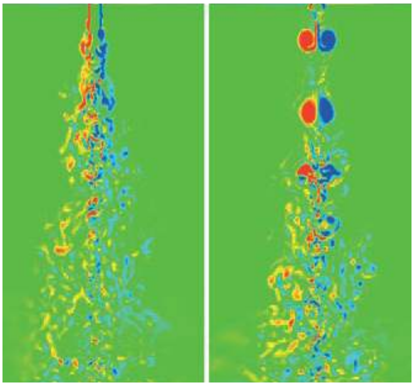
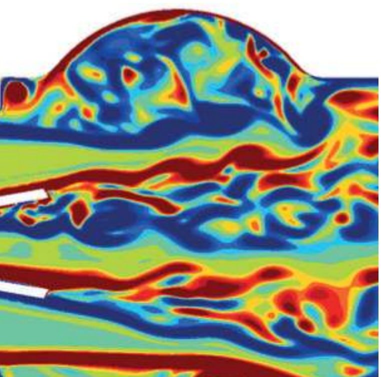
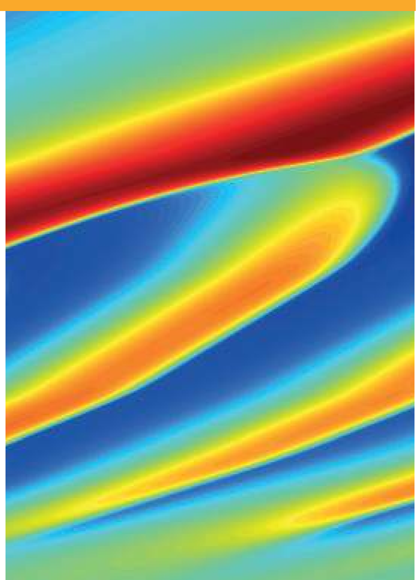




2018

Annual Report & Research Programme



J.M.Burgerscentrum

Research School for Fluid Mechanics

TUD, TUE, UT, RUG, WUR, UU

Annual Report & Research Programme 2018

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 2018. 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 (more than 300). In addition, about 50 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. Sponsoring of projects via the European Research Council is increasing. Finding funds for our PhD projects remains an important task for all JMBC groups.

In the academic year 2017 – 2018 the following JMBC courses were organised: 'Dispersed Multiphase Flow', 'CFD 1', 'Turbulence', 'Fundamentals and Applications of Perturbation Methods in Fluid Mechanics', 'Shallow flows' (VKI-JMBC), 'Computational Multiphase flows', and 'Micro- and Nanofluidics'. The lecture course 'Shallow Flows' was organised jointly with the Von Karman Institute, and was given in Brussels (B).

The JMBC course programme for the academic year 2018 – 2019 contains the following courses: 'Particle-based Modeling Techniques', 'Fundamental Fluid Dynamics Challenges in Inkjet Printing', 'CFD 2', 'Combustion', 'Experimental Techniques in Fluid Mechanics', 'Particle Technology', 'Complex Flows and Complex Fluids' (CISM-JMBC), 'Capillarity-driven Flows in Microfluidics', and 'PIV'. The lecture course 'Complex Flows and Complex Fluids' is organised jointly with the institute CISM in Udine (It.).

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 2018 this Symposium was held on 5-6 June 2018 in Conference Centre 'De Werelt' in Lunteren. The programme included two plenary lectures: the Burgers Lecture by Prof. John Dabiri (Stanford University, USA) and the Evening Lecture by Prof. Charles Meneveau (Johns Hopkins University, 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 80 presentations by PhD students and postdocs were given. The Symposium was concluded by an Award session for various prizes: the Charles Hoogendoorn Fluid Dynamics Award 2017 (KIVI) was presented to the recipient, Dr. Sander Haase (former PhD student at UT), 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.

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 (at the age of 23 (!)) 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, its publication will be in 2019.

Also, a special symposium "100 Years of Fluid Mechanics in The Netherlands" was organized in Delft on 18 October 2018. Rather than looking backwards, the theme of the symposium was to look at possible developments of the field in the next 100 years. Presentations were given by renowned international speakers and also by a few freshly appointed junior staff members.

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 2018 a new group joined the JMBC: the group Interfaces of Mass Transfer of Prof. Cees van der Geld at the Department Chemistry and Chemical Engineering at TU/e.

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 has been 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
Chairman of the JMBC Board

Prof.dr.ir. GJF van Heijst
Scientific Director JMBC

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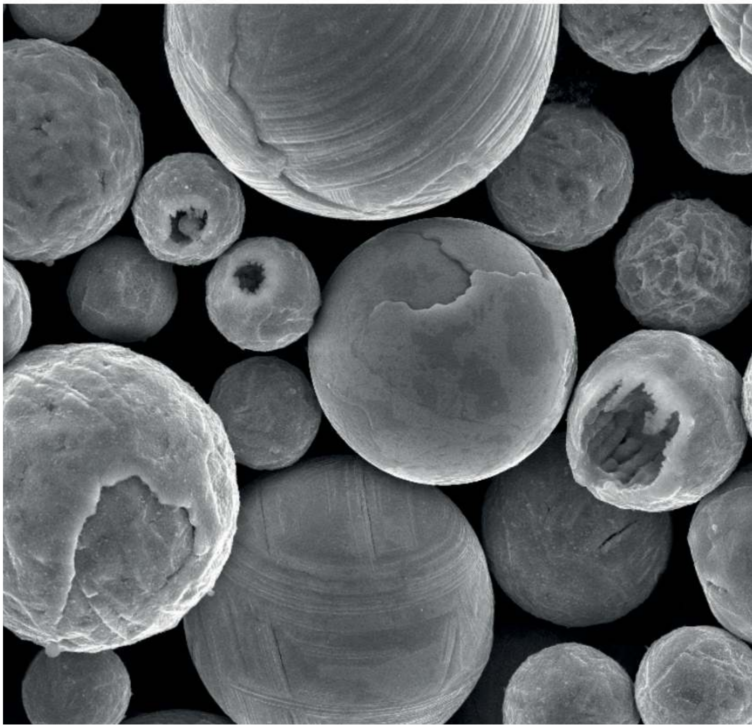
Organisation



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 this moment, more than 300 PhD-students and 50 postdocs are 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.

The JMBC has attracted top-experts in different fields of fluid mechanics to the JMBC. These experts have been appointed as JMBC-professors or Centre-of-Excellence professor at the three Universities of Technology, mostly financed by the Boards of the Universities of Technology or by the Research Centre for Fluid & Solid Mechanics. They contribute considerably to the achievements of the research school.

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 2018 approximately 70 presentations were given by junior speakers in a number of parallel sessions.

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 2018

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			
Mechanical Engineering			
BJ Boersma	0.7	5	3
C Poelma	0.7	9	
J Westerweel, DJEM Roekaerts, RAWM Henkes *(p)*, W van de Water *(p)*	2.5	9	3
Maritime Engineering			
R van 't Veer, TJC van Terwisga *(p)*	1.8	11	
C van Rhee	1.1	5	
Applied Mathematics			
C Vuik, C Oosterlee *(p)*	2.0	9	1
AWH Heemink, E Deleersnijder *(p)*, M Verlaan *(p)*	2.5	6	
Chemical Engineering			
CR Kleijn, RF Mudde, HEA van den Akker *(p)*, A de Haan *(p)*	2.0	12	1
M Kreutzer, JR van Ommen	1.4	4	
Radiation Science & Techn.			
THJJ van der Hagen (M Rohde)	0.8	5	
Aerospace Engineering			
F Scarano, S Hickel	3.8	24	
Civil Eng. & Geosciences			
AJHM Reniers, JD Pietrzak, WSJ Uijttewaal	3.4	14	2
HJJ Jonker, AP Siebesma, BJH van de Wiel	2.1	3	1
TUE			
Applied Physics			
AA Darhuber	1.1	5	1
HJH Clercx, GJF van Heijst, F Toschi	3.2	22	5
OCG Adan *(p)*	0.9	3	1
GWM Kroesen, V Banine *(p)*, U Ebert *(p)*	0.7	3	
Mechanical Engineering			
NG Deen, LPH de Goey, JGM Kuerten, M Golombok *(p)*, DJEM Roekaerts	4.1	23	3
DMJ Smeulders, EH van Brummelen, HA Zondag *(p)*	3.1	9	1
JMJ den Toonder	1.5	5	4
Biomedical Engineering			
FN van de Vosse	0.15	1	
Mathematics and Computer Science			
B Koren, MA Peletier, JJM Slot *(p)*	2.3	7	

University and (sub)faculty	Scientific staff (fte)	PhD students	Postdocs
Chemical Eng. & Chemistry			
JAM Kuipers	1.5	23	1
M van Sint Annaland	0.7	6	
CWM van der Geld	0.3	1	
Department Civil Engineering and Built Environment			
B Blocken	1.1	14	3
UT			
Applied Physics			
D Lohse, M Versluis, C Sun *(p)*, X Zhang *(p)*, D van der Meer, A Prosperetti *(p)*, J Snoeijer, R Verzicco *(p)*	3.0	39	11
F Mugele	0.7	5	1
Chemical Engineering			
RGH Lammertink	0.7	10	2
Mathematical Sciences			
EWC van Groesen	0.3		1
JJW van der Vegt	0.3	1	
BJ Geurts, JGM Kuerten *(p)*	0.7	1	1
Mechanical Engineering			
CH Venner	2.3	2	2
G Brem	1.5	3	1
S Luding	1.9	4	2
Water Engineering & Management			
SJMH Hulscher	3.0	12	1
RUG			
Mathematics			
RWCP Verstappen	1.1	5	2
WUR			
Experimental Zoology			
JL van Leeuwen	0.7	4	
Agrotechnology & Food Sciences			
CGPH Schroen	0.7	2	
J van der Gucht	1.1	3	
UU			
Physics			
H Dijkstra, LRM Maas	0.7	2	

Overview of university participants

	TUD	TUE	UT	RUG	WUR	UU	Total
Scientific staff *(effective fte)*	24.8	20.6	11.4	1.1	2.5	0.7	64.1
PhD-students	116	121	77	5	9	2	330
Postdocs	11	19	22	2	0	0	54

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.

In 2018 we took the initiative to host several workshops between a wide range of industries, academia and institutes. The aim of the workshops was to find areas of interest for different cross-sections of industries. As first outcome Industrial Granular Flow (or dense particle flow) was identified with interest from the food, chemicals, steel and energy sectors. During the other workshops the program content was further worked out. During that process some industries left the potential NWO sponsored project, while others joined. Also 4 different groups from three technical universities were identified, and the first new project was born. In 2019 the final proposal will be reviewed via the normal review and interview processes.

During the first workshop also a second area of interest was identified, namely dense bubbly flow in electrolysers. Also this project was further developed with as result participation of 4 different groups from three different universities. In 2019 this project will go through the regular review and interview processes.

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 are looking forward to additional new collaborations in other areas as well during 2019.

As separate item the fast development of computational science and digitalisation is on the agenda. These developments have, amongst others, significant effects on the traditional workflow and interactions between fundamental sciences and process engineering tools linked to plants in operation. Open source and open access are followed closely as they will also affect the ways of working in the fluid mechanics area.

Ir. P Veenstra
Shell
Chairman of the Industrial 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. On 16 November 2017 a very successful one-day meeting was held at Deltares in Delft, with the theme "Multiphase Flow Applications", with six technical presentations and a visit to the facilities of Deltares. The next meeting is tentatively scheduled for May 2019, to be organized by the new coordinators of this contact group.

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 2018, the annual CFD contact group meeting took place on Friday 16 March 2018 in Delft.

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

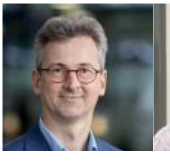
Contact group "Combustion"

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 2016, and was organized in association with ERCOFTAC and the International Combustion Institute.

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 2018, COMBURA took place in Soesterberg on 9 – 10 October.

The theme of Combura 2018 was 'Hydrogen, the fuel for energy transition', focusing on the role of hydrogen combustion within the rapidly changing energy landscape. Keynote lectures were given by dr. Jan-Jaap Aué, (Hanze University of Applied Science Groningen), ir. Geert Laagland (Vattenfall), and prof. Henry Curran (National University of Ireland Galway), 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 2017 meeting of the contact group Turbulence was held in Delft, while the next meeting is scheduled for April 2019, to be hosted by Dr.ir. RPJ Kunnen (TUE).

Contact: Dr. R Pecnik (TUD), Dr.ir. WP Breugem (TUD)

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 April 2017 and counted with more than 50 participants and 13 lecturers from all over the country. The next course will be held in 2019 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.

Although the contact group has led a rather dormant life during the last few years, a new start has been made with a fresh coordinating team. The next meeting of the rejuvenated contact group is scheduled for the Spring of 2019.

Contact: Dr.ir. S Kenjeres (TUD), Dr.ir. F Muijres (WUR)

Contact group "Microfluidics"

The purpose of this contact group is to bring together students, postdocs and senior researchers 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. In 2018, a new course "Micro- and Nanofluidics" has been organized, which took place on 28-31 May 2018 at Eindhoven University of Technology. The objective of this course was to let the participants learn about micro- and nanofluidic principles, technology, and applications, but also to give them extensive hands-on experience with designing, making, and testing microfluidic devices.

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

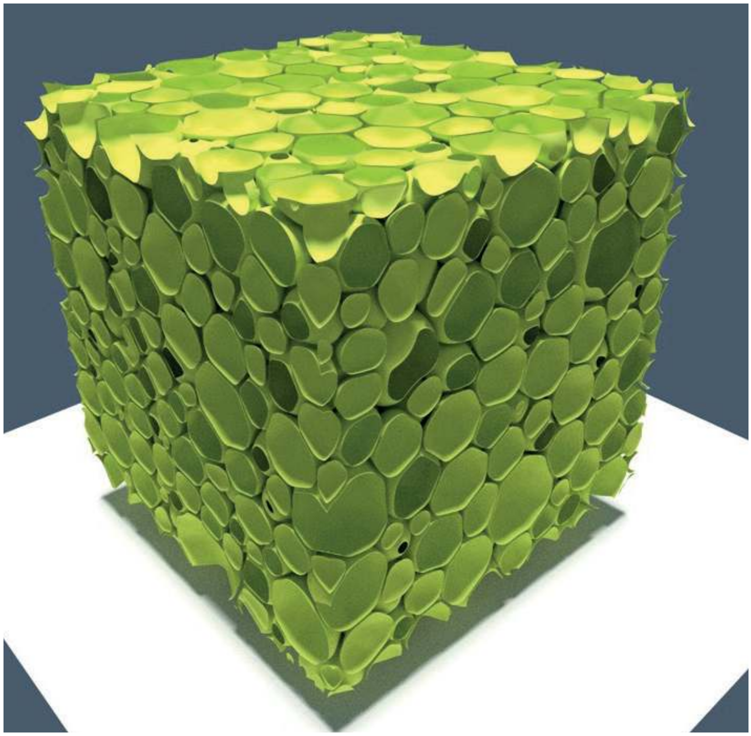
Burgers Program for Fluid Dynamics at the University of Maryland (USA)

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. Each spring semester the Burgers Program holds a Ph.D. 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 2018 a Research Summer School on ‘Topics in Turbulence’ was organized, while one on ‘Topics in Multiphase Flow and Thermal Transport’ is planned for 2019.

Prof.dr. JM Wallace
University of Maryland

HIGHLIGHTS



Unveiling Opaque Flows

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The food processing industry, dredging of rivers, suspension behavior in 3D printer heads and the behavior of blood in our cardiovascular system; they all benefit from a better physical understanding of multiphase flows, as a better understanding will optimize processes and improve predictions.

In our Opaque Flows project, we aim to unveil the physics of particle-laden flows. Next to optical imaging, state-of-the-art techniques such as ultrasound imaging velocimetry (UIV, [1]) and magnetic resonance velocimetry (MRV) are used to study the influence of relatively big, neutrally-buoyant particles in a fluid phase, which is an archetypal suspension. An example of a densely-laden pipe flow, captured with optical imaging can be seen in Figure 1.

Figure 1 : Snapshot of a densely laden pipe flow with a particle concentration of 22.5%, captured with optical imaging.

Ultrasound imaging velocimetry in transitional pipe flow

UIV has been successfully applied to study laminar-turbulent transition behavior of particle laden flows, with concentrations up to 14% [2]. In this study we show that neutrally buoyant particles completely alter the laminar-turbulent transition behavior.

First, time-averaged pressure drop measurements are performed to characterize the transition behavior (i.e. pressure drop as function of Reynolds number) for increasing particle concentration. For low concentrations, particles cause an earlier onset to transition. Where for a single-phase flow a critical Reynolds number of 2000 is found, this critical Reynolds number is decreasing for increasing particle concentration. Eventually, transition occurs at a critical Reynolds number of around 1350 for a particle concentration of 8%. The decreasing critical Reynolds number can be explained by the perturbations, which are introduced by the relatively big particles (1/19 of the pipe diameter).

In these cases with a moderate concentration, a sharp laminar-turbulent transition is found. However, for higher particle concentrations (i.e. higher than 15%), a smooth laminar-turbulent transition is found, with a monotonically decreasing dimensionless pressure drop (friction factor). This can only be explained by the fact that the transition mechanism changes. To investigate this change, UIV was applied to study two different transition curves more extensively, namely for a particle concentration of 1% and 14%, respectively. For a particle concentration of 1%, turbulent puffs are observed in the velocity fields. These turbulent puffs are characteristic for classic ('single-phase') transition behavior. However, for a particle concentration of 14%, turbulent puffs can no longer be observed in the transition region. Instead, continuous radial velocity fluctuations are observed, which are growing in magnitude with increasing Reynolds number.

High frame rate ultrasound imaging velocimetry in turbulent pipe flow

When UIV is operated in plane wave imaging mode, higher imaging rates can be achieved (in the kHz range). This can be leveraged to improve the signal-to-noise ratio, but also to image faster flows (i.e. higher Reynolds numbers). As a proof of principle plane wave imaging UIV is applied to a single phase turbulent flow with a Reynolds number of 44,000 [3].

This high frame rate UIV is applied to turbulent pipe flows. A typical velocity field with a particle concentration of 4%, is shown below. This approach will allow us to continue the investigation of the new particle-induced transition mechanism in a more quantitative way.

