertaken. Both analytical and numerical methods were developed to understand the role of explicit stochasticity on the structure of the solutions. The effects of adding stochasticity on the well-known dynamical attractor of Lorenz 63 were considered and the changes in the Lyapunov exponent were quantified.

Dissertations

-

Scientific Publications

1. Stochastic Lorenz 63 Equations, BJ Geurts, DD Holm, E Luesink, Journal of Statistical Mechanics, 2019: arXiv preprint arXiv:1706.05882.

Project leaders

Prof. B.J. Geurts, Prof. D.D. Holm

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

E. Luesink

Cooperations

Prof. C. Cotter (ICL)

Funded by

IC London, EPSRC

Funded %

University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

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PROJECT LEADERS
Prof. B.J. Geurts
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
G. Ong, B. Knipscheer, D. Alblas, J. Mikhal
COOPERATIONS
Dr. J. Boogaarts – Radboud Medical Center
FUNDED BY
UT, Radboud
FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2016
INFORMATION
Bernard Geurts
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PROJECT AIM

The objective of this research is to develop computational models for the prediction of pulsatile flow in diseased cerebral vessels displaying an aneurysm or in the carotid artery, showing stenosis. Starting from medical imagery of an individual patient, methods are developed to automatically construct the flow domain corresponding to the diseased region. This implies translation of a surface representation (STL format) to a volume representation with which the incompressible Navier-Stokes equations can be treated using an immersed boundary method. The simulation platform is implemented in OpenFOAM to allow easy transfer of methods to other groups in the field. Next to pulsatile flow analysis, the inclusion of flow-diverting stents is studied with the aim to predict location, size and shape of aneurysm that would be best suited for the patient. Moreover, the dynamics of thrombus formation and multiscale shape remodeling is included to simulate the long-term healing process.

PROGRESS

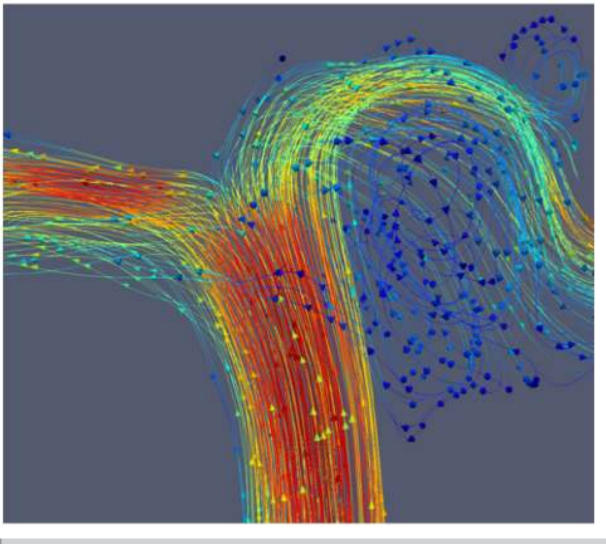
The flow inside a side-wall aneurysm and a bifurcation aneurysm was simulated successfully. The required spatial resolution for accurate prediction of the flow was determined and a systematic upper- and lower bounding solution was obtained from geometry variations, showing the sensitivity of the solution to input uncertainties. For the first time a full flow-diverting stent was simulated at appropriate resolution – the requirements are considerably stricter as the very fine structure of the stent needs to be resolved in order to capture the flow in its smallest detail.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. G. Ong, Analysis of Flow in Stented Aneurysm, Thesis MSc Applied athematics, University of Twente, 2018.
2. B. Knipscheer, Computational Fluid Dynamics for Bifurcation Aneurysm with Flow Diverters, Thesis MSc Technical Medicine, University of Twente, 2019.



Flow in a bifurcation aneurysm showing extended residence time because of the diseased vessel geometry.

Stochastic structure-preserving models for geophysical fluid dynamics

Project Aim

Geophysical fluid dynamics is at the heart of studies into weather predictions, upper ocean mixing and long-term climate change. We aim to develop structure-preserving stochastic models with which first principles of the flow are retained while allowing for significant coarsening of the computational models. Through data-assimilation further connections to observed mixing behavior can be established.

Progress

A solver for the rotating shallow water equations was developed and the wave interactions associated with flow over a 2D ridge were simulated. A detailed comparison of predictions obtained with a Discontinuous Galerkin (DG) method was prepared to quantify the resolution requirements for accurate direct numerical simulation. The flow structures were analyzed using empirical eigenfunctions.

Dissertations

-

Scientific Publications

-

Project leaders

Prof. B.J. Geurts, Prof. D.D. Holm

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

S. Ephraty

Cooperations

-

Funded by

NWO TOP 1 Grant

Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

Erwin Luesink
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PROJECT LEADERS
Prof. B.J. Geurts
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
Dr. James-Michael Leahy
COOPERATIONS
-
FUNDED BY
NOW Top 1 Grant
FUNDED %

University	-
FOM	-
STW	90 %
NWO Other	-
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2020
INFORMATION
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PROJECT AIM

Coarsening flow models for upper ocean circulation will require both spatial and temporal regularization as well as the inclusion of structure-preserving stochastic forcing. This is aimed at capturing the main aspects of turbulent motion while reducing computational costs such that accurate simulations are possible on planetary scales, and for extended periods of time.

PROGRESS

Work on Rotating Rayleigh-Benard convection has started with the development of a suitable 2D formulation in which backscatter is investigated next to stochastic forcing based on empirical eigenfunctions.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Stochastic structure-preserving simulation methods for turbulent flow

Project Aim

The simulation of high-Reynolds number turbulence as occurs in geophysical flow problems requires computational models that consistently reflect the underlying structure of the equations. We develop new structure-preserving high-performance computational models for ocean-atmosphere models and incorporate stochastic dynamics.

Progress

A new solver for 2D Rotating Rayleigh-Benard convection was developed and tested. First steps toward PDF modeling of the coarsened dynamics were made.

Dissertations

-

Scientific Publications

-

Project leaders

Prof. B.J. Geurts

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

P. Cifani, A. Franken

Cooperations

Imperial College London

Funded by

NWO Top 1 Grant

Funded %

University	-
FOM	-
STW	90 %
NWO Other	-
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2019

Information

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High-performance simulation methods for turbulence modulation in bubbly flows

Project leaders
Prof. B.J. Geurts, Dr. P. Cifani
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
S. Ephrati, A. Franken, J. Froehlich (TU Dresden)
Cooperations
-
Funded by
University of Twente
Funded %

University	-
FOM	-
STW	90 %
NWO Other	-
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2018
Information
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Project Aim

The objective of this research is to create simulation methods for direct numerical simulation of turbulent bubbly multiphase flow. Resolving all scales of motion of bubbles embedded in a liquid requires precise reconstruction and tracking of the bubble interfaces and the interaction with the surrounding liquid. This creates a basis for understanding the modulation of turbulence in multiphase flows, in particular drag reduction near solid walls.