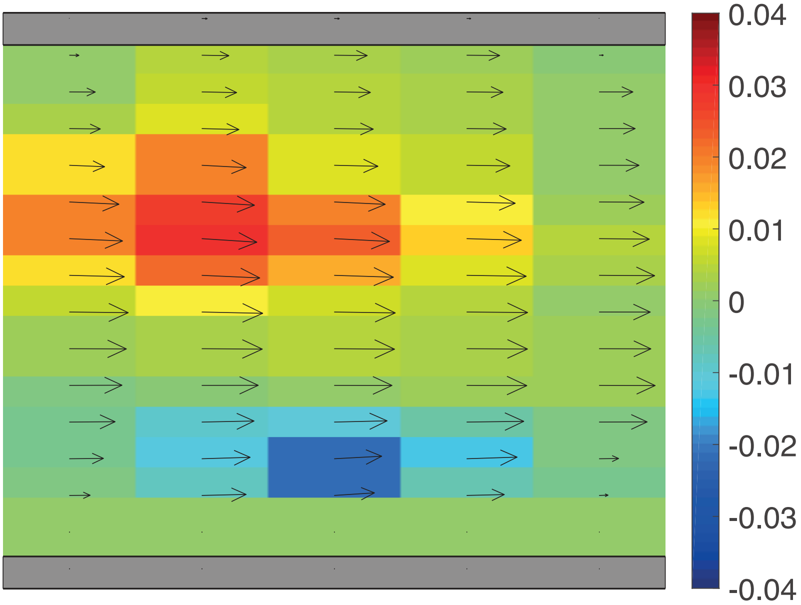

Figure 2 : A snapshot of a turbulent flow with a particle concentration of 4% in a 1-cm diameter pipe, captured with high frame rate UIV. Color represents the radial velocity fluctuations (v'/Uc), where the vectors are the absolute velocities.

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From patient data to clinical predictions – flow in stented aneurysms

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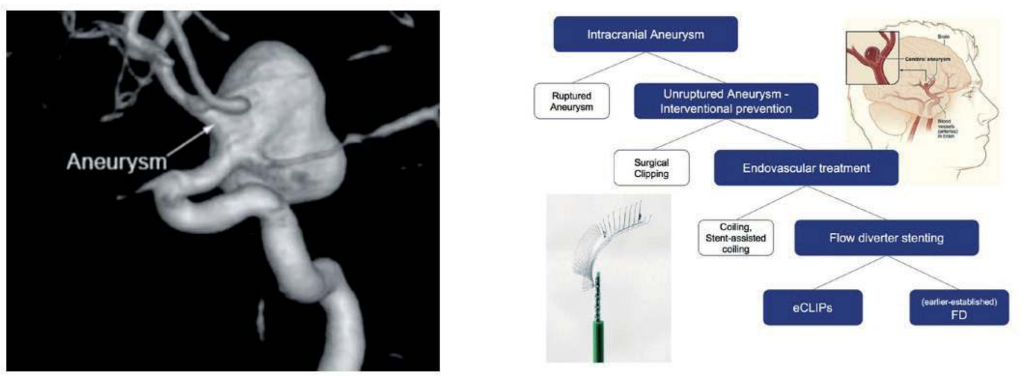
A timely challenge in the simulation of the flow of blood in the human brain is the automated analysis of flow in so-called stented aneurysms. From a fluid-mechanical perspective, the primary aim is to connect raw medical imagery data obtained from a particular patient, via a sequence of steps, to a quantitative numerical prediction of the flow and forces acting on the diseased region. Moreover, the digital model of the diseased region can also be used to quantify possible benefits of the placement of a so-called flow-diverting stent, ahead of any actual surgery – this way, clinical decision support can be provided to clinicians and different treatment options can be compared, all based on validated digital models. Starting from data documenting the local vasculature of the patient, we sketch the workflow that leads to the desired fluid-mechanical analysis – this is illustrated with a specific case-study.

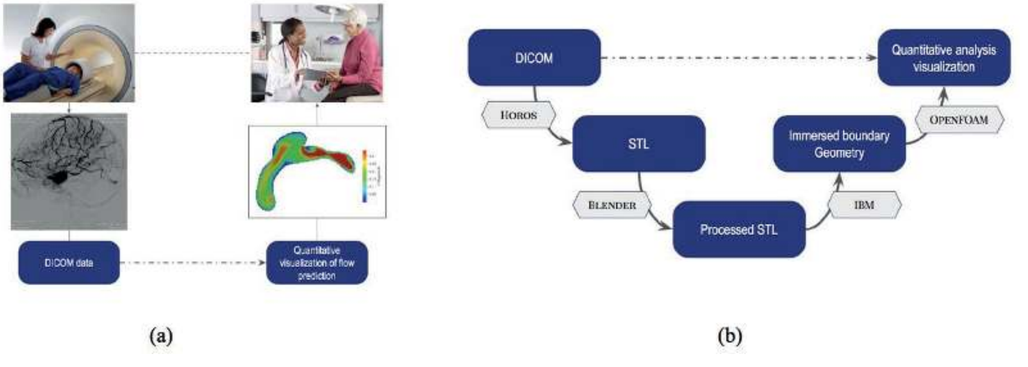


(a) (b)

Figure 1: (a) 3D visualization of an intracranial aneurysm connected to its local vasculature. (b) Overview of treatment options ranging from surgical clipping, to endovascular procedures such as coiling and stenting.

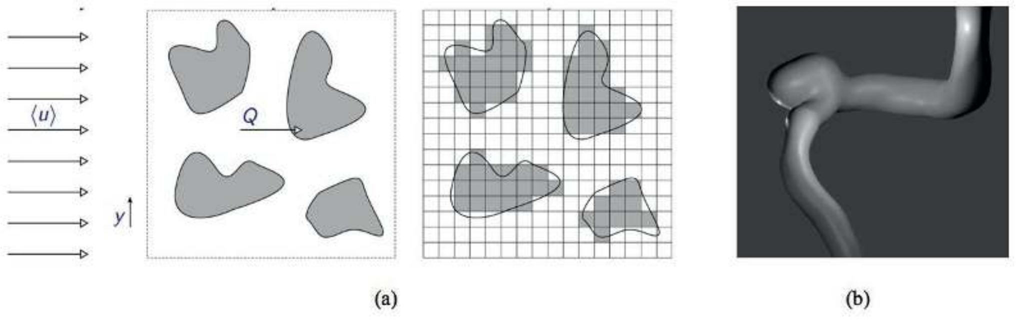
An example of an aneurysm is shown in Figure 1(a), connected to its local vasculature. An extensive widening of the vessel at the location of the aneurysm is clearly visible. Often, such aneurysms do not present any complaints for the patient and go undetected until they rupture, causing serious and often lethal consequences. In Figure 1(b) a sequence of currently available treatment options is presented. These days, surgical clipping is chosen less and less frequently as the surgery itself presents considerable threat to the patient since it involves opening the skull. Instead, endovascular treatment is the preferred option in many cases, distinguishing two principally different philosophies. In ‘coiling’ procedures a flexible wire is inserted in the aneurysm, thereby filling up the aneurysm sac and preventing blood from flowing into the aneurysm, thus reducing the risk of rupture. A more recent option is that of placing a flow-diverting stent across the affected area, in an attempt to re-direct the flow away from the aneurysm, allowing thrombus to form over time, closing the aneurysm sac and preventing possible future rupture. While the principle of these endovascular treatment options is clear, the actual execution of such surgery, the selection of the stent/coil that is appropriate for a particular patient, regarding its size, location and accessibility, and the issue whether or not the treatment will induce long-term closure of the aneurysm, are important open challenges. Fluid-mechanical analysis and computational modeling can provide critical information to support successful treatment.

Figure 2: (a) Clinical treatment challenge – selecting the approach that is best suited for a patient. After recording the specific problem in ‘DICOM’ format, a sequence of steps should provide quantitative flow prediction to support clinical decisions. (b) Suggested workflow connecting the raw DICOM representation to a fluid-mechanical analysis.



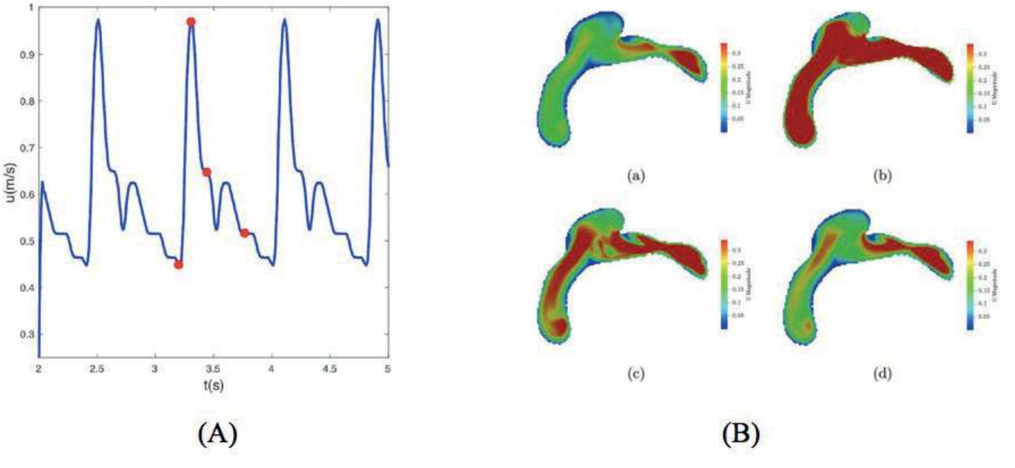
With the impressive growth of medical visualization capabilities in the past decades, it is now possible to generate highly resolved 3D representations of the vasculature in the entire brain, as depicted in Figure 2(a). By appropriately zooming in on the aneurysm and extracting the precise geometry of the patient, a computational model may be envisioned with which the precise pulsatile flow and stresses can be predicted, supporting the selection of suitable treatment options to help cure the patient. The main challenge is to devise a workflow that would connect the DICOM representation of the patient’s aneurysm to a quantitative fluid mechanical analysis. A possible workflow is depicted in Figure 2(b) in which a sequence of steps renders the DICOM representation suitable for an immersed boundary method treatment of the fluid-mechanical problem. Public domain software tools such as ‘Horos’ and ‘Blender’ were used to prepare the geometry as recorded. In-house developed software was applied to translate the surface representation of the aneurysm in the ‘processed STL’ to a volume representation defining the precise flow domain. The immersed boundary method was developed further to yield a robust algorithm and accurate flow predictions – the entire simulation approach was implemented in ‘OpenFOAM’, an open source software platform for flow simulation. In this study an immersed boundary method was adopted [1,2], a ‘volume penalization method’ to be precise, with which even highly complex flow domains can be approximated effectively on a Cartesian grid. The concept is illustrated in Figure 3(a) and an example side-wall aneurysm is depicted in Figure 3(b).

Figure 3: (a) Concept of the immersed boundary method – flow through a complex domain with solid objects denoted in grey, is represented on a Cartesian grid in which a masking function H(x) takes the value ‘1’ in case solid material is located at x and ‘0’ otherwise. (b) An example of a side-wall aneurysm extracted from raw medical data and prepared for numerical simulation – the masking function equals ‘1’ outside this vessel structure and ‘0’ inside.



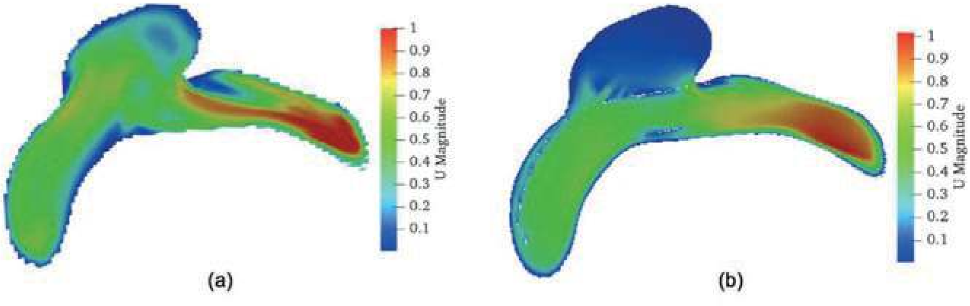
We illustrate the pulsatile flow as predicted by the immersed boundary method applied to incompressible flow in the geometry as shown in Figure 3(b). The characteristic features of a heart beat are shown in Figure 4(A) with a beating frequency slightly higher than one beat per second. The pulsatile flow shown here was driven at the inflow by the registered flow rate as a function of time, using Doppler anemometry. The detailed flow field that develops is depicted in Figure 4(B) at four characteristic stages during the heartbeat. Significant dynamics in the blood flow is clear, even at the low physiological Reynolds number of 250 adopted here. While the flow shows large, rather low velocity structures in Figure 4B(a), a strong jet is seen to form at the time of peak flow (Figure 4B(b)), putting considerable stress on the walls of the aneurysm sac. Later in Figure 4B(c) a patchy flow developed with many, smaller regions of high flow velocity, which calms again toward the end of the heart beat (Figure 4B(d).

Figure 4: (A) Flow velocity during a few heart beats, starting from quiescent flow. (B) Velocity magnitude shown in a plane through the aneurysm sac at four characteristic moments, showing considerable dynamics with periods of a jet forming at high velocity followed by much reduced flow at later times. This process repeats every heartbeat.



The main question of clinical relevance is what the qualitative and quantitative changes in the flow field are, induced by the placement of a stent across the aneurysm. This question can be answered in detail using the computational approach outlined here, fully in the virtual domain, i.e., even before an actual surgery has taken place. A sample of such analysis is shown in Figure 5. The unstented situation in (a) is altered significantly after placement of a flow-diverting stent in (b). The entire aneurysm sac is characterized by almost total absence of any flow inside. This is highly beneficial for the formation of a thrombus over time, behind the delicately braided structure of the flow-diverting stent. The stent is recognizable in the Figure by the rows of white dots, corresponding to cross-sections through the wires of the stent. Such thrombus can effectively stabilize the aneurysm and take away almost all stresses and forces on the aneurysm wall, thereby considerably reducing the chance of rupture.

Figure 5: Effect of placing a flow diverting stent across the side-wall aneurysm as illustrated in Figure 3(b): velocity magnitude at a typical time in (a) the unstented case and (b) the stented case. After placement of the stent, seen by the sequence of white dots in this cross-section, the velocity inside the aneurysm sac is much reduced and a thrombus may form, reducing the risk of rupture.



The workflow sketched in this brief sketch was applied successfully to the (automated) fluid-mechanical analysis of flow in intracranial aneurysms. Detailed, patient-specific medical imagery was used to define the precise flow domain representing the diseased tract of the vasculature. Using an immersed boundary method, implemented in OpenFOAM, the flow and stresses could be predicted in order to understand the risk to the patient. High-resolution simulations could be applied to predict the qualitative and quantitative modification of the flow due to the placement of a flow diverting stent.

Acknowledgement

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Turbulent emulsions

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How can turbulence transform a viscous multi-component fluid into an elastic solid? How do jammed emulsions flow? What is the relation between the stirring protocol and the final emulsion (jammed) state?

Turbulence, the chaotic state of fluid motion, is ubiquitous and responsible for the development of intermittent velocity fluctuations with non-trivial correlations spanning a broad range of length- and time-scales. This complex flow behavior is present even in simple Newtonian fluids, such as water, which are characterized by a linear relation between the viscous stresses, arising from the flow, and an applied shear.

However, many ordinary fluids such as toothpaste, ketchup and mayonnaise, are non-Newtonian. These fluids are characterized by an internal microscopic composition responsible for the emergence of a non-linear relationship between viscous stresses and the locally applied shear.

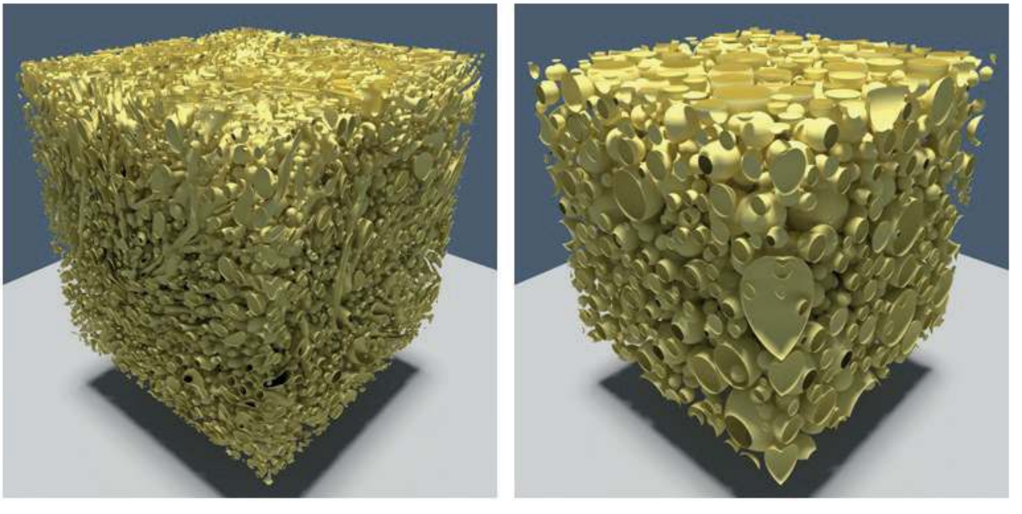

Figure 1: How does a complex fluid flow under turbulence? Current computing capabilities allow to study the dynamics of complex fluids in complex flows. This requires accurately modeling and resolving both the small-scale physics (e.g. surface tension, disjoining pressure) as well as the large-scale turbulence. The dynamics of the formation of a jammed state in a stabilized emulsion, such as oil in water systems, can be investigated e.g. via multicomponent Lattice Boltzmann methods capable of modeling fluid-fluid interfaces with surface tension and disjoining pressure. (Left panel) Under the influence of a turbulent stirring, oil droplets constantly undergo coalescence and breakup: droplets shapes are visibly non-spherical. (Right panel) After that the turbulent stirring is switched off the emulsion achieves a metastable equilibrium: in this case spherical droplets corresponding to a non-jammed state (volume fraction of dispersed phase ~40%).

Despite the weakness of microscopic forces, these can interplay with turbulent stresses in a non-trivial way and, as a consequence, (turbulent) non-Newtonian fluids can display a remarkably rich phenomenology. One well known example is the turbulent drag reduction due to the addition of a small amount of polymers: even few parts per million in weight of polymer can reduce turbulent drag by up to 80% [1].

One of the most fascinating and complex aspects of turbulence in complex fluids is the tight interplay between macroscopic turbulent fluctuations and small-scale internal structure. Indeed, while the presence of small-scale forces can considerably alter the large-scale flow, this same large-scale flow does, in turn, modify the microscopic structure of the complex fluid. For example, polymeric stresses influence turbulent drag while turbulent stresses stretch polymers. Similarly, turbulent stresses break-up droplets, while the presence of a dispersed droplet phase influences the macroscopic (turbulent) flow itself.

As a concrete example of turbulence in complex flow we focus on turbulent emulsions, i.e. turbulence in fluids made of two (or possibly more) immiscible fluid components. When subject to turbulence such fluids will form droplets, giving rise to turbulent emulsions. The physical properties controlling the dynamics of such emulsions include the densities and the viscosities of the two fluids, the surface tensions and the Reynolds number of the flow. Another key ingredient is the volume fraction of the two fluid components. Think of a layer of oil on top of water: when stirring the fluids sufficiently strong the (flat) interface between oil and water will be broken and droplets will be formed. In a turbulent flow, the droplets size is controlled by inertial effects, droplets deform and break under the influence of turbulent velocity fluctuations. The relative importance of turbulent velocity fluctuations with respect to surface tension forces is measured by the dimensionless Weber number. Combining Kolmogorov K41 theory of turbulence with surface tension energy estimate one can readily compute a critical droplet diameter (usually named after Kolmogorov and Hinze): droplets larger than this critical diameter will break up due to turbulent stresses, while smaller droplets are stable, except for eventual coalescence events. This idealized picture is actually just a small part of the story. In fact, due to the strong intermittency of turbulent fluctuations the distribution of droplet radii is rather polydisperse around the critical Hinze diameter (Perlekar et al. [2]). When the two fluids have the same physical properties, it is energetically favorable to form droplets of the minority phase dispersed into the majority phase and not vice-versa, in this way the energy associated to surface tension is minimized. It is interesting to notice that the physical arguments leading to the Kolmogorov-Hinze critical droplet diameter apply also in the case of dense emulsions (e.g. 50%-50%) where no droplets are present but rather a bi-continuous (turbulent) morphology occurs. Turbulence can arrest spinodal decompositions maintaining the system in a statistically stationary conditions with turbulence constantly breaking structures larger than the Hinze length-scale (Perlekar et al. [3]) . However, all these emulsions are unstable and, when the turbulent stirring is switched off, the two fluid components invariably separate via spinodal decomposition or via droplets coalescence, according to the volume fractions.

The physical picture is however very different for stabilized emulsions, e.g. via the addition of agents capable of inducing a disjoining pressure between droplets (e.g. surfactants). In this case switching off turbulence will lead to a metastable state characterized by a dispersed droplet phase that will, eventually and extremely slowly, destabilize the emulsion due to diffusion (Ostwald ripening).

Many common food products, such as mayonnaise, fall in this category and display a remarkable phenomenology ranging from that of a viscous fluid to that of an elastic solid. Stabilized emulsions, additionally, can display much of the rich phenomenology typically associated with soft glassy systems, including aging, metastability, yield stress, thixotropy, etc.

The presence of a disjoining pressure between droplets induces an elasticity in the system. In order to be able to break up droplets one needs to overcome the energy barrier associated to surface tensions, while, in order to let two droplets coalesce, one need to push them strongly enough against each other in order to win the disjoining pressure. Today's computer and numerical models allow to incorporate the physics associated to these small-scale forces, as well as to resolve systems large enough to allow capturing the macroscopic rheology and turbulent dynamics.

As much as in the kitchen, in order to achieve large volume fraction of the dispersed droplet phase (i.e. larger than 50%) it is necessary to adiabatically increase its volume fraction. This allows to maintain the system in a local minimum of the free energy, escaping more (stable) minima corresponding to the inverted emulsion (where the minority phase is dispersed). Strong forcing, too rapid increase or too large values of the dispersed phase volume fraction will however invariably lead to the so-called catastrophic phase inversion (a sudden non-equilibrium process through which the emulsion rapidly destabilize and phases invert).

How does phase inversion occur? How do dense stabilized emulsions flow? What is the nature of turbulence in such complex fluids? These fascinating questions are still in search for complete answers. High performance computers, new theoretical insights and innovative experimental techniques will be key in this endeavor.

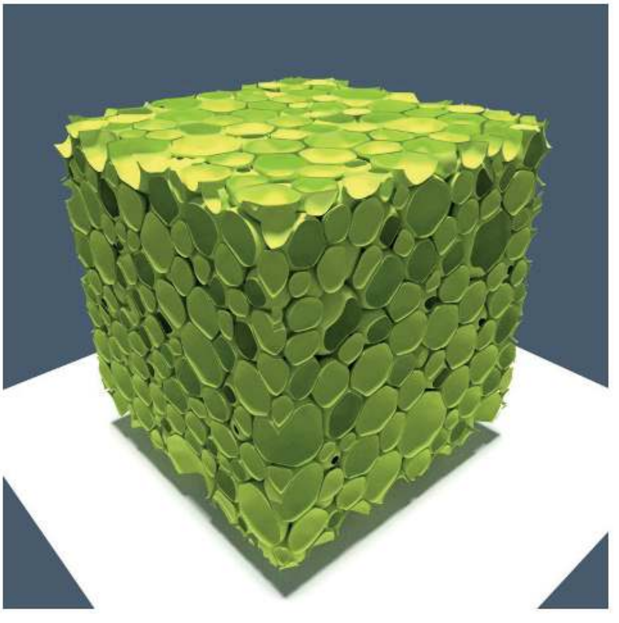

Figure 2: In this case a jammed state was produced by adiabatically increasing the volume fraction of the dispersed phase. Droplets are now clearly non spherical and, despite pushing against each other, they do not coalesce thanks to the action of a sufficiently strong disjoining pressure (volume fraction of the dispersed phase ~75%).

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Symmetry-reversals in chiral active matter

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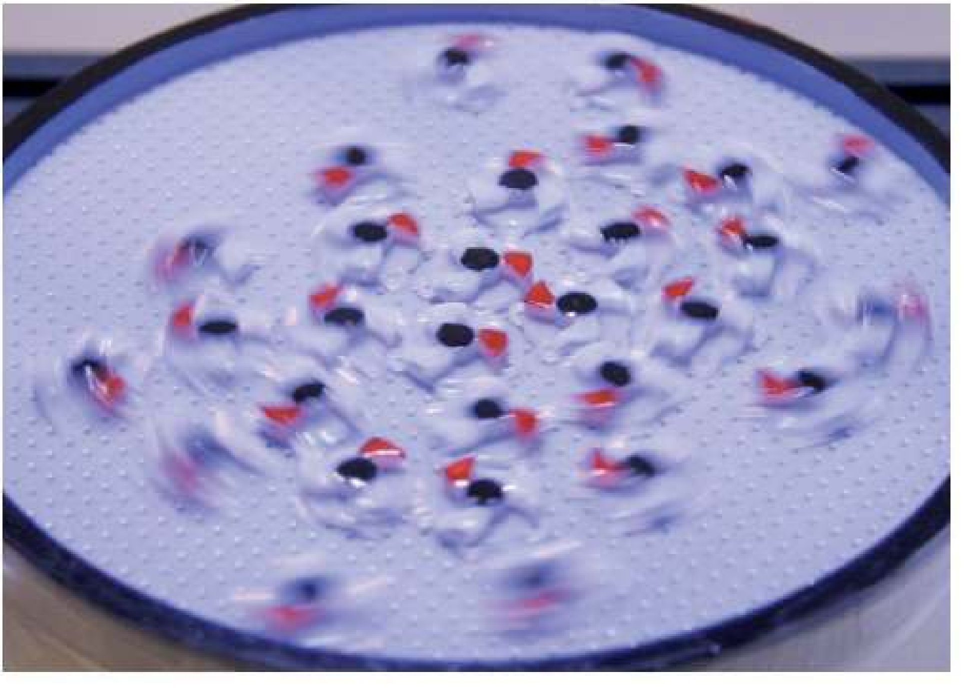
Visiting the Aquarium in Monterey, California one can see splendid examples of fluid dynamics in action: the high Reynolds number flows that surround you in the Splash Pool, or the fluid-structure interactions that allow jellyfish to propel themselves in subtle and elegant ways. Imagine the fluid dynamics of oxygen absorbing gills where an intricate balance between diffusion and flow speed is maintained. One amazing fluid dynamics aspect can also be viewed, even though it is not traditionally included in fluid dynamics textbooks. The "Open Sea" exhibit displays a school of fish that continuously swirls as a fluid in a fluid, sometimes quickly responding to external stimuli (sharks) while also slowly setting its own pace, wandering like a ghostly cloud through the entire tank. Amazing videos can be watched live [2], for a still see Figure 1.

Figure 1: Still from webcam watching the Open Sea exhibition in the Monterey Bay Aquarium

The collective behavior of schools of fish, but also flocks of birds, swarms of bacteria and crowds of people has gained substantial attention in the last two decades, as there is surprising and deep physics in these systems, often referred to as “active materials”. These materials are composed of components with some source of internal energy that propels them. Computer modelling of flocking dates back to Reynolds [3], but one of the earliest insights of statistical mechanics hiding in the collective behavior of these active materials is the modelling by Vicsek et al. [4]. They showed that even the simplest model system of an active material shows a phase transition between collective aligned dynamics and disordered motion. In the same year, the Toner-Tu equation [5] was developed as a Navier-Stokes equivalent for such “fluids”. Theoreticians flocked to the field and have amassed a tremendous understanding of active materials and their rich phase behavior [6, 7].

Experimental studies of the behavior of active matter systems can be done in an aquarium on live animals; one can even do oscillatory rheology on a swarm of small flies [8] that turn out to display negative storage moduli associated with inertia. However, living systems can be challenging to get into a steady state. Living systems do not allow for easy adaptation to test the microscopic ingredients that geneate collective dynamics. The search for model systems has produced systems at various lengthscales: cars in a circle [9], robots that can be programmed [10] and even self propelling droplets [11] and colloidal systems [12] are being explored as ways to study active materials in the lab. It is evident that even these systems present their own level of complexity and inadaptability. We therefore resorted [1] to a system of simple 3D printed, “self-propelling” particles or disks levitated by a layer of forced air; see Figure 2. The particles are not truly self-propelling: they receive their energy from the stream of air they are floating on. The particles are designed such that a small part of the supporting air gives them a torque via their asymmetric “exhausts”. The torque makes the particles spin, while small fluctuations from the turbulent air surrounding the particles makes them bounce into each other. We studied the collective dynamics of a collection of such floating, spinning and bouncing disks. This simple system allows one to answer questions about how the emergent behavior of the disks depends on the way the particles interact with each other.

Figure 2: Motion blur visible in the rotating spinners from [1]. The arena measures about 13cm in diameter. The spinners are marked with different colors to facilitate tracking. Airflow through the small holes in the base levitates the spinners and drives their rotation.



The twist here is that the torque pushes energy into the rotational degree of freedom of every particle, while the particle collisions transfer this energy to the two translational degrees of freedom. We showed that the translational degrees of freedom have almost perfect Maxwell-Boltzmann distributions, even though the system is highly dissipative. An almost identical spinner system published back-to-back in the same Soft Matter volume 14 (2018) did not show such ideal gas behavior. We believe that the coupled set of Langevin equations that determine the microscopics of these active spinners [13] have the answer: the coupling between the driving torque and translational degrees of freedom depend on four factors: the moments of inertia and the transfer of energy between particles and among their degrees of freedom. The former are different in the two studies; the latter are set by the interparticle friction. The ratio of these prefactors decides what kind of collision statistics emerges.

When one packs more "spinners" per unit volume, the gas turns into a solid, slowing all dynamics. Yet we found that there is a less trivial way the volume fraction of particles controls the collective behavior of the spinners. Friction also matters here. We find that the spinner swarm swirls counterclockwise when few particles are bouncing around, while the swarm spins clockwise when density increases. We attribute this to the asymmetry in scattering dynamics of particles with an intrinsic spin. Note that all particles spin counterclockwise. A left-sided collision essentially slows down a particle, where a right collision accelerates a particle. With more particles in the arena, the ratio of left versus right sided collisions changes, changing direction in swarming. Indeed, enhancing friction among the particles or between particles gives the ability to control the swarming to great extent.

Active materials display all the beauty and depth that traditional fluid dynamics systems show, while also presenting a whole new set of challenges and opportunities. In the arena of active materials, there is ample space for experimental model system analysis. We have found that these model systems give new scientific insights and are even simple enough to serve as teaching material for advanced laboratory classes.

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Modelling statistical wave interference over variable bathymetry and currents

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SWAN ([1]) is a state-of-the-art numerical model to predict the generation and subsequent evolution of wind-generated waves in the coastal environment. The model is based on a stochastic description of the wave field represented by the frequency-directional spectrum of the wave energy subject to changes in the propagation as well as non-linear interactions, wind forcing and dissipation. Engineers, consultants and academics use the model to predict the wave transformation over complex bathymetry and flow fields yielding insight into the nearshore conditions that are relevant for the computation of for instance harbour access, sediment transport and design storm conditions for coastal safety. The stochastic description assumes that the wave field is 1) quasi-homogeneous and 2) Gaussian, which implies that the wave field is completely defined by the variance only. As a result, a fundamental limitation of the model is that it does not predict constructive and destructive interference that comes with waves that are phase coupled. These interference patterns come about when waves interact with rapidly varying bathymetry and flow fields or in the presence of quay walls as well as harbour access channels. In these cases both refraction and diffraction are important physical processes that determine the locally varying wave height. Furthermore, the presence of these kinds of features may not only affect the near field but also the far field due to wave focusing and defocusing, resulting in alongshore varying wave conditions along the coast and subsequent design conditions.

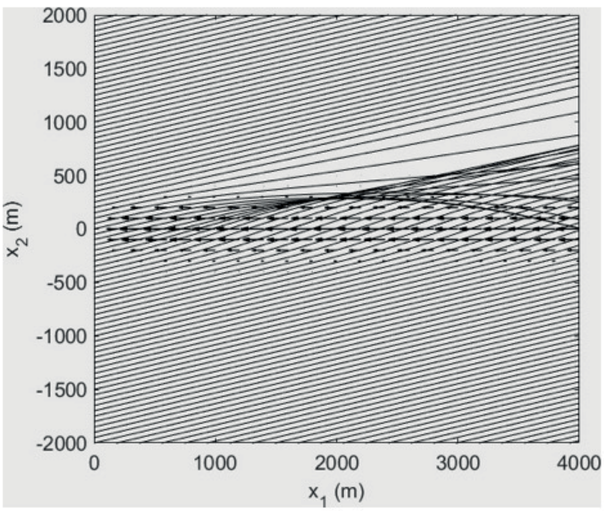

Figure 1: Wave rays over tidal jet. The rays are indicated by solid curves, and arrows mark the ambient current.

To account for interference effects the standard transport equation for spectral wave energy that is used in SWAN is modified, taking into account the evolution of the correlation of different wave components when interacting with bathymetric variability ([2], [3]) as well as current variability ([4]). Inclusion of both bathymetric and flow variability is of key importance in the prediction of wave transformation in for instance tidal basins where ebb and flood channels intersect shallow shoals. To test the performance of the new model, which is referred to as the QCM (quasi-coherent model), the wave transformation of a narrow banded wave field over a narrow tidal jet is examined. The example is formulated over a spatial domain of 4000 [m] × 4000 [m] and a constant depth of 10 [m]. Waves enter the domain along the left boundary, at x1= 0. In this example a symmetric Gaussian shape is selected to describe the initial wave spectrum over the wavenumber space. The parameters governing the initial spectrum are the peak wavenumber (or the corresponding peak wave period, T0, and direction, θ0), the standard-deviation, Sd, and the significant wave height, Hs0. These parameters are given as follows: T0 = 20 [s], θ0 = 15 [deg], Sd = 0.001 [1/m] and Hs0 = 1 [m], respectively.

The evolution of the wave field in this wave-current interaction problem is described in Figure 1. Arrows indicate the tidal jet, and the evolution pattern of the wave field is represented by the wave-rays at the peak wave number represented by the solid lines. Over areas where rays converge and form focal zones, higher wave heights are expected. It is clearly shown how the waves refract and form a focusing zone close to x1 = 2000 [m]. Beyond zones of ray crossing (x1 > 2000 [m]), interference structures emerge.

The evolution of the wave field shown in Figure 1 will assist in interpreting the main results of the example shown in Figure 2. These results present a comparison between three different models in terms of the spatial distribution of the significant wave height, Hs. The left panel shows the results of the new model (the QCM). These results are verified through a comparison to the results due to REF/DIF1 model ([5]), which provides a numerical solution of the parabolic approximation of the well-known mild-slope equation (e.g., [6]). Since REF/DIF1 provides the results due to an initial monochromatic wave condition, the final results due to the complete initial spectrum is constructed through a superposition of the individual ones as detailed in [7]. Ultimately, in order to demonstrate the statistical contribution of the interference terms, the results due to QCM are also compared to the results of the present SWAN model ([1]).

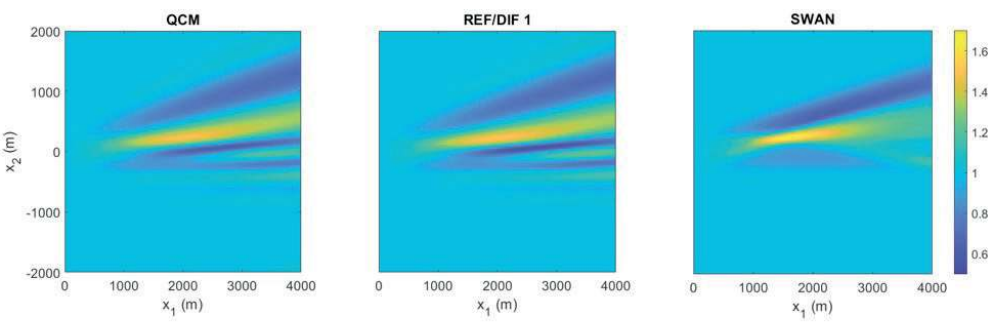

Figure 2: The distribution of the significant wave height due to wave interaction with a tidal jet. Results are due to QCM (left), REF/DIF 1 (centre) and SWAN (right). Colour scale in m.