Progress

A Volume-of-Fluid approach was adopted and a simulation method with excellent parallel performance was developed in cylindrical coordinates. Many deformable bubbles can be successfully simulated in a turbulent Taylor-Couette flow and drag reduction can be investigated. The method was also adopted to the fundamental study of a single bubble interacting with a solid wall and in collisions with other bubbles.

Dissertations

-

Scientific Publications

-

REPORTS OF INDIVIDUAL RESEARCH GROUPS

university of groningen

COMPUTATIONAL MECHANICS AND NUMERICAL MATHEMATICS (CMNM)

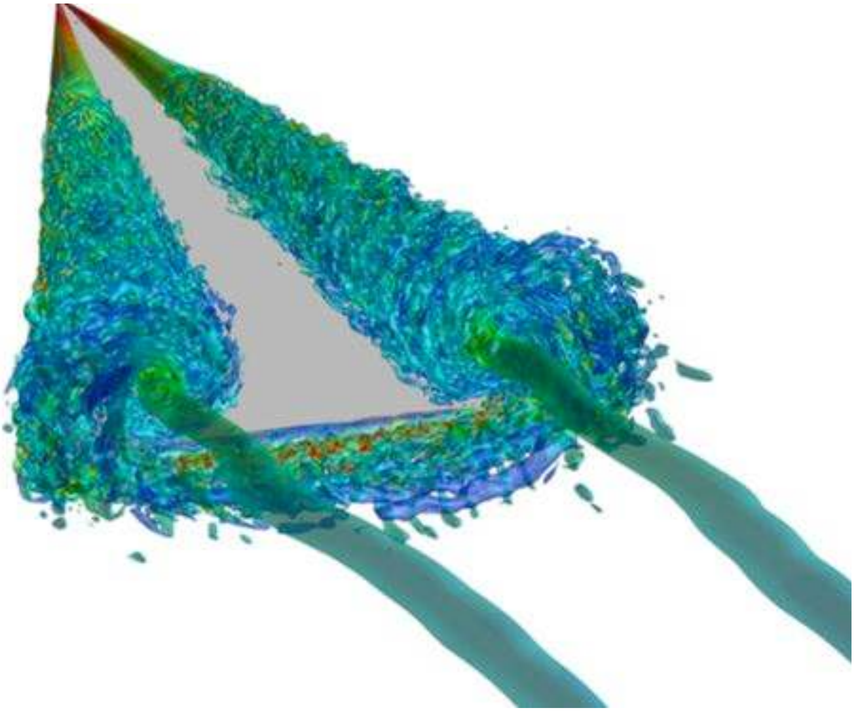
Computational mechanics and numerical mathematics

Prof.dr.ir. RWCP Verstappen

Prof.dr.ir. AEP Veldman

The group Computational Mechanics and Numerical Mathematics at the University of Groningen focuses on the development of numerical solution methods for partial differential equations in general, and for (aero- and hydrodynamic) flow simulation in particular (CFD). Keywords for our algorithmic developments are symmetry-preserving discretization, Cartesian cut-cell approach, sharp-interface methods, efficient sparse-matrix solvers and large-scale continuation methods. It is our strategy to combine all algorithmic innovations from the individual research projects into one coherent CFD concept, such that all projects can profit from each other.

Application areas are direct and large-eddy simulation of turbulent flow, free-surface flow in aerospace (sloshing onboard spacecraft) and maritime engineering (hydrodynamic wave loading), oceanography (stability of the global ocean circulation), bio-medical fluid dynamics (hemodynamics) and heat transport (Rayleigh-Bénard flow). We plan to extend our research efforts towards multi-physics: fluid-structure interaction, two-phase flow, atmospheric flow and turbulent combustion. In the process of knowledge transfer, the in-house developed computer codes ComFlo and MRILU play an important role.



DNS of flow past a delta wing at Re=200,000.

Project Aim

In the ComFLOW project, together with the maritime industry, concerns the design of numerical simulation methods for extreme waves and their impact on floating and moored constructions like offshore platforms and coastal protection systems. The most recent development phase concerns the interaction of extreme waves and floating and/or deforming bodies.

Progress

In the ComMotion project, extensions of the ComFLOW simulation method are being designed featuring moving and deforming objects. A quasi-simultaneous solid-fluid coupling method has been developed that is stable for any added-mass ratio. Absorbing boundary conditions allow for the presence of a current. Several algorithmic details near the free surface have been further refined. The STW-funded part of the project has been closed with ComFLOW release 4.2.0. The JIP project will be continued with an industry-funded User Group coordinated by MARIN. Applications are e.g. free-fall life boats, green-water events and floating fish farms.

Dissertations

1. Henri van der Heiden. Modelling viscous effects in offshore flow problems - a numerical study. Supervisor: A.E.P. Veldman, co-supervisor: R. Luppes. University of Groningen, 22 March 2019.

Scientific Publications

1. Arthur E.P. Veldman, Henk Seubers, S. Matin Hosseini Zahraei, Xing Chang, Peter R. Wellens, Peter van der Plas and Joop Helder, Computational methods for moving and deforming objects in extreme waves. Proc. 38th Int. Conf. Ocean, Offshore Arctic Eng. OMAE2019, June 9-14, Glasgow (Scotland). Paper OMAE2019-96321 (10 pages).
2. Arthur E.P. Veldman, Henk Seubers, S. Matin Hosseini Zahraei, Xing Chang, Peter R. Wellens, Peter van der Plas and Joop Helder. The ComMotion project: Computational methods for moving and deforming objects in extreme waves. R. Bensow and J. Ringsberg (eds.) Proc. MARINE2019, Gothenburg (Sweden), 13-15 May 2019. Paper a735 (12 pages).