The physical pattern described by the rays in Figure 1 is also reflected statistically in the results of Figure 2. While the results of QCM and REF/DIF1 agree quite well and share a similar evolution pattern, the results due to SWAN increasingly deviate beyond the crossing zone. As explained earlier, the transport equation employed by SWAN disregards the generation of cross-correlations (correlations of different wave components), which transport the information about wave interference. The QCM, on the other hand, does account for this information, and therefore, in regions where the statistical contribution of wave interference is significant, the discrepancies between the results of QCM and SWAN will be pronounced.

The effect of wave interferences can contribute significantly for cases where the variation scale of the medium is at the same order or smaller than the scale of the correlation length ([2], [3]). Specifically, as demonstrated in [4], in order to obtain a statistical signature of wave interferences, correlation should emerge between the incoming field and the interference structure it forms, with the dominance of the interference effect determined by the correlation value itself.

In the example considered here, the value assigned to Sd corresponds to a correlation length of a few kilometers. As a result, a strong correlation emerges between the incoming wave field and the interference pattern it forms. This leads to the generation of cross-correlation terms which are transported together with the variance terms, and eventually, altering dramatically the statistics of the scattered field, as appeared through the comparison of QCM and SWAN in Figure 2 in terms of Hs.

As can be seen in Figure 2, the contribution of the interference terms to the distribution of Hs is not confined to the focusing areas, but spreads over the whole domain and beyond. It is therefore concluded that for regions involving rapid variability in the medium (e.g., coastal regions or oceanic regions which tend to contain submesoscale currents), consideration of the statistical information of wave interference might be crucial for many applications, such as, wave-induced circulation and transport process in coastal regions or for prediction of extreme elevations in the open ocean. To account for this, SWAN will be extended with the QCM method, thus allowing for the description of the evolution of a quasi-coherent wave field subject to wind forcing, non-linear interaction and wave dissipation.

References

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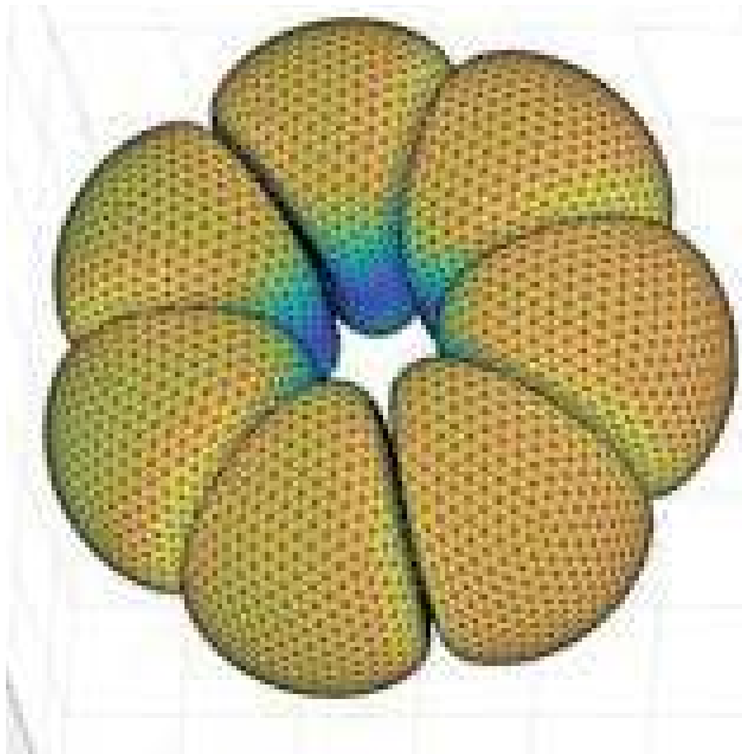
6. Dingemans, M. W. (1997) Water wave propagation over uneven bottoms, volume 13. World Scientific, Singapore.
7. Chawla, A., Özkan-Haller, H. T., and Kirby, J. T. (1998) Spectral model for wave transformation and breaking over irregular bathymetry. J. Waterw. Port Coastal Ocean Eng. 124, 189–198.

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)

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

Fluid mechanics of cellular membranes and their ultrastructures

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. G.J. Amador, D. van Dijk, M.E. Aubin-Tam, D.S.W. Tam L20.00002 Fluid mechanics at the cellular membrane, The 71st Annual Meeting of the American Physical Society's Division of Fluid Dynamics (DFD), Georgia World Congress Center in Atlanta, Georgia, November 18-20, 2018.

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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Heavy Fuel-oil combustion in a HiTAC boiler

Project leaders
MJ Tummers, DJEM Roekaerts
Research theme
Complex dynamics of fluids
Participants
H.R.C. Rodrigues
Cooperations
T.H. van der Meer (U Twente)
S. Zhu (U Twente)
Funded by
Technology Foundation STW
(CCC program), Stork Thermeq, Shell
Funded %

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

Start of the project
2010
Information
M.J. Tummers
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www.cleancombustionconcepts.nl

Project Aim

This project concerns the extension of the application of High Temperature Air Combustion (HiTAC) to heavy-oil combustion processes in a boiler and is a joint project of University Twente and Delft University of Technology. To generate the knowledge needed to be able to develop and design such a boiler, experimental and computational investigations will be made of turbulent spray flames under HiTAC conditions. At TU Delft, an experimental study of spray flames of light fuel oil burning in a co-flow of hot air diluted with combustion products will provide detailed knowledge of the relations between atomization process, ignition, entrainment and burnout.

Progress

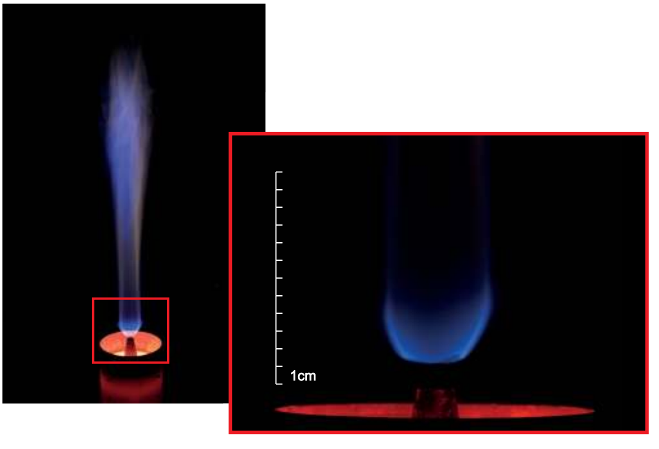
In the published article we numerically investigate the Delft Spray-in-Hot-Coflow (DSHC) using ethanol in high temperature diluted combustion air, and extend it to more co-flow conditions. We employ different temperatures and oxygen concentrations of the co-flow in order to dilute the oxidizer/fuel before it reacts with the fuel/ oxidizer. The results indicate that the decreased peak temperature in many HiTAC applications with high temperature combustion air is mainly due to the reduced oxygen concentration by entraining flue gas. A low oxygen concentration slows the evaporation process of droplets. It results in an enlarged combustion zone, a lowered peak temperature and minor NOX emission. However, decreasing the oxygen concentration may lead to problems of cracking, soot formation and flame extinction, especially for heavy oils. The optimization needs to be carried out based on the analysis of a specific fuel in order to create a HiTAC-like condition. Based on the results of the current study, the 1500 K and 6%vol oxygen concentration case is considered as a HiTAC condition.

Dissertations

-

Scientific Publications

1. Shanglong Zhu; Artur Pozarlik; Dirk Roekaerts; Hugo C Rodrigues; Theo van der Meer. Numerical investigation towards HiTAC conditions in laboratory-scale ethanol spray combustion, Fuel, 211 (2018) 375-389. http://dx.doi.org/10.1016/j.fuel.2017.09.002.



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 will be used for simulations of turbulent hydrothermal flames.

Dissertations

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Scientific Publications

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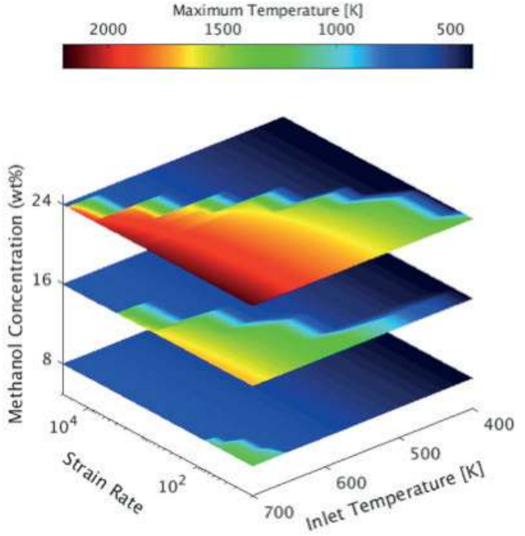

Project leaders

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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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
06 52096201
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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 focussed on the finalization of a new numerical scheme to track pigs and by-pass pigs in single-phase and twophase flow pipe flow. The results of this serve as input to the last technical chapter of the PhD thesis. Furthermore, a Master student (Mengting Jiang) has carried out a CFD study with Fluent to simulate ball pigs, which basically is a ball with a diameter smaller than the pipe that is transported with the main flow along the pipeline. Variations were made with respect to Reynolds number, location of the centre of the ball, and the ratio of the ball and pipe diameter.

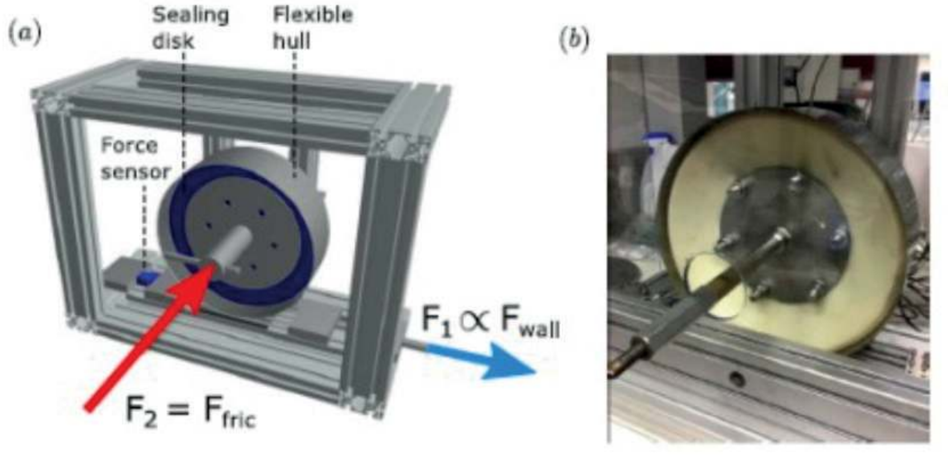
Dissertations

-

Scientific Publications

1. Hendrix, M.H.W., IJsseldijk, H.P., Breugem, W.P., Henkes, R.A.W.M., Experiments and modelling of by-pass pigging under low-pressure conditions, J. Process Control 71, 1-13, 2018.
2. Hendrix, M.H.W., Graafland, C.M., Van Ostayen, R.A.J., Frictional forces for disc-type pigging of pipelines, J. Petroleum Science and Eng. 171, 905-918, 2018.

Pull tests to measure normal and frictional forces for a pig disk in a pipe



Liquid accumulation in nearly horizontal pipelines with multiphase flow at low gas production rates

Project Aim

The project aims at improving the basic understanding of a key aspect of multiphase flow in pipelines, which is the liquid accumulation, with wave formation and slug flow, in systems under low flow rates. The experimental lab configuration consists of a horizontal pipe with a flow of water and air. The turbulence levels and the waves at the liquid-gas interface are measured with Particle-image Velocimetry. The experimental data will be used for the validation of pipe flow models of various types (1D engineering models, and 3D RANS and LES models).

Progress

In 2018 the extension of the PIV facility to enable fully time resolved measurements has been completed. No new experiments were carried out yet. Instead, the focus was on the numerical modelling of the pipe flow. Using a two-fluid model, the transition from stratified flow to the roll-wave regime has been simulated, the results of which were presented at the Multiphase Flow conference. Furthermore, a publication was realized on the CFD modelling of the stratified liquid-gas flow. The PIV data as obtained earlier in this project were used for the model validation, as well as other data sets that were available in the literature.

Dissertations

-

Scientific Publications

1. Chinello, G., Ayati, A.A., McGlinchey, D., Ooms, G., Henkes, R.A.W.M., Comparison of CFD simulations and experiments for stratified air-water flows in pipes, J. Fluids Engineering 141, 051302-1, 2018.
2. Sanderse, B., Misra, S., Dubinkina, S., Henkes, R.A.W.M., Oosterlee, C.W., Numerical simulation of roll waves in pipelines using the two-fluid model, Proc. 11th North American Conference on Multiphase Flow, BHR Group, pp. 373-386, 2018.

Project leaders

R.A.W.M. Henkes, M.T. Tummers

Research theme

Complex dynamics of fluids

Participants

R.A.W.M. Henkes, M.T. Tummers

Cooperations

-

Funded by

-

Funded %

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

Start of the project

2017

Information

R.A.W.M. Henkes
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Fundamentals of the creation of foam for the transport of liquid and gas in pipeline systems

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
2016
Information
R.A.W.M. Henkes
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Project Aim

This project is a combined experimental/modeling study on the performance of surfactants, creating a foam, for the deliquification of gas wells as used in the gas and oil industry. Foam can possibly also be used as a means to mitigate slugs in the multiphase flow transport in flowline-riser systems. The study includes flow experiments using a 12 m, 5 cm diameter facility in the Process & Energy lab. The specific project aims are:

1. Investigate how the foamer performance at different conditions in a desktop scale setup relates to their performance at continuous and batch injection in a mid-scale setup, and in field cases.
2. Develop and validate a model for the foam-based multiphase flow transport.
3. Determine how the foamer performance in flow transport is related to their physicochemical foamer properties.

Progress

The flow facility, which was previously located in the Kramer lab, is now in operation again in the Process & Energy lab. In collaboration with TNO, who carried out desktop experiments, the midscale experiments in the flow loop were performed for different types of surfactants, both with fresh and salt water. Furthermore, tests were also carried out for thermally aged surfactants. Pressure drop curves and liquid and foam holdup curves were obtained for a range of superficial gas velocities, with a fixed value of the superficial liquid velocity. The performance in the flow loop was compared with the foam characterization in the desktop experiments. A study report was prepared.

Dissertations

-

Scientific Publications

1. Van Nimwegen, A.T., Portela, L.M., Henkes, R.A.W.M., Modelling of upwards gas-liquid annular and churn flow with surfactants in vertical pipes, Int. J. Multiphase Flow 105, pp. 1-14, 2018.
2. E.J. Pronk, Ellepola, J.H., Henkes, R.A.W.M., The effect of a surfactant on slugs in a flowline-riser system, Proc. 11th North American Conference on Multiphase Flow, BHR Group, pp. 85-94, 2018.

Small-scale and midscale foam experimemts

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 alonmg 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

In 2018, a Master student (Kangjun Lia) has been working on this project. He has carried out CFD simulations with the OpenFoam code for the flow at various conditions (total flow rate, watercut, and oil viscosity). He found that it is crucial to apply the proper numerical scheme at the interface to prevent the spurious dispersion of oil as droplets in the water layer. If separated oil and water phases are maintained in the numerical solution, a good agreement is found with the experimental values for the pressure drop as obtained earlier in our lab. In Q4 of 2018 a new PhD student, Haoyu Li, started to work in this project.

DISSERTATIONS

-

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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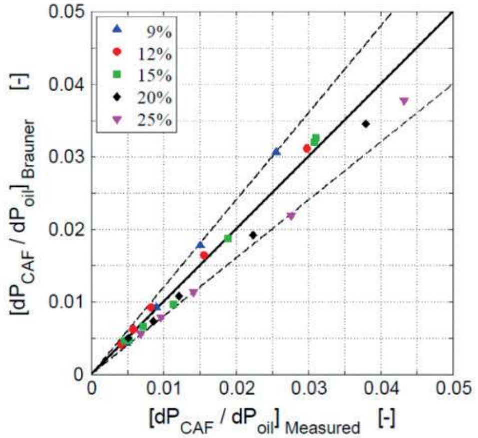
06 52096201
R.A.W.M.Henkes@tudelft.nl

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, January 2018.

Predicted scaled pressure drop (using simplified model) versus the measured value for various watercuts. The solid line denotes perfect agreement, and the dashed lines denote the 20% accuracy interval.



PROJECT LEADERS
Daniel Tam
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Abel-John Buchner, Parviz Ghoddoosi Dehnavi, Junaid Mehmood, Ahmad Reza Motezakker
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

- 3D tracking data has been acquired for the hydrodynamic “puller” species C. Reinhardtii, and another, “pusher” based organism A. Carterae.
- Checks for gravitaxis and phototaxis have been performed, and unwanted background flows rectified.
- Evidence regarding the hydrodynamic interaction with wall boundaries and its effect on cell trajectories and population density distribution has been deduced.
- The effect of viscoelasticity and shear-thinning in the suspending medium is being investigated.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Abel-John Buchner, Koen Muller, Da Wei, Daniel Tam (2018) Interactions of free-swimming motile cells with surfaces. 71st Annual Meeting of the APS Division of Fluid Dynamics, Atlanta, Georgia, 18 – 20 November.
2. Abel-John Buchner, Koen Muller, Daniel Tam (2018) Tracking three-dimensional surface interactions in motile cells (poster). Microbes2018, Gif-sur-Yvette, France, 28 August – 06 September.

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 written a draft for the measurement technique. We are further improving a robust tracking method to track individual fish that is being extended from previous work.

Dissertations

-

Scientific Publications

1. K. Muller, D.S.W. Tam, J. Westerweel, Multiple-View Camera Calibration for Large Scenes with Limited Spatial Access at the Rotterdam Zoo, Proceedings of the 19th International Symposium on the Application of Laser and Imaging Techniques to Fluid Mechanics, page 1818 - 1822-LISBON | PORTUGAL -JULY 16 – 19, 2018.
2. Dutch Biophysics - Three-dimensional Tracking of Fish in a Large School - K. Muller, A-J. Buchner, C.K. Hemelrijk, J. Westerweel, D.S.W. Tam.
3. K. Muller, J. Westerweel, Charlotte Hemelrijk, D.S.W. Tam F22.00009 Three-dimensional Tracking of Fish inside a Large School at the Rotterdam Zoo, The 71st Annual Meeting of the American Physical Society's Division of Fluid Dynamics (DFD), Georgia World Congress Center in Atlanta, Georgia, November 18-20, 2018.