Project leaders

A.E.P. Veldman

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

H Seubers, AEP Veldman (RUG), M Hosseini, X Chang, P Wellens, RHM Huijsmans (TUD), J Helder, P van der Plas (MARIN), B Iwanowski (FORCE), M Borsboom (Deltares)

Cooperations

TU Delft, MARIN, FORCE Technology (Norway). Deltares, GustoMSC, Damen Shipyards, DNV-GL (Norway), Hyundai Heavy Industries (Korea)

Funded by

STW

Funded %

University	-
FOM	-
STW	60 %
NWO Other	-
Industry	30 %
TNO	-
GTI	-
EU	-
Scholarships	10 %

Start of the project

2014

Information

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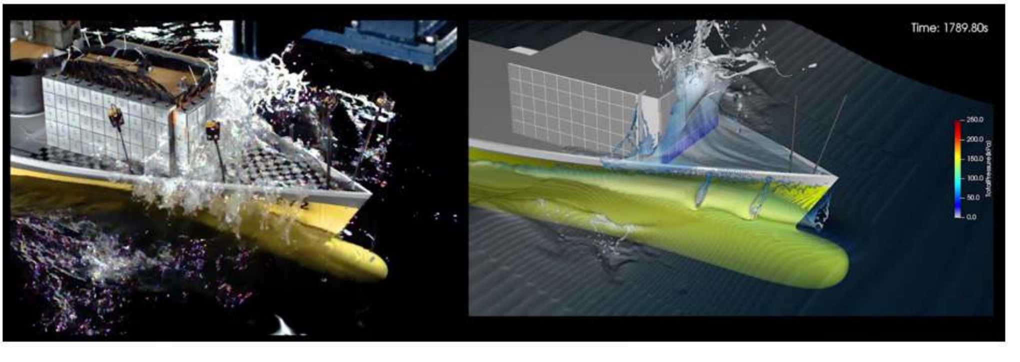
Comparison between experiment (MARIN) and numerical simulation (ComFLOW) of green water over the deck of a container ship.



Project leaders
RWCP Verstappen
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
MH Silvis, LB Streher, J Parekh, D.L. Sun, P. Cifani, J. Hidding, P. Rodriguez-Sanchez, RA Remmerswaal, AEP Veldman, FX Trias (UPC), A Oliva (UPC), HJ Bae (CTR)
Cooperations
Polytechnica University of Catalunya (UPC), eScience Center, Stanford University (CTR)
Funded by
NWO, RUG
Funded %

University	20 %
FOM	20 %
STW	20 %
NWO Other	20 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	20 %

Start of the project
1998
Information
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Project Aim

Our project concentrates on improving numerical techniques for direct numerical simulation (DNS) of turbulence, as well as on large-eddy simulation (LES). Finding a closure model represents the main difficulty to LES. Because turbulence is so far from being completely understood, there is a wide range of models, mostly based on heuristic arguments. The aim of the present project is to construct a class of LES-models that preserves (symmetry) properties of the Navier-Stokes equations, and ensures that the nonlinear dynamics is truncated properly, meaning that the formation of fine details is counterbalanced by the model.

Progress

In collaboration with UPC Barcelona, a mathematical methodology to combine eddy-viscosity models with the scale-similarity models in a consistent manner has been developed. A two-layer approach was successfully tested for wall-bounded turbulent flows. An uncertainty quantification method has been implemented in OpenFOAM to approximate the uncertainty in large-eddy simulations resulting from uncertainties in the subgrid model.

Dissertations

1. D.L. Sun, Variants of the block GMREX method for solving multi-shifted linear systems with multiple right-hand sides simultaneously, Promotor: R.W.C.P. Verstappen, co-promotor: B. Carpentieri, University of Groningen, February 15th, 2019.

Scientific Publications

1. P. Cifani, Analysis of a constant-coefficient pressure equation method for fast computations of two-phase flows at high density ratios, J. Comput. Phys. 398, 108904 (2019).
2. A.E.P. Veldman. A general condition for kinetic-energy preserving discretization of flow transport equations. J. Comput. Phys. 398, 08894 (2019).
3. M.H. Silvis, R. Verstappen, Nonlinear subgrid-scale models for large-eddy simulation of rotating turbulent flows, Direct and Large-Eddy Simulations XI, Springer, pp. 129-134 (2019).
4. M.H. Silvis, H.J. Bae, F.X. Trias, M. Abkar, R. Verstappen, A nonlinear subgrid-scale model for large-eddy simulations of rotating turbulent flows. In: arXiv: 1904.12748 (2019).
5. D.L. Sun, T.Z. Huang, B. Carpentieri, Y.F. Jing, Flexible and deflated variants of the block shifted GMRES method. J. Comput. & Appl. Maths. 345, 168-183 (2019).
6. D.L. Sun, T.Z. Huang, B. Carpentieri, Y.F. Jing, A new shifted block GMRES method with inexact breakdowns for solving multi-shifted and multiple right-hand sides linear systems, J. Scient. Comput. 78, 746-769 (2019).
7. J. Parekh, R. Verstappen, Intrusive polynomial chaos for CFD. Proceeding Workshop on Frontiers of Uncertainty Quantification in Fluid Dynamics, Pisa (2019).
8. J. Parekh, R. Verstappen, Intrusive polynomial chaos for CFD using Open FOAM, Proceedings Int. Conf. on Computational Science (2019).

Project Aim

We develop improved means for quantifying flow features focusing on the cardiovascular system through: (a) boundary conditions incorporating the neglected physical domain in an efficient and robust fashion, and (b) to parametrize the models using magnetic resonance data, which also cope the imaging drawbacks (e.g. noise, aliasing) (c) pressure field estimation from 3D+time data.

Progress

For (a) we have developed reduced models to represent distal vasculature in a more general and simpler way. We also proposed general boundary conditions that allow coping for geometry's uncertainties due to the limited resolution of medical images. For (b) we also have accomplished flow velocity reconstruction methods in magnetic resonance imaging more robust to aliasing than the state of the art. We also started to formulate, analyze and solve inverse problems as in (a), but with undersampled MRI data in order to allow fast clinical scans, (c) we have validated the most important methods for pressure recovery using experimental and phantom data, and we have started to perform theoretical analysis to understand systematic differences that we have observed in experiments.

Dissertations

1. Hemodynamic analysis based on biofluid models and MRI velocity measurements. David Nolte. PhD thesis, Universidad de Chile & University of Groningen, 2019 - PDF.

Scientific Publications

1. Junction of models of different dimension for flows in tube structures by Womersley-type interface conditions. C. Bertoglio, C. Conca, D. Nolte, G. Panasenko, K. Pileckas. SIAM J. Applied Mathematics, 79:959-985, 2019. DOI. Preprint.
2. Reducing the impact of geometrical errors in flow computations using velocity measurements. D. Nolte, C. Bertoglio. Int.J.Num.Meth.Biomed.Eng., e3203, 2019. OpenAccess.
3. Probing Hemodynamic Load – Using Virtual Fields to Estimate Cardiovascular Relative Pressure. D. Marlevi, B. Ruijsink, M. Balmus, D. Dillon, D. Fovargue, K. Pushparajah, C. Bertoglio, M. Colarieti, M. Larsson, P. Lamata, A. Figueroa, R. Razavi, D. Nordsletten. Scientific Reports, 9:1375, 2019. OpenAccess.
4. Automatic mapping of atrial fiber orientations for patient-specific modeling of cardiac electromechanics using image-registration. J. Hörmann, M. Pfaller, L. Avena, C. Bertoglio, W. Wall. Int.J.Num.Meth.Biomed.Eng, e3190, 2019. OpenAccess.
5. The importance of the pericardium for cardiac biomechanics: From physiology to computational modeling. M. Pfaller, J. Hörmann, M. Weigl, A. Nagler, R. Chabiniok, C. Bertoglio, W. Wall. Biomech.Mod.Mechanobiology, 18:503-529, 2019. DOI. Preprint.
6. Optimal dual-venc unwrapping in phase-contrast MRI. H. Carrillo, A. Osses, S. Uribe, C. Bertoglio. IEEE Trans. Medical Imaging, 38:1263–1270, 2019. DOI. Preprint.

Project leaders
Cristóbal Bertoglio

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Cristian Cárcamo, Hugo Carrillo, Jeremías Garay, David Nolte

Cooperations
University of Saint-Etienne, France
Center for Biomedical Imaging, Chile
Center of Mathematical Modeling, Chile, King's College London
Universidad de Concepción
Technical University of Munich

Funded by
University of Groningen
Chilean Science Foundation (Conicyt)

Funded %

University	25 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	75 %

Start of the project
2016

Information
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Project leaders
F.W.Wubs
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
W Song (DLR/RUG), S Kotnala (RUG), S Baars (RUG), E. Mulder (IMAU), H.A Dijkstra (IMAU), J Thies (DLR).
Cooperations
IMAU (UU), DLR, TU Braunschweig
Funded by
NWO, University of Groningen, DLR, eScience
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
1994
Information
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Project Aim

The aim of this project is to provide fast and robust solvers for the study of dynamics and structures of incompressible fluids. Such solvers are necessary for among others (i) the coupled linear system arising from steady or implicit computations of fluid flow, (ii) the calculation of eigenvalues to study the stability of a current and (iii) the solution of a stochastic PDE to study transition probabilities of currents. The focus is on geophysical flows and flows in simple geometries.

Progress

Good scaling results have been obtained up to 4092 cores with our linear equation solver HYMLS for incompressible Navier-Stokes equations (paper is under review). Currently it is adapted to solve the systems in an implicit method for the global oceans IEMIC. A new project has been started on speeding up the high-resolution explicit ocean model POP by the low-resolution IEMIC model using machine learning and stochastic techniques to deal with the lack of detail in the latter model. Detailed results were obtained by a projected version of Trajectory-Adaptive Multilevel Sampling method to compute transition probabilities in quasi-geostrophic flow (paper is under review).

Dissertations

1. W. Song: Matrix-based techniques for (flow-)transitison studies. S. Baars: Numerical methods for studying transition probabilities in stochastic ocean-climate models.
2. T.E. Mulder: Design and bifurcation analysis of implicit Earth System Models (Utrecht University).

Scientific Publications

1. Castellana, D., Baars, S., Wubs, F. W., & Dijkstra, H. A. (2019). Transition Probabilities of Noise induced Transitions of the Atlantic Ocean Circulation. Scientific Reports, 9(1), [20284]. https://doi.org/(...)8/s41598-019-56435-6.
2. Mulder, T. E., Dijkstra, H. A., & Wubs, F. W. (2019). Numerical bifurcation analysis of marine ice sheet models. In A. Gelfgat (Ed.), Computational Methods in Applied Sciences (pp. 503-527). (Computational Methods in Applied Sciences; Vol. 50). Springer Netherland. https://doi.org/(...)978-3-319-91494-7_14.

Reports of Individual Research Groups

WAGENINGEN UNIVERSITY & RESEARCH

Experimental Zoology (EZO)

Food Process Engineering (FPE)

Experimental zoology

Prof.dr.ir. JL van Leeuwen

The mission of the Experimental Zoology Group is to unravel the relationships between form and function in zoological systems in a developmental and evolutionary context and to provide bioinspired solutions for technological and health problems. The current main research area of the Experimental Zoology Group is the biomechanics of motion systems in vertebrates and insects, with three research lines that profit from one another: (1) Biomechanics of animal flight, including the biofluid dynamics of avian and insect flight and in-flight host detection of malaria mosquitoes. (2) Biomechanics of fish swimming, including swimming and developmental mechanics in larval fish, fin propulsion, visuo-motor-system development and effects of a livebearing reproductive strategy on swimming performance. This research line also includes developmental mechanics of bones and muscles linking bone remodelling to molecular regulation. (3) Bioinspired design solutions for human health, including development of steerable needles (inspired by the mechanics of the ovipositor in parasitic wasps), and construction of gentle grippers for delicate human tissues (inspired by wet adhesion of toe-pads in tree frogs). The Experimental Zoology Group participates also within the graduate school Wageningen Institute of Animal Sciences (WIAS).

PROJECT AIM

Flying animals such as birds, bats and insects are extremely maneuverable. Although the fluid dynamics of steady flight in animals is quite well understood, the dynamics that underlies maneuvers was not yet well known. We study the aerodynamics and control dynamics of flying animals, with the aim to understand how animals use their flapping wings to manipulate aerodynamic forces and torques, in order to rapidly and precisely control flight stability and maneuverability.

PROGRESS

We studied how birds escape by flying upwards [1,2]. We tested two conditions, birds with molt gaps and birds with added weights. To compensate for wing molt gaps, an upward escaping songbird actively reducing the molt gap by moving the adjacent feathers closer to each other, and by increasing the angle-of-attack of the wings during the downstroke movement [1]. Using a functional model, we quantified how the reduction in escape flight performance scales with added weight [2].

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Tomotani, BM & Muijres, FT (2019). A songbird compensates for wing molt during escape flights by reducing the molt gap and increasing angle of attack. J. Exp. Biol. 222.
2. Tomotani, BM, Bil, W, van der Jeugd, HP, Pieters, RP & Muijres, FT (2019). Carrying a logger reduces escape flight speed in a passerine bird, but relative logger mass may be a misleading measure of this flight performance detriment. Methods Ecol. Evol. 10, 70–79.