Project leaders

Daniel Tam, 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

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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
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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

In the final year of the project the computational model for simulation of turbulent flameless combustion in furnaces was further developed and the PhD Thesis presenting the experimental and computational results was written.
In the model the effect of dilution is taken into account in FGM tabulated chemistry using counterflow diffusion flames of fuel and diluted air (DAFGM). The dilution gives an extra controlling parameter in addition to mixture fraction, progress variable and enthalpy loss. This approach has been included in an assumed PDF RANS turbulent combustion and radiation model in OpenFOAM-2.3.1 and was applied to natural gas combustion in the lab-scale furnace with recuperative FLOX® burner, thermal power 9 kW at equivalence ratio 0.7, 0.8 and 0.9. The impact of progress variable PDF assumptions and quality of predictions of one-point temperature statistics was investigated. In conclusion, the project has provided fundamental scientific knowledge and insight on the nature of flameless combustion. The experimental results not only show the combustion characteristics of flameless combustion in a furnace, but also provide a database for numerical simulation validation.

DISSERTATIONS

1. X. Huang, Measurements and Model Development for Flameless Combustion in a lab-scale furnace. Ph. D. Thesis, Delft University of Technology. 2018.

SCIENTIFIC PUBLICATIONS

-

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 reviewed available statistics on metal dust explosions and focused on the specific explosion hazards of aluminum finishing operations. The analysis of seven case studies shows that the proper design, monitoring and maintenance of dust collection systems are particularly important. Furthermore, the isolation of deflagrations occurring in dust collection systems, as well as good housekeeping practices in buildings, are critical safeguards to avoid the occurrence of catastrophic secondary explosions. 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.

Dissertations

-

Scientific Publications

1. Taveau, J., Hochgreb, S., Lemkowitz, S., & Roekaerts, D., Explosion hazards of aluminum finishing operations, Journal of Loss Prevention in the Process Industries 51 (2018) 84-93. DOI: 10.1016/j.jlp.2017.11.011

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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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. We have presented several novel concepts. First, we proposed linear relations between fluctuations in radiative quantities (emission, incident radiation and absorption coefficient) and temperature fluctuations, where the coefficients of proportionality are solely functions of averaged quantities. The validity of these linear relations was supported by an excellent agreement with DNS for all considered gray gas cases. Using these linear relations we showed that gray gas TRI can be fully characterized without accounting for fluctuations in absorption coefficient. Second, we investigated TRI for non-gray gases and extended the developed concepts to account for the spectrally varying absorption coefficient. In particular, we used the derived linear relations to show that the influence of a wavelength dependent absorption coefficient manifests itself in an increase of the “effective” optical thickness of the flow. A new turbulence based spectral averaging is proposed that results in a mean absorption coefficient, which uniquely characterizes TRI of non-gray participating media. Finally, we applied our models to estimate classical TRI (impact of fluctuations in radiative quantities on the mean radiative source) observing a perfect agreement with DNS.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. S. Silvestri, A. Patel, D.J.E.M. Roekaerts and R. Pecnik. Turbulence radiation interaction in channel flow with various optical depths. Journal of Fluid Mechanics, J. Fluid Mech. (2018), vol. 834, pp. 359–384. http://dx.doi.org/10.1017/jfm.2017.738.
2. S. Silvestri, D.J.E.M. Roekaerts, and R. Pecnik. Direct numerical simulation of turbulence radiation interaction interactions in non-grey media. In:Proceedings of Eurotherm Seminar 110 – Computational Thermal Radiation in Participating Media – VI, April 11-13, 2018, Cascais, Portugal.
3. S. Silvestri and R. Pecnik. A fast GPU Monte Carlo Radiative Heat Transfer Implementation for Coupling with Direct Numerical Simulation. eprint arXiv: 1810.00188.

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.

Dynamics of partial cavitation in a converging-diverging nozzle

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
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Scientific Publications

1. Jahangir, S., Hogendoorn, W., & Poelma, C. (2018). Dynamics of partial cavitation in an axisymmetric converging-diverging nozzle. International Journal of Multiphase Flow, 106, 34-45.
2. Dash, A., Jahangir, S., & Poelma, C. (2018). Direct comparison of shadowgraphy and x-ray imaging for void fraction determination. Measurement Science and Technology, 29(12), 125303.
3. Jahangir, S., Wagner ,E., Mudde, R., & Poelma, C. (2018). X-ray computed tomography of cavitating flow in a converging-diverging nozzle. 10th International Cavitation Symposium, Baltimore, USA.

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

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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

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 2018, experiments with Ultrasound Imaging Velocimetry (UIV) in pipe flow unveiled a complete new laminar to turbulent transition behavior for particle laden flows (see e.g. Hogendoorn, W., & Poelma, C. (2018)). For particle concentrations bigger than 15% a smooth transition is found. Further research is focusing on the physics behind this phenomenon. An image of a particle laden pipe flow with a particle concentration of 22.5% is added below.

Dissertations
-

Scientific Publications
1. Jahangir, S., Hogendoorn, W., & Poelma, C. (2018). Dynamics of partial cavitation in an axisymmetric converging-diverging nozzle. International Journal of Multiphase Flow, 106, 34-45. DOI: https://doi.org/10.1016/j.ijmultiphaseflow.2018.04.019.
2. Hogendoorn, W., & Poelma, C. (2018). Particle-laden pipe flows at high volume fractions show transition without puffs. Physical review letters, 121(19), 194501. DOI: https://doi.org/10.1103/PhysRevLett.121.194501.
3. Dash, A., Jahangir, S., & Poelma, C. (2018). Direct comparison of shadowgraphy and x-ray imaging for void fraction determination. Measurement Science and Technology, 29(12), 125303. DOI: https://doi.org/10.1088/1361-6501/aaea49.

Next to this, experiments with particles in a Taylor-Couette flow are in a start-up phase.

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 focussed on the finalization of a new numerical scheme to track pigs and by-pass pigs in single-phase and twophase flow pipe flow. The results of this serve as input to the last technical chapter of the PhD thesis. Furthermore, a Master student (Mengting Jiang) has carried out a CFD study with Fluent to simulate ball pigs, which basically is a ball with a diameter smaller than the pipe that is transported with the main flow along the pipeline. Variations were made with respect to Reynolds number, location of the centre of the ball, and the ratio of the ball and pipe diameter.

Dissertations

-

Scientific Publications

1. Hendrix, M.H.W., IJsseldijk, H.P., Breugem, W.P., Henkes, R.A.W.M., Experiments and modelling of by-pass pigging under low-pressure conditions, J. Process Control 71, 1-13, 2018.
2. Hendrix, M.H.W., Graafland, C.M., Van Ostayen, R.A.J., Frictional forces for disc-type pigging of pipelines, J. Petroleum Science and Eng. 171, 905-918, 2018.

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

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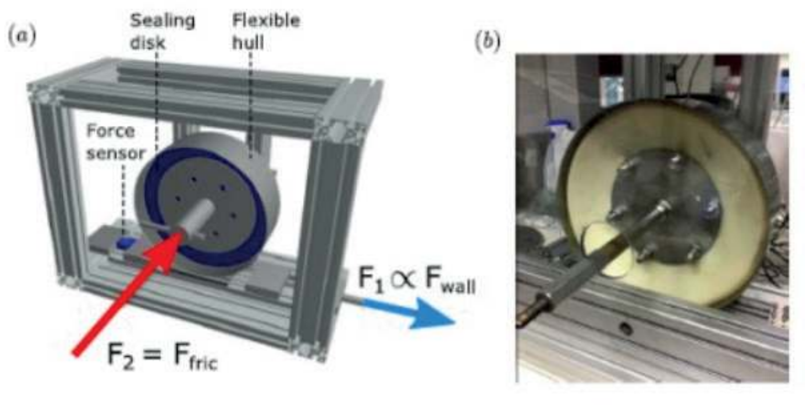
Pull tests to measure normal and frictional forces for a pig disk in a pipe



PROJECT LEADERS
R.A.W.M. Henkes
M.T. Tummers

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
R.A.W.M. Henkes, M.T. Tummers

COOPERATIONS
-

FUNDED BY
-

FUNDED %

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

START OF THE PROJECT
2017

INFORMATION
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PROJECT AIM

The project aims at improving the basic understanding of a key aspect of multiphase flow in pipelines, which is the liquid accumulation, with wave formation and slug flow, in systems under low flow rates. The experimental lab configuration consists of a horizontal pipe with a flow of water and air. The turbulence levels and the waves at the liquid-gas interface are measured with Particle-image Velocimetry. The experimental data will be used for the validation of pipe flow models of various types (1D engineering models, and 3D RANS and LES models).

PROGRESS

In 2018 the extension of the PIV facility to enable fully time resolved measurements has been completed. No new experiments were carried out yet. Instead, the focus was on the numerical modelling of the pipe flow. Using a two-fluid model, the transition from stratified flow to the roll-wave regime has been simulated, the results of which were presented at the Multiphase Flow conference. Furthermore, a publication was realized on the CFD modelling of the stratified liquid-gas flow. The PIV data as obtained earlier in this project were used for the model validation, as well as other data sets that were available in the literature.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Chinello, G., Ayati, A.A., McGlinchey, D., Ooms, G., Henkes, R.A.W.M., Comparison of CFD simulations and experiments for stratified air-water flows in pipes, J. Fluids Engineering 141, 051302-1, 2018.
2. Sanderse, B., Misra, S., Dubinkina, S., Henkes, R.A.W.M., Oosterlee, C.W., Numerical simulation of roll waves in pipelines using the two-fluid model, Proc. 11th North American Conference on Multiphase Flow, BHR Group, pp. 373-386, 2018.

PROJECT AIM

This project is a combined experimental/modeling study on the performance of surfactants, creating a foam, for the deliquification of gas wells as used in the gas and oil industry. Foam can possibly also be used as a means to mitigate slugs in the multiphase flow transport in flowline-riser systems. The study includes flow experiments using a 12 m, 5 cm diameter facility in the Process & Energy lab. The specific project aims are:

1. Investigate how the foamer performance at different conditions in a desktop scale setup relates to

their performance at continuous and batch injection in a mid-scale setup, and in field cases.

2. Develop and validate a model for the foam-based multiphase flow transport.

3. Determine how the foamer performance in flow transport is related to their physicochemical foamer properties.

PROGRESS

The flow facility, which was previously located in the Kramer lab, is now in operation again in the Process & Energy lab. In collaboration with TNO, who carried out desktop experiments, the midscale experiments in the flow loop were performed for different types of surfactants, both with fresh and salt water. Furthermore, tests were also carried out for thermally aged surfactants. Pressure drop curves and liquid and foam holdup curves were obtained for a range of superficial gas velocities, with a fixed value of the superficial liquid velocity. The performance in the flow loop was compared with the foam characterization in the desktop experiments. A study report was prepared.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Van Nimwegen, A.T., Portela, L.M., Henkes, R.A.W.M., Modelling of upwards gas-liquid annular and churn flow with surfactants in vertical pipes, Int. J. Multiphase Flow 105, pp. 1-14, 2018.
2. E.J. Pronk, Ellepola, J.H., Henkes, R.A.W.M., The effect of a surfactant on slugs in a flowline-riser system, Proc. 11th North American Conference on Multiphase Flow, BHR Group, pp. 85-94, 2018.

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

2016

INFORMATION

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Small-scale and midscale foam experimemts

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
R.A.W.M. Henkes
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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 alonmg 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

In 2018, a Master student (Kangjun Lia) has been working on this project. He has carried out CFD simulations with the OpenFoam code for the flow at various conditions (total flow rate, watercut, and oil viscosity). He found that it is crucial to apply the proper numerical scheme at the interface to prevent the spurious dispersion of oil as droplets in the water layer. If separated oil and water phases are maintained in the numerical solution, a good agreement is found with the experimental values for the pressure drop as obtained earlier in our lab. In Q4 of 2018 a new PhD student, Haoyu Li, started to work in this project.

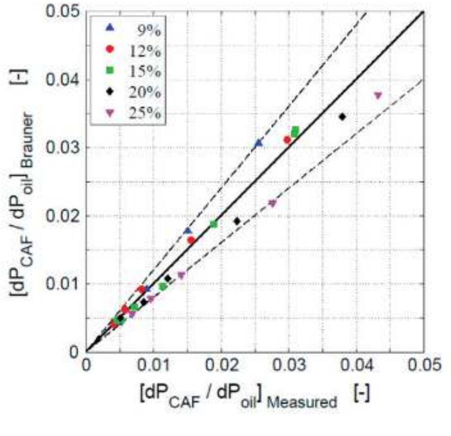
DISSERTATIONS

-

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, January 2018.

Predicted scaled pressure drop (using simplified model) versus the measured value for various watercuts. The solid line denotes perfect agreement, and the dashed lines denote the 20% accuracy interval.



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 and the effect of liquid compressibility on the liquid loads during sloshing events by varying the gas and liquid compressibility, density ratio and phase transitions.

PROGRESS

Two experimental setups are developed at the TU Delft in order to evaluate novel experimental techniques required for the complex measurements in the MARIN test facility. 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. Also, velocities of pressure waves, propagating through aerated liquids, are measured by high-speed imaging of (micro)bubbles at different conditions.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. van Meerkerk, M., Poelma, C. & Westerweel, J. (2018). Non-intrusive measurement of complex free surfaces using laser induced fluorescence and stereo imaging, 19th International Symposium on the Application of Laser and Imaging Techniques to Fluid Mechanics, Lisbon, Portugal.
2. Cornel, W.A., Westerweel, J. & Poelma, C. (2018). Local microbubble concentration by defocused volumetric shadowgraphy with a single camera. 18th International Symposium on Flow Visualization, Zürich, Switzerland.

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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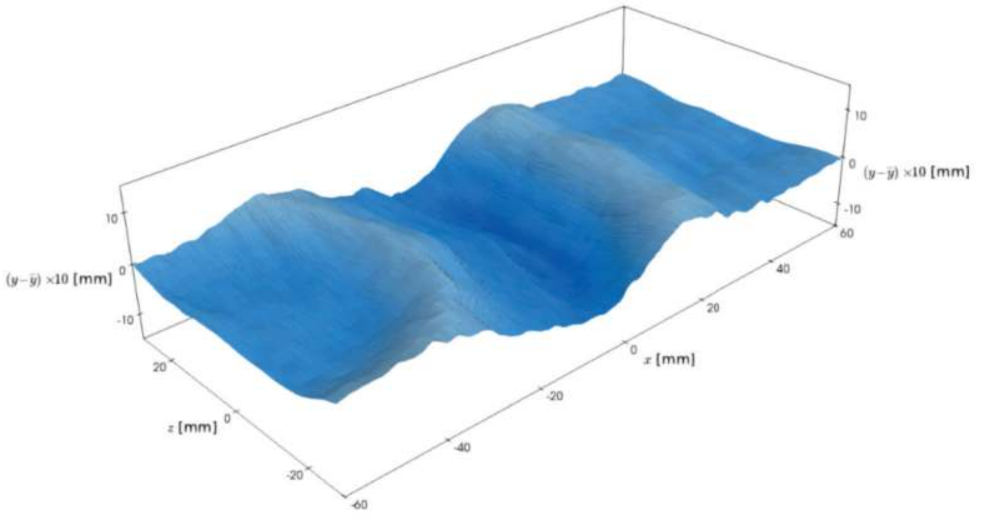
Propagating free-surface ripples after droplet impact



Prof.dr.ir. AP van 't Veer

Prof.dr.ir. TJC van Terwisga

SEAKEEPING AND MANOEUVRING - PROF. AP VAN 'T VEER

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.

MANIFAST: The Manoeuvring of Fast Ships in Waves

Project Aim

ManiFast project aims to investigate the manoeuvrability features of small (up to 20 meter) high-speed craft in following and stern-quartering seas and the inception of dynamic instabilities in such conditions. Particular attention will be focused on the manoeuvrability-in-waves of these vessel.

Progress

1) The manoeuvrability behaviour of high-speed craft must be investigated.

2) The data obtained from the point 1) are utilised to validate and implement a 3D potential flow boundary element method, suited for the simulation of the motion of high-speed vessels in the seaway.

3) The mathematical model will be applied to following seas problems in order to understand the dynamic instability phenomena inception mechanism and the most important factors involved in it.

Dissertations

-

Scientific Publications

1. Bonci M., Renilson M., De Jong P., Van Walree F., Van't Veer R. (2018) On the direct assessment of broaching-to vulnerability of a high-speed craft, 13th International Conference on the Stability of Ships and Ocean Vehicles, 16-21 September, Kobe (Japan).
2. Bonci M., Renilson M., Jong P., Walree F., Keuning A. J., & Huijsmans R. (2018). The heel-sway-yaw coupling on a high-speed craft in calm water. The Transaction of The Royal Institution of Naval Architects, Part B - International Journal of High-Speed Craft Technology, 160, 121-129.
3. Bonci, M., De Jong P., Van Walree F., Renilson, M., Keuning, J.A., Van't Veer, R. (2018) A novel experimental technique for the investigation of the heel-sway-yaw hydrodynamic coupling of a high-speed craft in following waves, accepted for publication Journal of Marine Science and Technology.

Project leaders

Ido Akkerman

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

TU Delft

Cooperations

-

Funded by

-

Funded %

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

Start of the project

2015

Information

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FASTFEM: Behaviour of Fast Ships in Waves

Project leaders
Prof. dr. ir. J.J. Hopman
Prof. dr. ir. J.J.W. van der Vegt
Dr. ir. I. Akkerman

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
G. Jacobi (PhD Student TU Delft)
F. Brink (PhD Student University Twente)

Cooperations
-

Funded by
STW

Funded %

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

Start of the project
2015

Information
Gunnar Jacobi
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Project Aim

The main aim of the FastFEM project is the development of a new simulation tool for the dynamics of fast ships and surrounding waves in breaking seas. The proposed numerical method guarantees exact preservation of energy and wave amplitude, while wave and ship dynamics are fully and nonlinearly coupled. The validation of the method is supported by advanced and novel towing tank laboratory experiments which includes PIV measurements to picture the flow around the ship hull and a reconstruction of the pressure distribution on the hull from measured velocities.

Progress

A novel Hamiltonian structure preserving finite element discretization for nonlinear water waves has been developed, implemented in an efficient C++ code, and tested on several wave problems. The finite element discretization is energy preserving on unstructured time dependent meshes and stable and accurate for long time integrations. To guarantee a high level of accuracy for the validation measurements, the behavior of an underwater PIV system was analyzed for high towing tank carriage speeds up to 5 m/s. After the development of a vibration correction procedure, the technique has been applied to record the flow field in the transom and bow region of a fast ship. Afterwards, results from these measurements have been successfully used to reconstruct the pressure field close to the ship model.