PROJECT LEADERS

Dr. Ir. FT Muijres

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Prof. JL van Leeuwen

COOPERATIONS

Prof. MH Dickinson (Caltech, USA)
Dr. GCHE de Croon (TU Delft)
Dr. BM Tomotani (NIOO)

FUNDED BY

NWO ALW Veni
Wageningen University (WUR)

FUNDED %

University	50 %
FOM	-
STW	-
NWO Other	50 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2012

INFORMATION

FT Muijres
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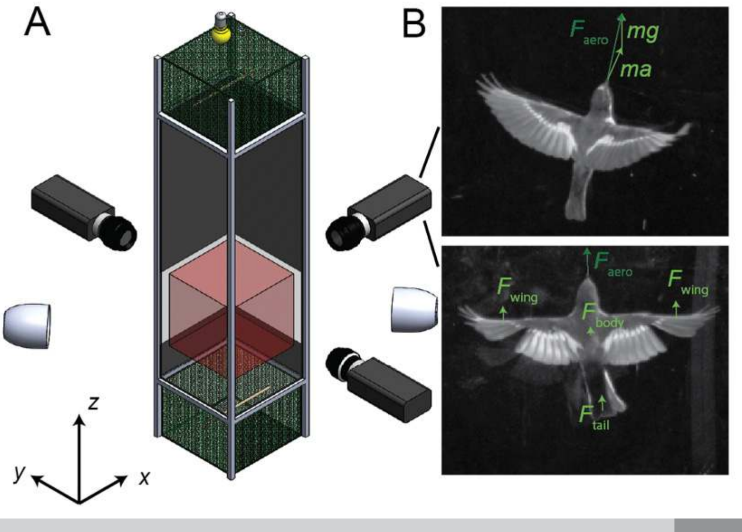
(A) The flight arena for studying escape flights in birds, including a three-camera high-speed videography system. (B) video stills of Pied Flycatchers without and with wing molt gaps (top and bottom images, respectively), including the aerodynamic forces modelled (from [1]).



PROJECT LEADERS
JL van Leeuwen

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
CJ Voesenek (PhD candidate)
MJM Lankheet (co-supervisor)
FT Muijres (co-supervisor)

COOPERATIONS
G Li (Chiba University, Tokyo)
H Liu (Chiba University, Tokyo)
UK Müller (Univ. of Fresno)
GJ van Heijst (TUE)

FUNDED BY
NWO/ALW

FUNDED %

University	20 %
FOM	-
STW	-
NWO Other	80 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2012

INFORMATION
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PROJECT AIM

Zebrafish larvae start swimming within two days post fertilization (2 dpf) and develop rapidly over the next few days. We study how these developmental changes affect locomotory performance. To achieve this, we will create a numerical model of the larvae that accounts for the mechanics of the muscular system, the external fluid mechanics, and their mutual interactions. This approach allows us to unravel how muscle activation patterns lead to swimming motions and identify causes of changes in swimming performance across development.

PROGRESS

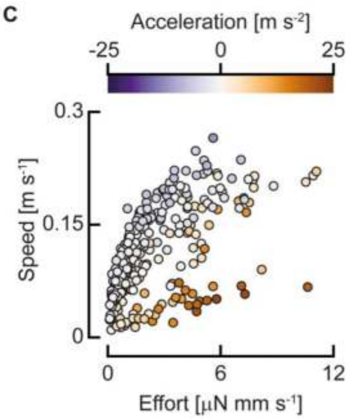
We published a paper on the 3D fast-start performance of larval fish. To avoid predation, fish larvae need to generate high-enough escape speeds in a wide range of possible directions, in a short-enough time. We filmed the fish motions using five synchronised high-speed video cameras. Using an inverse dynamics analysis, we showed that larval fish can independently control their escape speed and escape direction. Furthermore, we submitted a paper to PLoS Biology about the internal bending moment distributions of swimming zebrafish larvae (accepted for publication in 2020). This paper describes a novel methodology to compute bending moments for recorded arbitrary large amplitude 3D motions. The main biological conclusion of this paper is that fish larvae use a strikingly simple net actuation to control their swimming motions, which results in complex fluid-structure interactions. Cees Voesenek defended his PhD Thesis successfully (cum laude). He will receive the JMBC Hoogendoorn award 2019 for his work.

DISSERTATIONS

1. Cees Voesenek, 2019. How fish larvae swim: from motion to mechanics Wageningen University. https://www.wur.nl/en/article/Summary-of-the-thesis-How-fish-larvae-swim-from-motion-to-mechanics.htm.

SCIENTIFIC PUBLICATIONS

1. Voesenek CJ, Pieters RPM, Muijres FT, Van Leeuwen JL (2019). Reorientation and propulsion in fast-starting zebrafish larvae: an inverse dynamics analysis. Journal of Experimental Biology 222(14), jeb203091.
2. Van Leeuwen JL, Voesenek, CJ, Li G & Muijres FT (2019) Learning how to swim: lessons from bending moment patterns. Animal Biology abstracts2, Society for Experimental Biology 172–172.



Mean swimming speed of larval fish against effort (defined as the peak bending moment along the fish divided by the time of the half beat). Colour indicates the mean acceleration of the half tail beat. High speeds and high acceleration require effort. From: https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.3000462

PROJECT AIM

We study the flight dynamics of the malaria mosquito (Anopheles coluzzii) with the applied goal to improve current and/or develop novel mosquito trap systems for vector control. We aim to reach this goal by quantifying mosquito flight dynamics during host searching with diverse attractive cues and mosquito escape manoeuvres when swatted. These should provide novel insights into mosquito flight behaviour and the mechanisms involved for odour and wind gust detection and response.

PROGRESS

The building of our experimental setup (figure 1) was completed and experiments have been carried out successfully, and CFD simulations of the piston-induced airflow have been made. High-speed video recordings of mosquito escapes are currently being analyzed with the goal of estimating the kinematics of body and wing movements. All of these will be combined to better understand how mosquitoes detect a looming threat (the piston) and how good their escape performance in variable light conditions.

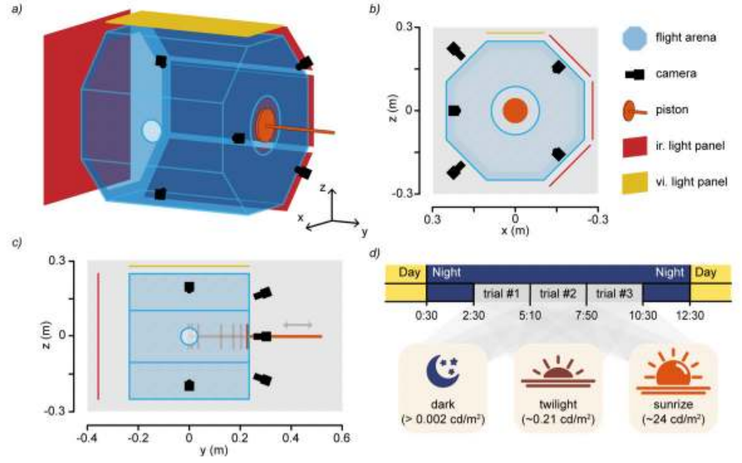
DISSERTATIONS

\-

SCIENTIFIC PUBLICATIONS

1. Cribellier, A., Spitzen, J., Straw, A., van Leeuwen, J. L., & Muijres, F. T. (2019). When swatted in the dark, mosquitoes use airflow movements to trigger their evasive manoeuvers. Abstract from the 2nd International Workshop Insect bio-inspired microtechnology workshop, 2019, Grenoble, France.

Flight arena with mechanical swatter and real-time mosquito tracking system. The tracking system consists of 5 Basler infrared-enhanced cameras at 90 fps. The piston (in orange) was triggered when a mosquito was predicted to enter a 5 cm radius sphere in the centre. (a) three-dimensional view, (b) front view and (c) side view of the flight arena. (d) Experimental protocol. Every day, the piston disk type was changed and 50 female mosquitoes were released into the arena. Then, during the night, three experimental trials were conducted with different light conditions (dark, twilight or sunrise).



PROJECT LEADERS
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RESEARCH THEME
Complex dynamics of fluids

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W Takken (advisor)
RPM Pieters (technician)

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M Geier (external partner)
MH Dickinson (external advisor)
R Dudley (external advisor)

FUNDED BY
Graduate School Wageningen Institute of Animal Sciences (WIAS)

FUNDED %

University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2016

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To be as nimble as a bee: A bio-inspired sensory-motor system for gust control of Micro Air Vehicles

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RPM Pieters (technician)
Cooperations
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B W van Oudheusden (TU Delft)
MH Dickinson (Caltech)
Funded by
NWO
Funded %

University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017
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Project Aim

State-of-the-art drones have difficulty flying outdoors or in natural environments due to the presence of wind gusts. But, the insects navigate through complex environments in the presence of wind gusts very easily. The aim of this project is to study and understand the gust rejection capabilities of insects. Specifically, we aim to understand how bumblebees fly and land in various wind conditions including no wind condition.

Progress

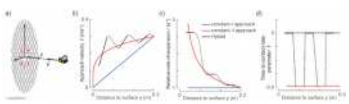
We worked on the dataset obtained from the first set of experiments (different light conditions and landing patterns) and obtained the following major result: Bumblebees land rapidly by stepwise adjusting their setpoint of relative optical expansion rate Using a novel analysis method, we identify a previously unknown deceleration strategy that bumblebees exhibit during a landing approach. Specifically, we show that they decrease their velocity towards the landing platforms by holding the relative-rate-of-expansion constant within a wide range of set-points and collectively exhibit an increase in these set-points as distance from the platforms reduces. This increase in set-points with distance results in a discrete approximation of deceleration strategy of birds that use constant time-to-contact-rate to regulate their expansion rate with distance (Figure 1), thereby results in relatively fast landings. This robust landing strategy occurs in a wide range of luminance and with variable degrees of expansion cues, suggesting that bumblebees adequately controls landing by using neural summation.

Dissertations

-

Scientific Publications

1. Goyal, P., de Croon, G. C. H. E., van Leeuwen, J. L., & Muijres, F. T. (2019). Flight control model of landing maneuver in bumblebees. Poster session presented at 2nd International Workshop Insect bio-inspired microtechnology workshop, 2019, Grenoble, France, Grenoble, France.
2. Goyal, P., Lankheet, M. J. M., van Leeuwen, J. L., & Muijres, F. T. (2019). How bumblebees reject sideways wind while landing. Abstract from WIAS Science Day 2019, Lunteren, Netherlands.
3. Goyal, P., de Croon, G. C. H. E., van Leeuwen, J. L., & Muijres, F. T. (2019). Flight control model of landing maneuver in bumblebees. Abstract from Zoology 2019, Groningen, Netherlands.



The landing strategies described in honeybees (Baird et. al., 2013), birds (Lee et. al. 2012, Lee et. al. 1991) and observed in bumblebees (our study). (a) An animal that approaches a vertical landing platform along its axial direction experiences a relative optical expansion rate as symbolized by the red arrows. At time t, the animal is at distance y from the object and has an approach flight velocity V. At t, the relative-rate-of-expansion equals $r=V/y$, and the instantaneous time-to-contact $\tau=y/V$. (b–d) The variation with distance from the landing surface of (b) approach velocity, (c) relative-rate-of-expansion, and (d) time-to-contact-rate (taudot = $d\tau/dt$) for the constant-r landing approach observed in honeybees (blue), the constant-taudot landing approach of birds (red) and the hybrid landing approach of bumblebees (black). The hybrid landing approach consists of constant-r segments (solid lines), separated by transition phases (dotted curves). All results, and particularly the transition phases, are of idealized cases. For comparative purpose, all three landing strategies are plotted for an animal starting with 0.3 ms^{-1} approach velocity at 0.3 m distance from the surface.

Aerodynamics of the high-frequency flapping wings in flying mosquitoes

Project Aim

Mosquitos fly with exceptionally high wingbeat frequencies, which sets them apart from other flying insects. The goal of this project is to understand the aerodynamics behind high frequency flapping mosquito flight.

Progress

At the stroke reversal between upstroke and downstroke, insects wings rapidly pitch up, sometimes at more than 4000 rad per second. The unsteady aerodynamics that results from these fast wing pitch movements were not well understood, and thus we performed a computational fluid dynamics study on rapidly pitching insect wings [1]. Between simulations, we systematically varied the wingbeat kinematics, including speed of the wingbeat and pitching motion, as well as the wing morphology (figure 1). Based on the results, we developed an aerodynamic force model of pitching insect wings. Using this model, we showed that the so-called pitch-rate related aerodynamic forces are particularly high in the high-frequency wingbeat of mosquitoes.

Dissertations

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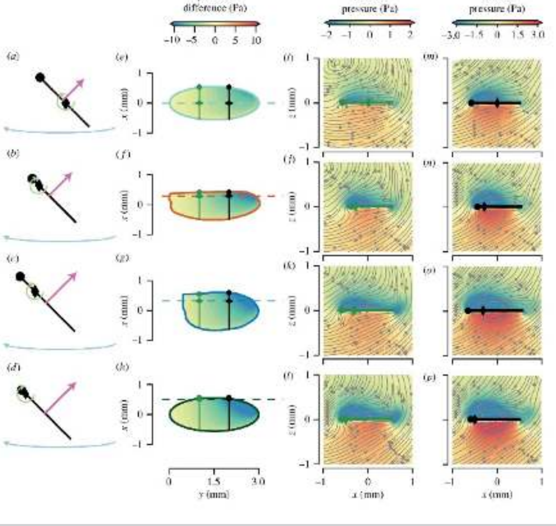
Scientific Publications

1. Van Veen, W. G., van Leeuwen, J. L., & Muijres, F. T. (2019). A chordwise offset of the wing-pitch axis enhances rotational aerodynamic forces on insect wings: A numerical study. Journal of the Royal Society Interface, 16(155), [20190118]. https://doi.org/10.1098/rsif.2019.0118.