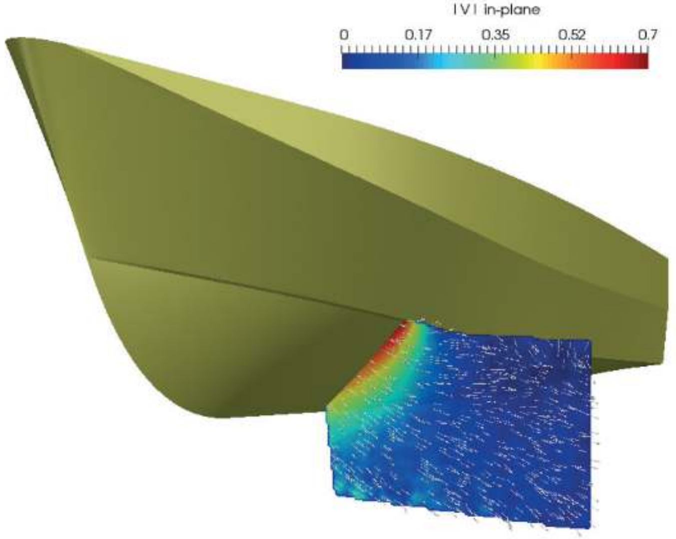
Dissertations

-

Scientific Publications

-

Velocity field, measured in the bow region of a fast ship with PIV measurements



Project Aim

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

Progress

A generating and absorbing boundary condition (GABC) for waves in the presence of currents was derived and implemented in the CFD program ComFLOW. The performance of GABC in the simulation of waves (both regular and irregular) and currents with various speeds was verified by comparing the numerical reflection coefficients with the analytical ones. The validation study on a travelling ship in waves is under investigation to test the GABC completely.

Dissertations

-

Scientific Publications

-

Project leaders

Peter Wellens (DUT/MTT)
Arthut E.P. Veldman (RUG)

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Peter van der Plas, Henk Seubers, Matin Hosseini

Cooperations

TU Delft, Rijksuniversiteit Groningen, 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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Project leaders
Peter Wellens
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
-
Cooperations
-
Funded by
China Scholarship Council
TU Delft
Funded %

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

Start of the project
2017
Information
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Project Aim

Offshore ships and installations are facing the long-term environmental loads. One of the most difficult to forecast and evite large loads is the impingement of breaking waves. Conventionally, the load exerted by breaking waves is computed deriving from presupposition that the structure is fixed and rigid. Information on the mutual influence of hydroelasticity is lost. This research is to look into the structural response to breaking waves with the method of Fluid-Structure Interaction. The structure will be restricted to a bottom-mounted pile mounted or a floating barge.

Progress

The numerical experiment has been established, including the water tank, the slope-induced breaking wave and the cylinder structure.

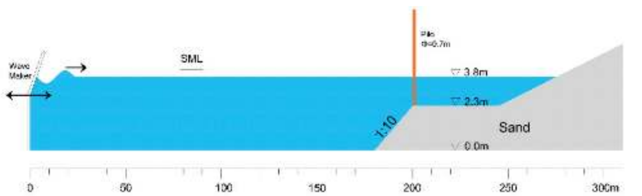
Dissertations

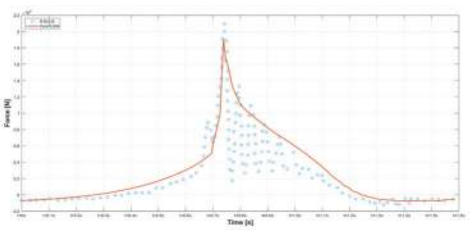
-

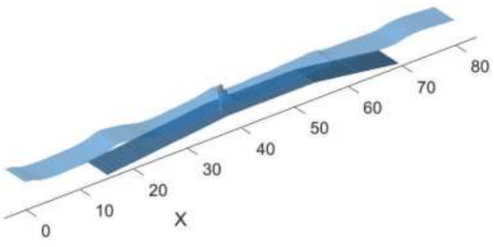
Scientific Publications

-

The simulations on the interaction between the breaking waves and the rigid pile is finished.







A linear wave-barge interaction model is established.

Project Aim

In a loosely coupled fluid-structure system, the solution can become unstable when physics encompass a two-way interaction. The solution is to strongly couple the two sub-systems. The strong coupling can be achieved using different methods. Once the partitioned approach is adopted, the sub-iterative scheme between fluid and the structure can diverge. Added mass of the structure relative to the mass of the structure identifies the intensity of the interaction. Sub-iterative loop's convergence depends on the ratio of added mass to the structural mass. For flexible structures, stiffness also play an important role in this ratio. The aim of this study is to develop a novel method to resolve the divergence issue by not suppressing the efficiency. Efficiency is the key factor since an inefficient method can make reaching to the solution relatively impracticable.

Progress

It has been the last year of the Commotion project. During this year, the final committee meetings with industrial partners as well as NWO has been held. The final merge for all the work-packages has been performed. The single one software ComFLOW for interactively moving-deforming is under validation and bench mark testing. The part of the deformable bodies only consists of one structure which is coupled to the software through dynamic libraries creating the possibility of future extension to the other structural software. The novelty of the fluid-deformable-structure part is its efficiency under any mass ratio. The introduction and implementation of the interaction law has made the efficiency and accuracy of the solution relatability independent of the interaction strength.

Dissertations

-

Scientific Publications

1. Arthur E.P. Veldman, Henk Seubers, S. Matin Hosseini Zahraei, Peter van der Plas, Peter R. Wellens and Rene H.M. Huijsmans. Preventing the added-mass instability in fluid-solid coupling for offshore applications. 37th Int. Conf. Ocean, Offshore and Arctic Eng., Madrid, 17-22 June, 2018. paper OMAE2018-77308, 10 pages.
2. A quasi-simultaneous coupling approach for fluid-solid interaction in offshore applications. Henk Seubers, Matin Hosseini, Peter van der Plas, Arthur E.P. Veldman, Peter R. Wellens and Rene H.M. Huijsmans.

Project leaders
Peter Wellens (TUD)
Arthur Veldman (RUG)

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
University of Groningen, MARIN, DNV GL, Force Technology, Gusto MSC, Hyundai

Cooperations
TU Delft, Rijksuniversiteit Groningen, MARIN, Deltares

Funded by
NWO

Funded %

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

Start of the project
2014

Information

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DREDGING ENGINEERING

Prof.dr.ir. C van Rhee

Large volumes of sediment are displaced nowadays using different types of dredging equipment. Especially the last decade, large land reclamation projects attained global attention. Examples of these enormous projects are the new airports in Hong Kong and Singapore, the large land reclamations for ports and industry in Singapore, the spectacular projects in Dubai like the palm Islands and “the World” and the Maasvlakte II currently under construction in the Netherlands.

All dredging processes involve slurry flows and are dominated by erosion, transport and sedimentation under special hydraulic conditions like high volumetric sediment concentration and or high flow velocity.

The research topics within the section of Dredging Engineering are focused on the physical processes encountered during dredging (and mining):

- Excavation processes of saturated sediments (mechanical, hydraulic or a combination).
- Hydraulic transportation of sediment water mixtures.
- Mixing and separation process (like the sedimentation process in a hopper of a Trailing Suction Hopper Dredge)
- Erosion and settling of sediments.
- Wear of flow components due to hydraulic transport.

Project Aim

Breaching is a gradual retreat of a sub-aqueous slope, which is steeper than the angle of repose near the top of the slope. While mainly investigated due to the application of this process in the breaching process, the breaching process can also be a cause for unwanted slope instability and failure. These failures are usually caused by unstable breaching, where the size of the retreating slope increases during the process. The aim of this project is to investigate the unstable breaching process using numerical methods. The main interest in this project is the 3D effects during the process, and the effect of large scale effects.

Progress

Validation of the numerical model with experiments. Finalizing the thesis. Year of defence will be 2019.

Dissertations

-

Scientific Publications

-

Project leaders

C van Rhee

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

D Weij

Cooperations

Deltares

Funded by

SSB, Rijkswaterstaat

Funded %

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

Start of the project

2013

Information

D Weij
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Towards Responsible ExtrAction of SUbmarine mineral REsources (TREASURE)

PROJECT LEADERS
C. van Rhee, G.H. Keetels
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
F. van Grunsven
COOPERATIONS
NIOZ
Wageningen University/WUR
FUNDED BY
STW / NWO, Royal IHC, Royal Boskalis, Van Oord
FUNDED %

University	-
FOM	-
STW	65 %
NWO Other	-
Industry	35 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2014
INFORMATION
Frans van Grunsven
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PROJECT AIM

Develop a numerical model capable of predicting the three dimensional initial development of turbidity plumes which are expected during future deep-sea mining operations. The model will be validated by scientific literature and own experiments in the TU Delft dredging laboratory. Data gathered during field expeditions in the Mid-Atlantic Ridge by research partners will be used in combination with the model as a case study to develop advice for the industry.

PROGRESS

Using the experimental setup developed in 2016/2017, further experiments were conducted of a negatively buoyant jet with suspended particles, impinging on a sloped surface. Velocity and concentration profiles were taken from the resulting turbidity current down slope. The data was analyzed and partially presented at the Underwater mining conference. As the experimental work covered the remaining research time budget, work on writing the dissertation was started, which should be published next year.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Grunsven, F. van, G.H. Keetels and C. van Rhee, 2018. The initial spreading of turbidity plumes – Dedicated laboratory experiments for model validation. Deep-sea mining: Challenges of going further and deeper. Advances in Marine Research and Subsea Technology Beyond Oil & Gas, UMC 2018, Grieghallen, Bergen, Norway.

Project Aim

The manoeuvring behaviour of ship in many harbours (e.g. Rotterdam) can be influenced by the presence of a mud layer on the bottom. Mud is however a very complex medium between solids and liquid and it is a challenging task to correctly predict the manoeuvring behaviour of vessels in close vicinity of a mud layer. A numerical model for the mud will be implemented in the computational fluid dynamics (CFD) code, ReFRESCO, to predict the forces on the ships in muddy navigation areas. The results will be compared with novel experiments at laboratory scale levell.

Progress

Setup collaboration MUDNET with Dr. A. Kirichek. This framework unites fundamental research on mud rheology (rheoMUD), non-invasive measurement techniques (soniMUD), studies on biological activity (bioMUD) and nautical aspects (nautiMUD). Numerical implementation of non-Newtonian fluid model in ReFRESCO, the CFD code developed by MARIN. Code verification has been carried out on the Poiseuille flow. Solution verification and Validation have been performed on the steady laminar flow around a sphere settling in Herschel Bulkley fluid (see figure).

Dissertations

-

Scientific Publications

1. Lovato, Stefano & Vaz, Guilherme & Toxopeus, Serge & Keetels, Geert & Settels, Just. (2018). Code Verification exercise for 2D Poiseuille flow with non-Newtonian fluid. Numerical Towing Tank Symposium (NuTTS) 2018, Cortona, Italy.

Project leaders

Dr. G. Keetels (TU Delft)
Prof C. van Rhee (TU Delft)

Research theme

Complex dynamics of fluids

Participants

Dr. Keetels (TU Delft)
Dr. G. Vaz (MARIN)
Dr. S. Toxopeus (MARIN)
Dr. A. Kirichek (TU Delft)
MSc. S. Lovato (TU Delft)

Cooperations

Delft University of Technology
MARIN, Deltares

Funded by

NWO, Port of Rotterdam, MARIN, Deltares, Rijkswaterstaat

Funded %

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

Start of the project

2017

Information

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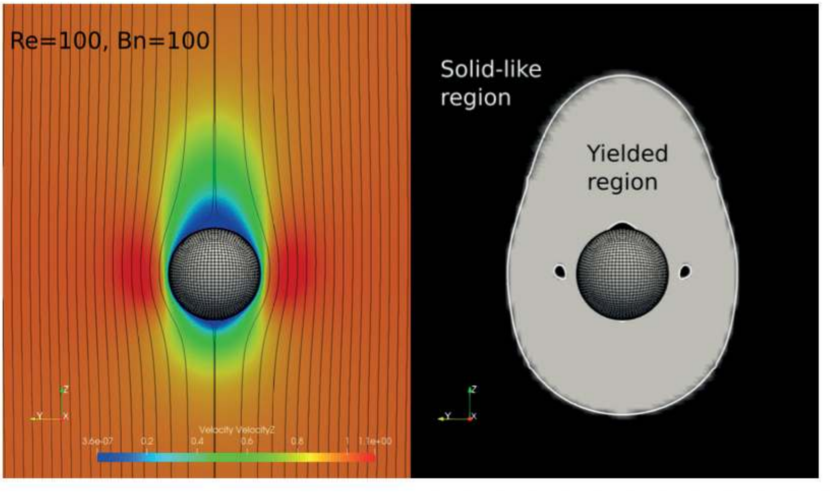

PROJECT LEADERS
Prof.dr.ir. C. van Rhee
Ir. R.F.J. Neelissen

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Dr.ir. G.H. Keetels
Dr.ir. A.M. Talmon
Ir. I.K. van Giffen

COOPERATIONS
Royal Boskalis Westminster,
van Oord

FUNDED BY
Stichting Speurwerk Baggertechniek (SSB)

FUNDED %

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

START OF THE PROJECT
2012

INFORMATION
Bas Nieuwboer
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PROJECT AIM

Current rock cutter heads spill up to 50% of the cut rock in most unfavourable conditions. Spillage can be defined as the amount of rock that is cut loose, but is not sucked up by the suction mouth. Spillage is caused by the cutting process and by the mixing process of cut rock with water in the cutter head. The goal of this research is to quantitatively describe the mixture processes of cut rock in a rotating dredge cutter head using a numerical model. With this knowledge an improved cutter head can be designed in the future or operational conditions can be changed to obtain more production.

PROGRESS

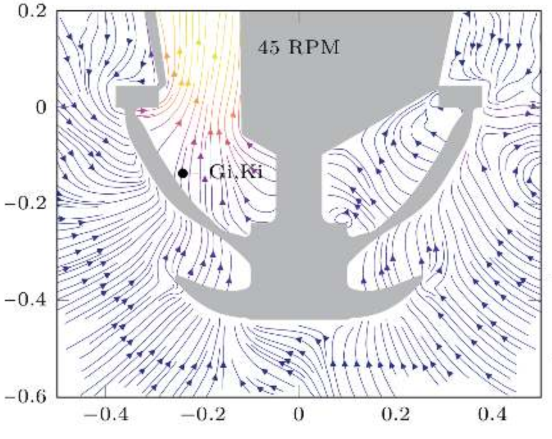
This years goal was to finish the modelling and combine the three research paths: modelling of the fluid flow in the rotating cutter head, modelling of distributed forcings on lagrangian particles and modelling collisions between particles. Relevent experimental data in literature was used to validate the modelling resuls. The models match the experiments well, showing that the model will be capable of modelling spillage in rotating cutter suction dredge heads.

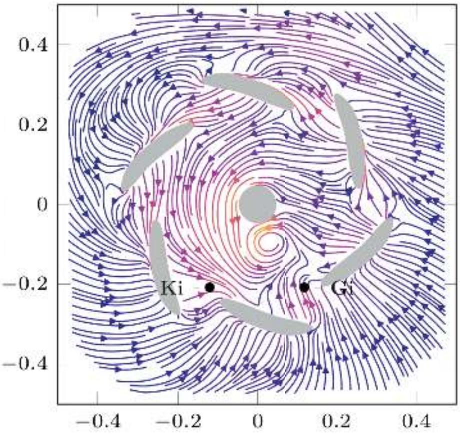
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-





Project Aim

In dredging applications typically large amounts of sediments are transported through pipes in the form of hyperconcentrated (40% sediment or more) sediment-water mixtures. These slurry's can flow at three different regimes. 1: fully suspended. 2: partially suspended with a sliding bed. 3: partially suspended with a fixed bed. At the moment it is hard to predict the transport regime, the volume flux of particles and the pressure drop (friction factor) of these slurry's within these regimes. The goal is to establish a 3D continuum model that is able to predict the aforementioned aspects of slurry flow in a wide range of slurry flow conditions.

Progress

The drag model of Di Felice(1994) has been implemented. Simulations have been performed in the fully suspended regime with a volume fraction up to 35%. The model is now capable of reproducing concentration and velocity profiles correctly. Experimental setup to validate simulations is ready to run experiments.

Dissertations

-

Scientific Publications

-

Project leaders

Dr. G. Keetels

Research theme

Complex dynamics of fluids

Participants

Dr. G. Keetels, Prof. C. van Rhee,
Dr. W.P. Breugem, Ir. T. D. Schouten

Cooperations

Royal Boskalis Westminster,
van Oord

Funded by

Stichting Speurwerk Baggertechniek (SSB), NWO

Funded %

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

Start of the project

2017

Information

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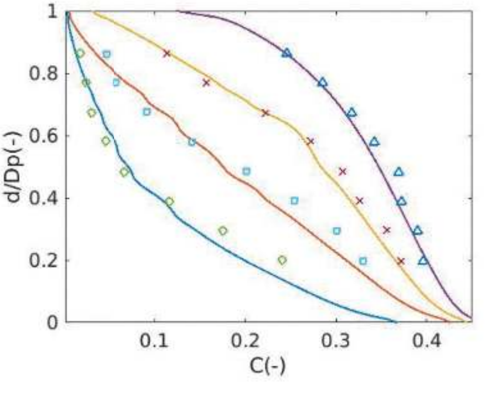

TRANSPORT PHENOMENA

Prof.dr.ir. CR Kleijn

Prof.dr. RF Mudde

Prof.dr.ir. HEA van den Akker

Prof.dr. AB de Haan

Prof.dr.ir. K Hanjalic

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

We started our project by considering openFOAM as a main numerical tool because of a lot of available solvers and flexibility in the original code modifying. However, it should be emphasized that regarding magnetohydrodynamics there is no solver suitable for us because we would like to consider three-dimensional unsteady turbulent two-phase flow with the free surface and the magnetic field influence. Thus, the first and the main step is the implementation and programming of a new solver. The current strategy lies in adding and validation step by step additional fundamental extensions, thereby increasing the solver capacity. Figure 1 shows results which we acquired using the first modules of our solver.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Pennerstorfer, I. Muttakin, M. Soleimani, S. Abouelazayem, J. Hlava, A. Blishchik, S. Kenjeres, Real-time control of the mould flow in a model of continuous casting in frame of the TOMOCON Project. IOP Conference Series: Materials Science and Engineering, 424, 012003 (2018).