The aerodynamics of four rapidly upward pitching wings, including a mosquito wing (red outline) and fruit fly wing (blue outline). (a–d) Schematic of the aerofoil, where the dot indicates the leading edge and the diamond the pitch axis. Pink arrow illustrates the resultant aerodynamic force. (e–h) The distribution of pressure differences across the wing surface. (i-p) Pressure and flow field around the wings at two spanwise locations indicated in (e-h) by green lollipops for (i-l) and black lollipops for (m–p), respectively. Figure from [1].



Project leaders

Dr. Ir. FT Muijres

Research theme

Complex dynamics of fluids

Participants

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JL van Leeuwen (promotor)

Cooperations

MH Dickinson (Caltech, USA)

Funded by

NWO ALW Veni
Wageningen University (WUR)

Funded %

University	50 %
FOM	-
STW	-
NWO Other	50 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2015

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Prof.dr.ir. CGPH Schroën

Microtechnology, membranes and modelling: M3

Membranes (and other microstructures) can be used for various purposes, such as separation, which is the traditional application for membranes, but also for formation of emulsions, foams, and sprays. Within the food microtechnology group, all these aspects are investigated (together with technical assistants Jos Sewalt and Maurice Strubel), and modelling is used as a tool to gain fundamental insight in the underlying mechanisms. For specific information on projects, please consult the pages indicated below, and the PhD thesis section which holds completed projects.

Modelling cross flow microfiltration: design for the concentration and fractionation of suspensions

Project Aim

This PhD project aims as modeling of particle behavior in flow through micro channels. During this process particles will migrate, and these effects can be used to facilitate amongst other microfiltration but also separation processes. Through detailed understanding of particle behavior we will design novel separation processes that are expected to be intrinsically more energy efficient than those that are currently available.

Progress

Starting from experimental results obtained in previous research, we started with a simple system, i.e. a microchannel, through which a particle containing dispersion flows, and modelled this with Star CCM software.
We compared the simulations with literature data, and found that idealized experiments could be predicted accurately. The main difference with other experimental data are caused by experimental non-idealities. After this, the model was extended to contain single and multiple pores, and again the trends that were observed earlier are confirmed. In a last experimental part, we investigated cream separation, and again the trends also held for this highly complex food system.

Dissertations

-

Scientific Publications

-

Project leaders

K Schroen

Research theme

Complex dynamics of fluids

Participants

Ivon van der Meer-Drijer

Cooperations

The project is part of the NanoNextNl program, and within the water theme we cooperate with UTwente, and Stork Veco.

Funded by

NanoNextNl, Stork Veco

Funded %

STW	-
University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2012

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Physical Chemistry and Soft Matter (PCC)

Prof.dr.ir. J van de Gucht

Physical Chemistry and Soft Matter at Wageningen University & Research is interested in phenomena at the nanoscale, where creative chemistry is essential, complex physics is a rule rather than an exception and biology comes to life.

PROJECT AIM

Develop a portable Laser Speckle Imaging (LSI) set-up with real-time data analysis and build a 3-dimensional LSI instrument. Apply these set-ups for the visualization of complex flows.

PROGRESS

Development of the portable set-up is finished and the set-up is being used now to study complex flow behaviour. The 3-D LSI set-up is being built.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Buijs, J., Gucht, J.v.d. & Sprakel, J. Fourier transforms for fast and quantitative Laser Speckle Imaging. Sci Rep 9, 13279 (2019). https://doi.org/10.1038 s41598-019-49570-7.
2. van der Kooij HM, Semerdzhiev SA, Buijs J, et al. Morphing of liquid crystal surfaces by emergent collectivity. Nature Communications. 2019 Aug;10(1):3501. DOI: 10.1038/s41467-019-11501-5.

PROJECT LEADERS
J van der Gucht

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Jesse Buijs (PhD student), Prof. dr. Joris H.B. Sprakel

COOPERATIONS
Unilever, Shell, Evodos

FUNDED BY
NWO/ISPT

FUNDED %

University	-
FOM	-
STW	-
NWO Other	50 %
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2018

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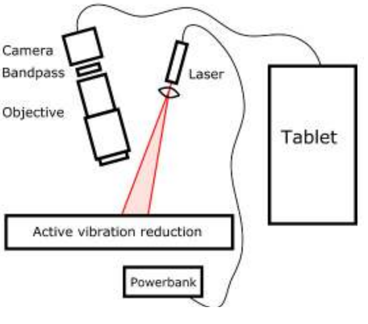

Reports of Individual Research Groups

Utrecht University

Institute for Marine and Atmospheric Research Utrecht (IMAU)

Prof.dr. LRM Maas

Prof.dr.ir. HA Dijkstra

The research of this Institute concerns transport processes in the ocean and in the atmosphere. Some sections of IMAU participate in the research school Buys Ballot. However, the section Dynamical Oceanography also participates in the JM Burgerscentrum.

One of the main topics is the role of the ocean circulation in the variability of the climate system and the processes controlling the large-scale ocean circulation. In particular, attention is focused on the path changes of the oceanic western boundary currents (such as the Gulf Stream in the Atlantic Ocean, the Kuroshio in the Pacific Ocean, and the Agulhas Current near South Africa), the El Nino / Southern Oscillation phenomenon in the Pacific, and the North Atlantic Multidecadal variability. Both theory development and (high-resolution) model simulation are used to better understand these phenomena and our favourite framework to analyse the complex behaviour of ocean flows is that provided by stochastic dynamical systems theory.

Another line of research focuses on ocean wave dynamics. Due to temperature and salinity differences, the ocean is stratified in density. This supports internal gravity waves, that have their maxima below the surface of the ocean. These waves are especially generated by surface tidal motions over topographic irregularities, like the continental shelf edge or Mid-Atlantic Ridge. When subject to friction at ocean boundaries, Reynolds-stresses induced by internal gravity waves are found to also drive horizontal mean flows. Another type of large-scale ocean wave is related to the rotation of the earth: the Rossby wave. This wave type exists due to variations in background potential vorticity, which represents the ratio of planetary vorticity (equal to twice the rotation rate of the fluid) and water depth. An explicit expression for the Green's function, describing the response to an impulsive point source is uncovered.