PROJECT LEADERS

Prof. Dr. Ir. C.R. Kleijn
Assoc. 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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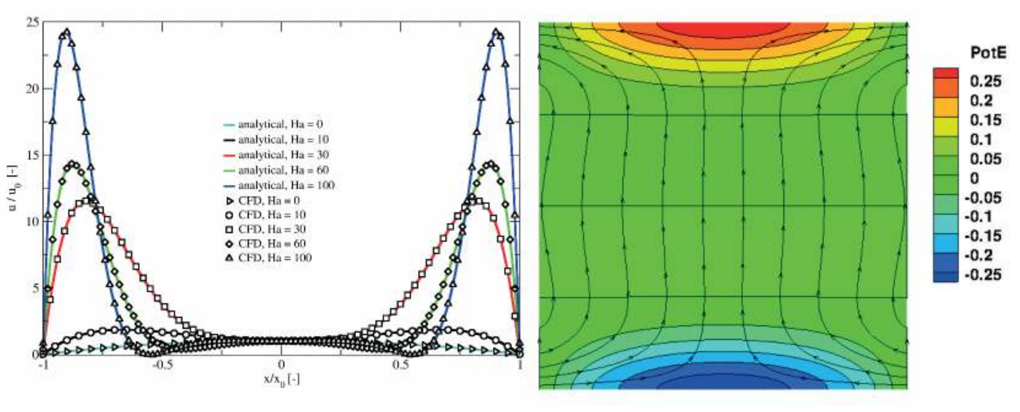
Velocity profile in the duct with fully conductive walls (on the left) and electric potential distribution with current density streamlines in the same duct in case of Hartmann number Ha = 30 (on the right).



Study of low Prandtl number heat transfer in the E-SCAPE liquid metal pool facility

Project leaders
Prof. dr. ir. Saša Kenjereš
Research theme
Complex dynamics of fluids
Participants
Ir. Katrien Van Tichelen (SCK•CEN)
Ir. Steven Keijers (SCK•CEN)
Bouke Kaaks (MSc - TU Delft)
Cooperations
SCK•CEN, VKI
Funded by
ENGIE, SCK•CEN
Funded %

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

Start of the project
2015
Information
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Project Aim

The Multi-purpose hYbrid Research Reactor for High-tech Applications (MYRRHA) at SCK•CEN is being designed as a pool-type fast reactor prototype cooled by Lead-Bismuth Eutectic (LBE). The aim of the project is to provide a fundamental understanding of, and experimentally validated models for, the Turbulent Heat Transfer (THT) phenomena in pool type fast reactors cooled by liquid metals (low Prandtl number - Pr -fluids). These insights and models will make it possible to develop a reliable Computational Fluid Dynamics (CFD) tool for industrial use.

Progress

In large components of the MYRRHA reactor, typical flow patterns are characterized by multi-jet interactions. Hence, the jet flow is recognized as fundamental test case to be investigated. Forced non-isothermal single- and triple-jet flows were studied through Large-Eddy Simulations (LES), Reynolds Averaged Navier-Stokes (RANS) and Unsteady-RANS (URANS) simulations at Pr = 5, 0.71, 0.2, 0.025 and 0.006. Numerical results are being compared with experimental data of reference. It was possible to test the available low-Pr THT models, mainly validated to wall-confined flows, and propose improvements towards.

Dissertations

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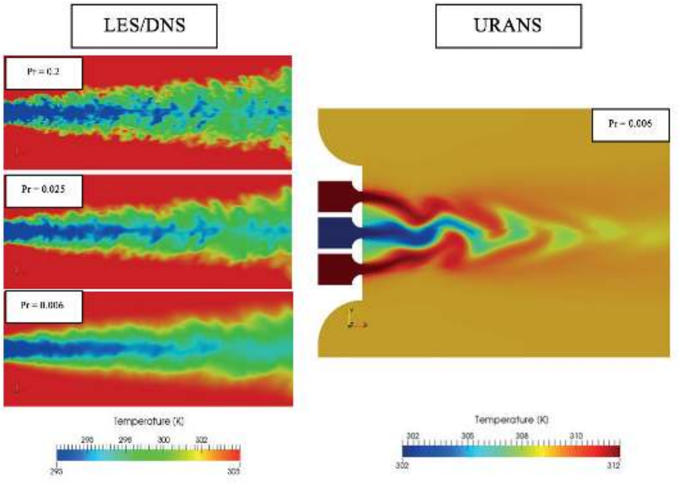
Scientific Publications

1. Oral presentation: 6th SESAME/MYRTE Progress Meeting, Ljubljana, Mar 2018 (WP3, D3.16).
2. Oral presentation: 7th SESAME/MYRTE Progress Meeting, Delft, Oct 2018 (WP3, D3.16).
3. Poster presentation: Day of the PhD's, SCK•CEN, Oct 2018.
4. Oral presentation: HiFiLeD Symposium, Brussels, Nov 2018.

Instantaneous thermal fields from LES/DNS of a planar jet with heated co-flow (left) and URANS simulation of a non-isothermal triple-jet (right) with low-Prandtl number fluids



Numerical modelling of 4D left ventricular blood flow using computed tomography imaging and computational fluid dynamics

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

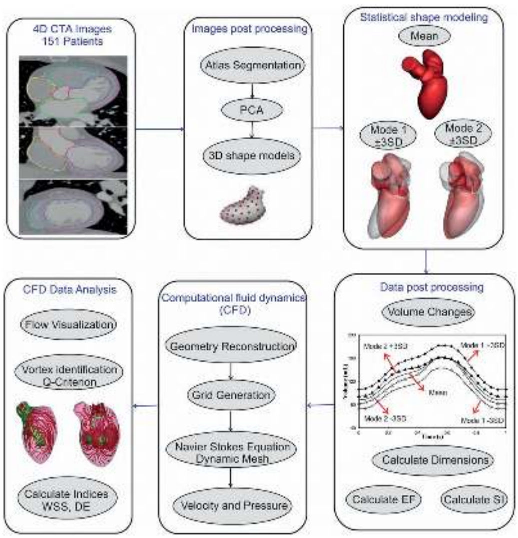
We have reconstructed the LV geometry for five shapes. For each segmented geometry, separate unstructured grids consisting of tetrahedral cells were generated. The time step resolution of CT data was not fine enough for CFD simulation. Thus intermediate geometries were needed to volume smoothly passed 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. S.S. Khalafvand, J.D. Voorneveld, A. Muralidharan, F.J.H. Gijsen, J.G. Bosch, T. van Walsum, A. Haak, N. de Jong, S. Kenjeres (2018), “Assessment of human left ventricle flow using statistical shape modelling and computational fluid dynamics”, Journal of Biomechanics 74, pp.116-125.
2. Voorneveld J., Muralidharan A., Hope T., Vos H. J., Kruizinga P., van der Steen A. F. W., Gijsen F. J. H., Kenjeres S., de Jong N., Bosch J. G. (2018) “High frame rate ultrasound particle image velocimetry for estimation of high velocity left ventricular flow patterns”, IEEE Transaction on Ultrasonics, Ferroelectrics, and Frequency Control,, doi: 10.1109/TUFFC.2017.2786340.



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

Project leaders

S.Kenjeres

Research theme

Complex dynamics of fluids

Participants

Dr. S.S.Khalafvand
Dr. S. Kenjeres

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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RADAR – Early Recognition of Aorta Dissection and Aneurysm Rupture

Project leaders
Dr. Saša Kenjereš, 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

Simulations with boundary conditions adapted from the MRI measurements have been performed on one case of a volunteer aorta and one case of patient specific aorta with thoracic aortic aneurysm. The simulations were performed on two different meshes – a fine mesh with a boundary layer and a coarse isotropic mesh with the cell size similar to the resolution of MRI - to estimate the error in the wall shear stress (WSS) calculation from MRI. It was found that the WSS based on the isotropic, 'MRI-like' mesh, was lower than the one, based on the fine mesh. Similar differences can be found also in the WSS estimated by MRI-solely.

Dissertations

-

Scientific Publications

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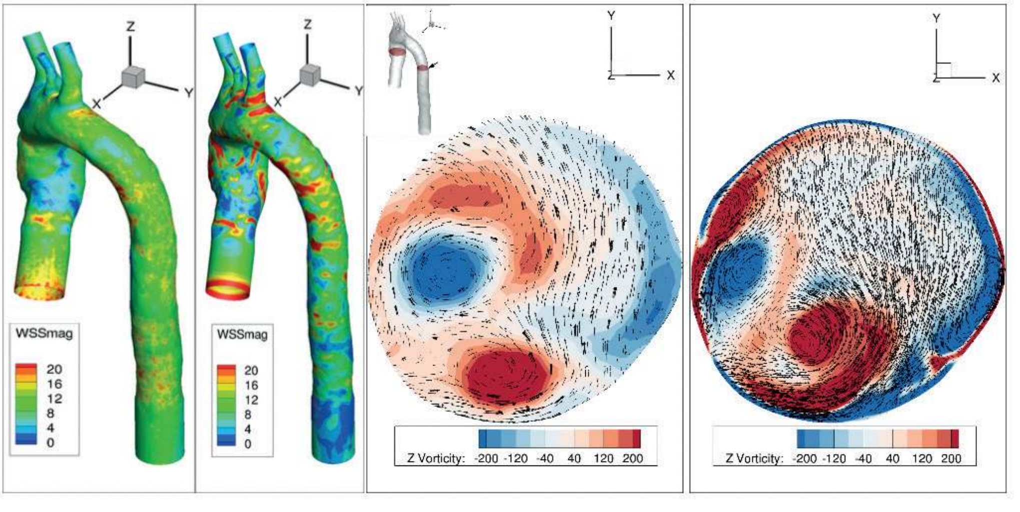
From left to right, contours of the wall shear stress magnitude for the MRI-like mesh and for the 'normal' computational mesh, velocity vector field and contours of the out of the plane vorticity (Z-vorticity) for the MRI-like mesh and for the 'normal' computational mesh.



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

We have implemented numerical simulations of the flow patterns within an aortic root model with the bi-leaflet mechanical valves in realistic conditions. The aortic model and the bi-leaflet mechanical valve is based on the experiment of Romano (2008) from which we acquire the geometry of the aortic model and the leaflets as well as the time dependent flow rate at inlet.

The simulations have been implemented in two steps.

1. The dynamics of the bi-leaflet is represented as a result of the fluid-structure interactions (FSI) together with the overset mesh technique. During the simulation leaflets are considered as solid rotating objects with a limited degree of freedom.

2. Various numerical approaches such as DNS, RANS, LES and DES have been implemented for the simulation together with the dynamic meshing technique. At this step, the kinematics of the valve is prescribed from the result of the first step.

The comparison with reference experiment data showed good agreements. The turbulence spectra at five locations reveled the transient transitional turbulent flow feature in such model for the first time.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. Fei Xu et al. (2018) "Numerical simulations and analysis of the flow patterns in an aortic root model through a bi-leaflet mechanical valve" CMBBE2018, Lisbon, 28th March 2018.

PROJECT LEADERS

Dr. Saša Kenjereš

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Fei Xu

COOPERATIONS

Erasmus Medical Center
Leiden University Medical Center

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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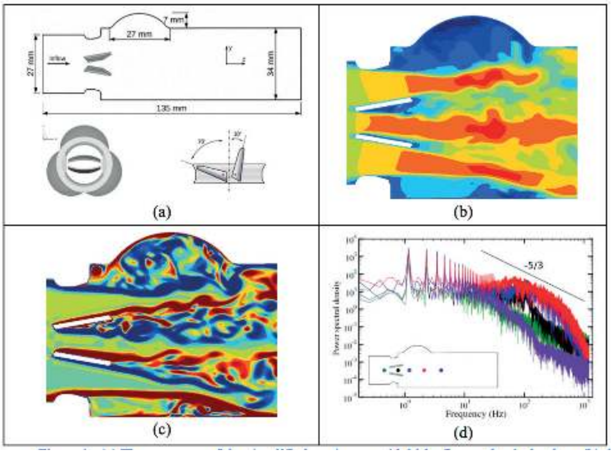

(a) The geometry of the simplified aortic root with bi-leaflet mechanical valve; (b) the stream-wise velocity contour on the central plane; (c) vorticity contour on the central plane; (d) turbulent kinetic energy spectra at five locations

Numerical simulations and experiments of flow, turbulence and mass transfer control of electrically conducting fluids by imposed electromagnetic fields

Project leaders
Dr. S. Kenjeres
Research theme
Complex dynamics of fluids
Participants
S. Kenjeres
Cooperations
-
Funded by
TU Delft
Funded %

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

Start of the project
2010
Information
S. Kenjeres
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Project Aim

Numerical cal simulations and modeling of thermal and magnetic convection at very high Rayleigh and Hartmann numbers has long been a serious challenge because of the profound effects that buoyancy and Lorentz forces have on the reorganization of the vortical structures, and because of the extreme thinning of the wall boundary layers which requires high numerical resolution. The aim of this study is to develop physically well-based and numerically efficient approaches to tackle problems of highly turbulent thermal and magnetic convection in complex geometries.

Progress

We performed DNS studies of flow around magnetic obstacles in transitional and turbulent flow regimes. A new model for the subscale turbulent heat flux for low-Pr fluids is proposed. A review paper published.

Dissertations

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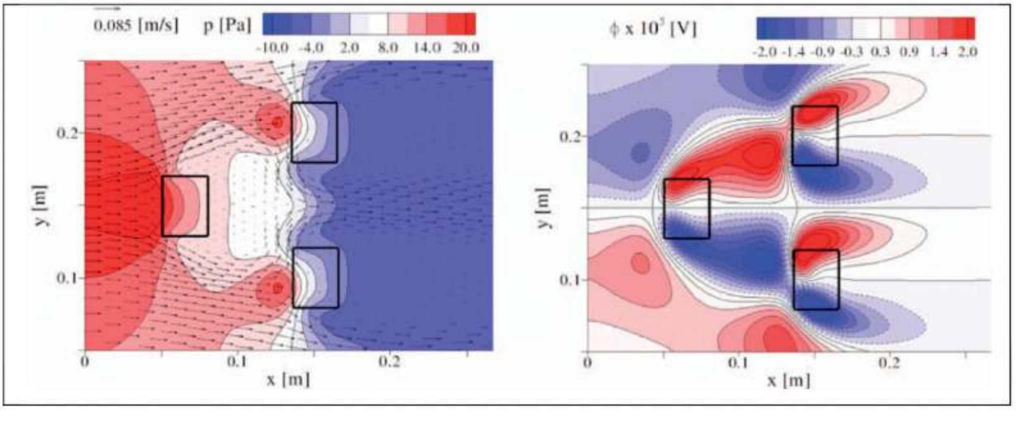
Scientific Publications

1. Kenjeres S. (2018), "On modeling and eddy-resolving simulations of flow, turbulence, mixing and heat transfer of electrically conducting and magnetizing fluids: A review", Int. J. Heat and Fluid Flow, Vol.73, pp.270-297 (doi:10.1016/j.ijheatfluidflow.2018.09.003).

A zoom-in of the pressure contours and velocity vectors (-left) and of electric potential (-right) of an instantaneous flow realization in the central horizontal plane in a channel flow of a fluid conductor subjected to the localized magnetic fields, Re = 1000, N = 10. The locations of the magnetic dipoles projections in the central horizontal plane are depicted by black rectangles, Kenjeres (2018).



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

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Scientific Publications

1. Voorneveld J., Saaid H., Schinkel C., van den Adel F., Radeljic N., Lippe B., van der Steen A. F. W., Gijsen F., de Jong N., Claessens T., Vos H. J., Kenjeres S., Bosch j. G. (2018), "High-volume-rate 3D ultrasound imaging and stereoscopic PIV in a dynamic left ventricular phantom", 2018 IEEE International Ultrasonics Symposium (IUS), October 22-25, 2018, Kobe, Japan.

Project leaders

Dr. S. Kenjeres

Research theme

Complex dynamics of fluids

Participants

S. Kenjeres

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

2010

Information

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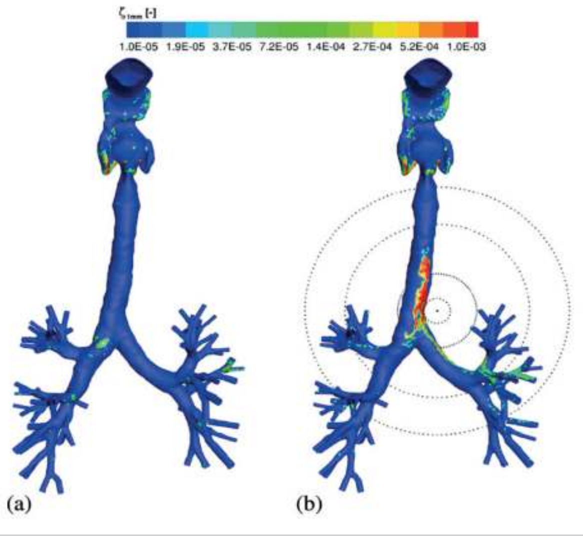

Contours of the local deposition efficiency (ζ) in the upper- and central-airways human respiratory system for the magnetic-core particles (dp = 3μm, St=4.3 × 10−2, Mnp=1.7 × 10−1) without (a) and with imposed magnetic field gradient (b), demonstrating potentials of the MDT

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

Project leaders
Dr. S. Kenjeres

Research theme
Complex dynamics of fluids

Participants
Dr. Sasa Kenjeres, 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
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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. We completed the first generation of an integrated solver that involves a coupling of crowd of people movement triggered by an incidental release of the heavy gas.