Project Aim

The Atlantic Ocean circulation, in particular its Meridional Overturning Circulation (MOC), is sensitive to freshwater anomalies. A tipping point may exist such that the present-day MOC will collapse if the northern North Atlantic freshwater forcing is gradually increased. In addition, if the MOC is in a multiple equilibrium regime it may undergo transitions due to the impact of noise. The aim of this project is to determine the probability of transitions of the MOC in a hierarchy of stochastic ocean-climate models. Both noise in the surface forcing as well as in the representation of turbulent mixing processes will be considered.

Progress

Using an idealized ocean model, we determined estimates of the transition probability of noise-induced transitions of the AMOC, within a certain time period, using a methodology from large deviation theory. We find that there are two types of transitions, with a partial or full collapse of the AMOC, having different transition probabilities. For the present-day climate state, we estimate the transition probability of the partial collapse over the next 100 years to be about 15%, with a high sensitivity of this probability to the surface freshwater noise amplitude. In a follow-up study, we will determine the transition probabilities of the AMOC in state-of-the-art climate models.

Dissertations

-

Scientific Publications

1. D. Castellana, S. Baars, F.W. Wubs, H. A. Dijkstra (2019) Transition Probabilities of Noise-induced Transitions of the Atlantic Ocean Circulation, Scientific Reports, 9, 20284.

Project leaders
HA Dijkstra
Research theme
Complex dynamics of fluids
Participants
D. Castellana MSc
Cooperations
CRITICS ITN partners
Funded by
EU-H2020
Funded %

STW	
University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2016
Information

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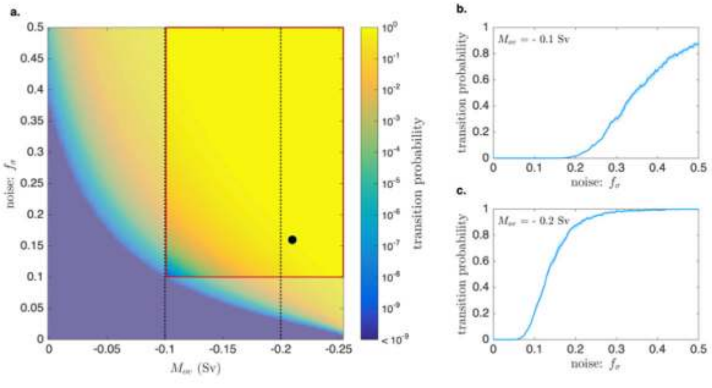
(a) Transition probabilities of partial AMOC transitions (cessation of the downwelling) in 100 years, calculated for each couple of the parameters (Mov, fσ), representing the freshwater transport by the AMOC and the noise level of the freshwater forcing, respectively. (b-c) Transition probabilities as a function of fσ for two particular choices of Mov as indicated by the dashed lines in (a). The shaded areas represent the interquartile range for the probabilities.



PROJECT LEADERS
LRM Maas
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
F. Beckebanze
COOPERATIONS
-
FUNDED BY
NWO
FUNDED %

STW	-
University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2015
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PROJECT AIM

Internal wave attractors.

PROGRESS

Internal waves in uniformly-stratified fluids propagate along rays (beams) that are inclined to the direction of gravity, at an angle that is determined by the ratio of their frequency and the buoyancy frequency (that essentially measures the rate with which density decreases with height above the bottom). This property constrains the wave propagation to the effect that it leads to focusing or defocusing. This happens under normal incidence, i.e. when an incident internal wave beam reflects from an inclined bottom while approaching it in a plane determined by the direction of gravity and the bottom gradient (the direction into which the water depth varies). Focusing dominates in enclosed fluid domains and the internal wave beam approaches a limit cycle, called wave attractor. But when the internal wave beam approaches the bottom under an oblique angle, i.e. from a horizontal direction that is not coinciding with the previously defined normal plane, this dominant focusing is accompanied by instantaneous refraction. This means that the reflected wave propagates in a horizontal direction that differs from that of the incident wave. Multiple reflections may alter its path completely, to the extent that in a uniformly-stratified channel with sloping bottom, an internal wave beam that initially propagates parallel to a sloping bottom, is at some distance completely trapped to a plane perpendicular to that sloping bottom, halting its down-channel propagation (Fig. 1). When the bottom is not only sloping in cross-channel, but also in along-channel direction, the internal wave beams are further localized onto what may be called a super-attractor (Fig. 2).

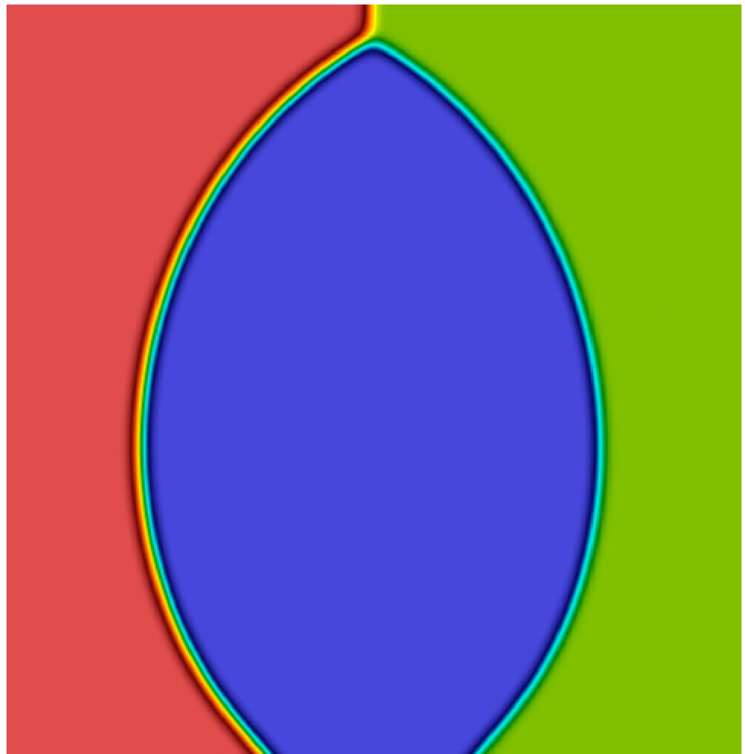
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

WHO & WHERE



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Civil Engineering / Built Environment (CEBE)

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Science and Technology (TNW)

Physics of Fluids (TNW-PoF)

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Physics of Complex Fluids (TNW-PCF)

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