Dissertations

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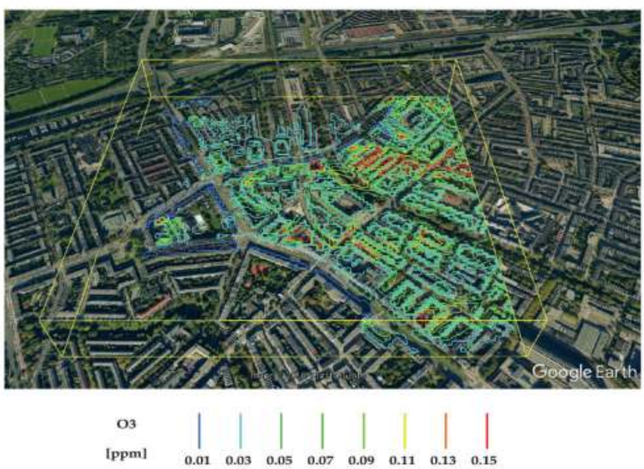
Scientific Publications

1. Zwinkels S., Kenjeres S. (2018), “Numerical predictions of the heavy gas turbulent dispersion and its influence on a people crowd evacuation: an integrated approach”, Turbulence, Heat and Mass Transfer 9 Conference Proceedings, Rio de Janeiro, Brasil, 10-13 July 2018, Edited by: A. P. Silva Freire et al., Begell House Inc., pp.539-542 (ISBN: 978-1-56700-467-0).
2. Kenjeres S., Zwinkels S. (2018), “Numerical modelling of macroscopic behavior of a crowd of people under emergency conditions triggered by an incidental release of a heavy gas”, Proceedings of the 12th International ERCOFTAC Symposium on Engineering Turbulence Modelling and Measurements, ETM12, Paper No. 142, pp.1-6, 26-28 September 2018, Montpellier (La Grand-Motte), France.



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

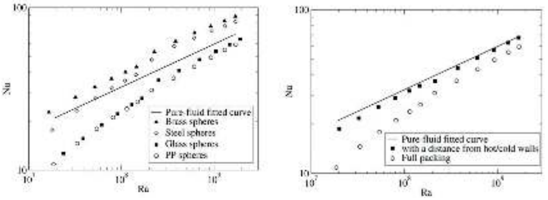
Overall heat transfer measurements were performed in a differentially-heated cubic cavity filled with various sphere conductivities, spheres sizes, sphere packings, and a packing with a gap near hot/cold walls for Rayleigh numbers between 107 and 109. The heat transfer results indicate that the presence of a porous medium in the cavity decreases the heat transfer with respect to the pure-fluid cavity unless the solid spheres are highly conductive. For the cavity with a gap near the hot/cold walls, the heat transfer reduction is significantly smaller which implies that most of the heat transfer reduction is caused by the spheres adjacent to the hot/cold walls. (see Fig. 1) Refractive index-matching of the fluid and the solid spheres enabled the use of PIV and LCT techniques to obtain velocity and temperature fields. The results show that the layers of spheres adjacent to the hot/cold walls play the most prominent role in the heat transfer reduction by hindering the high-velocity boundary layers along the hot/cold walls, and causing a portion of the fluid to divert away from these walls. This changes the stratified temperature distribution to a tilted one which leads to a lower overall heat transfer.

Dissertations

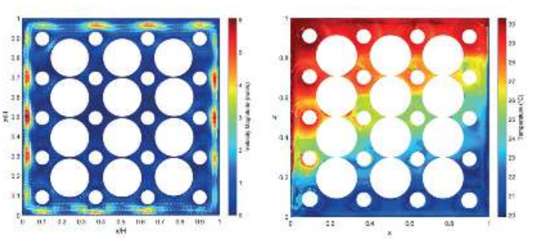
-

Scientific Publications

1. Ataei-Dadavi, I., Chakkingal, M., Kenjeres, S., Kleijn, C. R., & Tummers, M. J. (2019). Flow and heat transfer measurements in natural convection in coarse-grained porous media. International Journal of Heat and Mass Transfer, 130, 575-584.



Heat transfer data for spheres with different conductivities (left) and for a partially-filled cavity with a gap at hot/cold walls.



Mean velocity field (left) and mean temperature distribution (right) in the cavity filled with hydrogel spheres at Ra = 9.0×107.

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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PROJECT LEADERS
Dr. ir. Saša Kenjereš
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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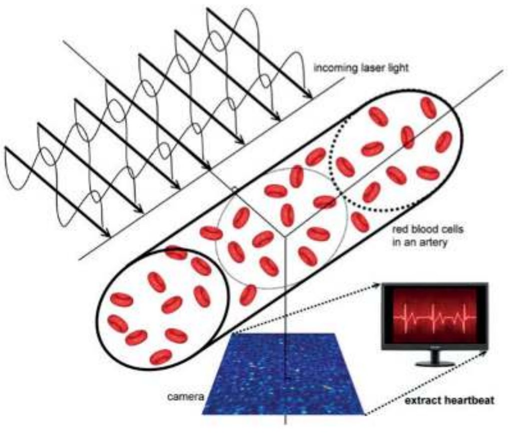
PROJECT AIM
Measuring inside turbid media – such as human tissue – is difficult, as they are non-transparent due to the heavy scattering of light. Coherent light scattering is a technique which makes use of the heavy scattering of the medium, and is thereby rapidly becoming a technique for non-invasive 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.

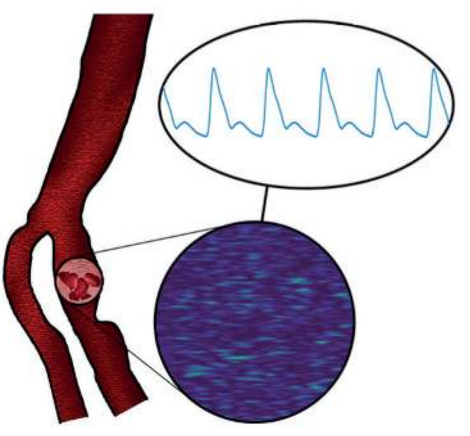
PROGRESS
We have created our own Mie optics code for computing the light scattering by spherical particles (representing red blood cells), and coupled it with OpenFOAM for simulating fluid dynamics. First, we have used our code for simulating simple cylindrical flows with a heartbeat modulation. From the scattered light (called speckle), we have retrieved the original heartbeat frequency. The same goal was achieved for flow inside a complex patient-specific carotid artery, where we took a first step towards detecting atherosclerosis using laser speckle imaging. Finally, we have made progress in measuring a local velocity; that is, a first step towards making the technique fully quantitative.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
1. “A custom OpenFOAM library for reducing spurious currents in (multiphase) volume-of-fluid simulations” was published via GitHub.
2. Manuscript in preparation for next paper.

(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-scale assisting and opposing mixed convection in a differentially heated cavity filled with coarse grained porous media (Figure 1) is carried out using open source CFD solver, OpenFOAM. Mixed convection at different Richardson numbers, in a cavity filled with water and hydrogel beads is analyzed. The heat transfer and flow in the cavity are compared with the results using Darcy assumption. Variation in heat transfer (Figure 2) between coarse grain media simulations and Darcy simulations is observed.

Dissertations

-

Scientific Publications

-

Project leaders

Prof. dr. ir. C. R. Kleijn
Prof. dr. Robert.F.Mudde
Dr.ir. Saša Kenjereš
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	88 %
NWO Other	-
Industry	12 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2016

Information

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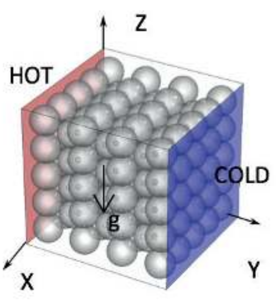
Cavity filled with coarse grained porous media. Mixed convection is induced by moving the hot and cold wall. Assisting: Hot wall moves up and cold wall moves down Opposing: Hot wall moves down and cold wall moves up

Change in heat transfer (Nuf) with Richardson Number (Rim) (a) Assisting mixed convection (b) Opposing mixed convection.



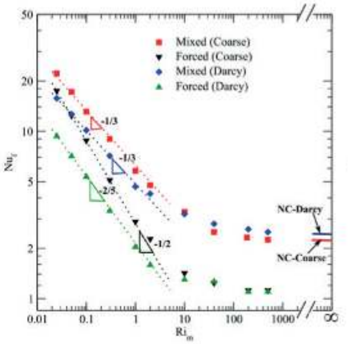


Figure 2(a)

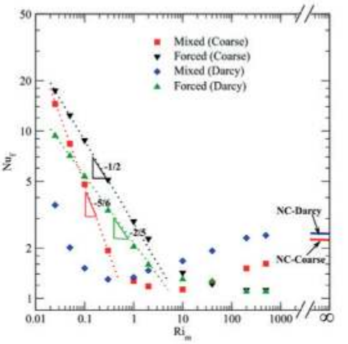


Figure 2 (b)

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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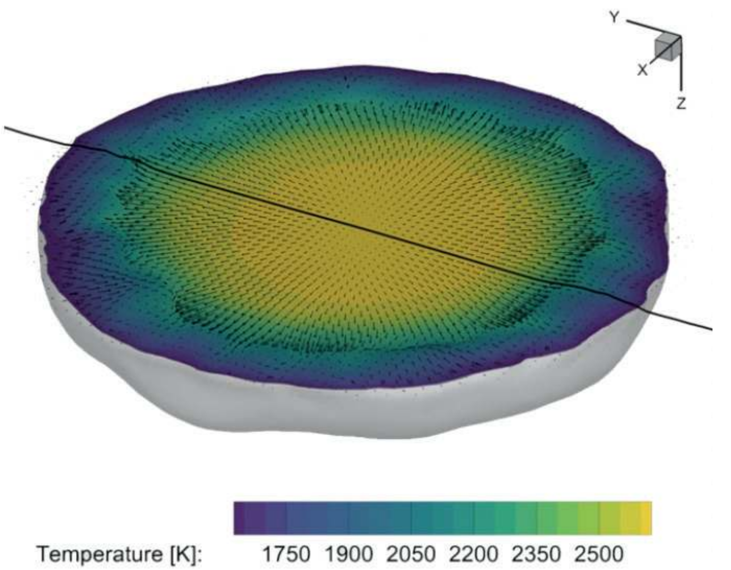
Project Aim
This project is devoted to the stability analysis of fusion welding processes. The primary aim of this research is to construct a novel, physically-based numerical approach for assessing the stability of a melt pool with two free surfaces, suspended between solid side walls and subject to 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
The performance of the enthalpy-porosity technique in modelling phase-change processes was scrutinised, with a focus on the influence of the permeability coefficient on the numerically predicted results. A dimensionless number was introduced to assess the sensitivity of numerical predictions to the permeability coefficient. The oscillatory thermo-capillary driven fluid flow behaviour in low-Prandtl melt pools was also studied for a surface melting process using different high energy flux distributions. Self-excited flow instabilities in the melt pool were observed and it was found that free surface deformations destabilise fluid flow inside the melt pool, which can influence the melt pool shape significantly.

Dissertations
-

Scientific Publications
-

Contours of temperature and the velocity vectors on the melt pool free surface during laser spot melting. The grey area shows the fusion boundary of the melt pool



PROJECT AIM

While the influence of perturbations at the film interface arising from thermal fluctuations have been extensively studied in the context of planar film rupture, their influence on non-planar film with a non-zero curvature has not yet been explicitly studied. The addition of curvature introduces an additional thinning mechanism of drainage, which is not present in the planar films. The aim of the present work is to systematically explore the parameter space consisting of the strength of the drainage and the strength of thermal noise, to delineate the relevance of thermal fluctuations, or the lack thereof in describing film lifetimes in foams and emulsions.

PROGRESS

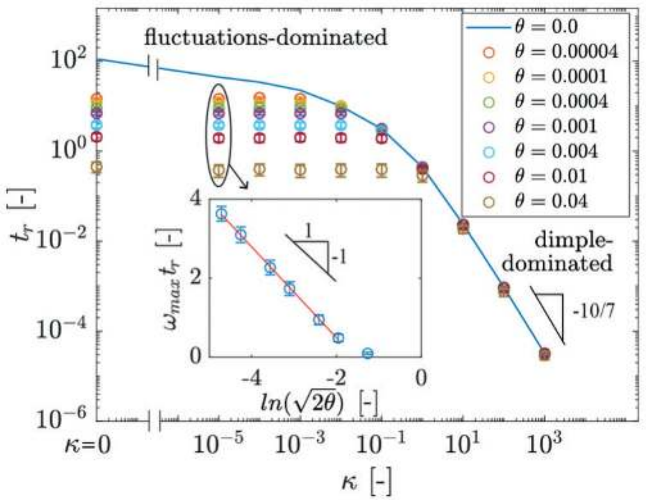
How film lifetimes depend on the strength of drainage, κ, and that of the noise strength, θ, is illustrated in figure 1. With strong drainage (κ » κtr, where κtr is the transition strength of drainage between the two regimes discussed below), film rupture occurs predominantly due to the dimple formation and the earlier established scaling rule for film lifetime with κ still holds, irrespective of the strength of noise. With weak drainage (κ « κtr), film rupture occurs due to spontaneous growth of perturbations of film interface due to fluctuations, and thereby depends only on the strength of noise, independent of κ. In this fluctuations-dominated regime, the dependence of film lifetimes on noise strength can be rationalized using a linear stability theory.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Kreutzer, M.T., Shah, M.S., Parthiban, P., Khan, S.A., Evolution of nonconformal Landau-Levich-Bretherton films of partially wetting liquids, Phys. Rev. Fluids 3, 014203.



Dimensionless rupture times [$t/(12\pi^2\gamma\mu h0^2/A^2)$] versus dimensionless curvature (ratio of two competing pressures: laplace pressure/van der Waals disjoining pressure ($\pi h0^3\gamma/Ar$) for different values of noise strength ($k_h T/\gamma h0^2$)

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

INFORMATION

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PROJECT LEADERS
Prof. dr. ir. C. R. Kleijn
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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

INFORMATION
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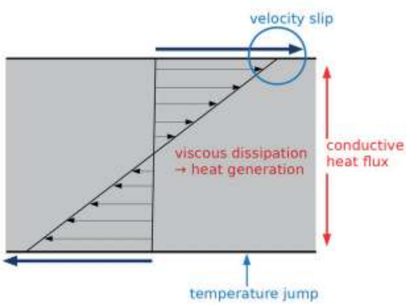
PROJECT AIM
Physical Vapor Deposition (PVD) processes are traditionally used at a small scale and for batch processes. For the upscaling to a continuous process it is necessary to use multiple vapor jets (see fig.1) with a high mass flow rate. The project aims at understanding the physics of the metal vapor transport towards the surface. There are three major aims in this project: First the development of a hybrid solver coupling a method appropriate for low Knudsen numbersand Direct Simulation Monte Carlo (DSMC). Secondly, understanding the physics in continuous a PVD line, especially interacting jets (see fig. 2). Eventually, using the obtained knowledge for process optimization.

PROGRESS
A collision limiter and multiple kinetic models based on the Bhatnagar-Gross-Krook formalism, which shall later be used as the CFD part of the problem, have been implemented in OpenFoam. They have been evaluated for a rarefied Couette flow between isothermal walls. The heat generated by the viscous dissipation is only partially transported towards the walls. A velocity slip and temperature jump occur at the walls. While the collision limiter agrees with the DSMC solution and the Bhtanagar-Gross-Krook model (BGK) behaves as expected, the implementation of the Ellipsoidal Statistical BGK model (ESBGK) shows an overpredicted velocity slip and temperature jump.

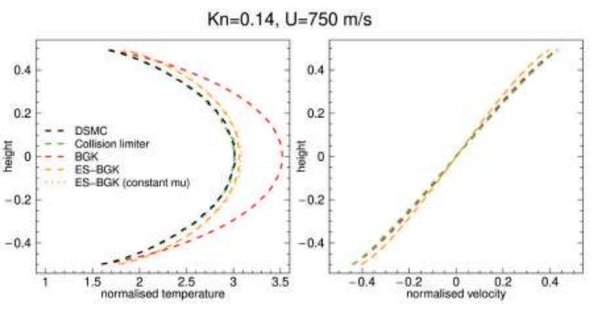
DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-

Sketch of the physical phenomena in a rarefied Couette flow.



Temperature and velocity profile of rarefied Couette flow. Comparison of implemented models



Project Aim

The project is aimed at studying the fundamentals of mass transfer in bubbly flows, inspired by industrial applications. The approach as part of the PhD project will involve a multiscale study: from bubble-bubble interaction studies to swarm flows. This involves understanding the interaction between local hydrodynamic forces and mass transfer and its implications on global transport process. Experimentally, focus is placed on developing and using minimally-intrusive light and radiation-based techniques to study flow and concentration profiles.

Progress

During the reporting period, focus was been placed on studying developing non-intrusive measurement techniques for measurement of hydrodynamics and mass transfer. Techniques such as: X-ray imaging, high speed imaging and bubble image velocimetry were used to measure dense bubbly flows, in presence of dissolved electrolytes. At single bubble level, dissolution of CO_2 into water has be studied using Laser induced fluorescence technique (figure 1 (a) & (b)). Furthermore, with visual tomographic technique, oscillations in bubble shape (figure 1 (c)) can be captured. Current knowledge of techniques will be used to understand interaction between shrinking cluster of bubbles to better decouple local phenomena in dense flows.

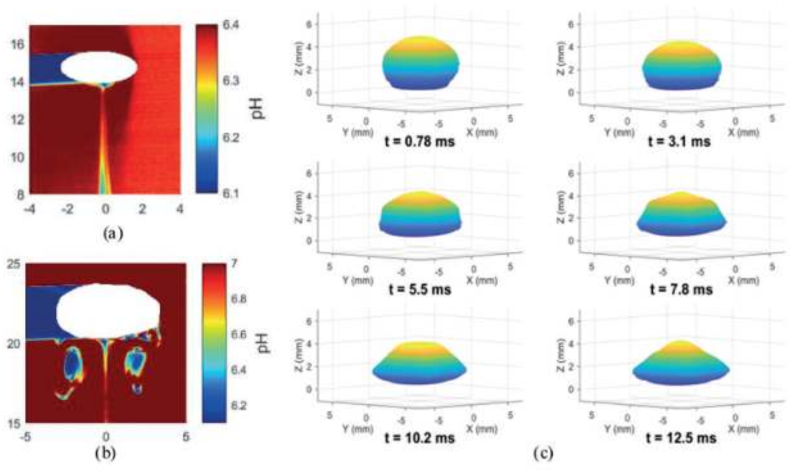
Dissertations

-

Scientific Publications

-

Results from experiments. Laser induced fluorescence: dissolution of CO_2 behind bubble of size: (a) 2.5mm (b) 5.2mm (white area indicates location of bubble); (c)Visual tomographic reconstruction: shape oscillations of a single 5.2mm N_2 bubble (colors used for 3D contrast).



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

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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
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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. Our equipment is unique in the world; only at the Rossendorf Forschungscenter a similar type of device is available, but - unlike our setup - the latter cannot measure in equipment of 10cm diameter or larger.

Progress

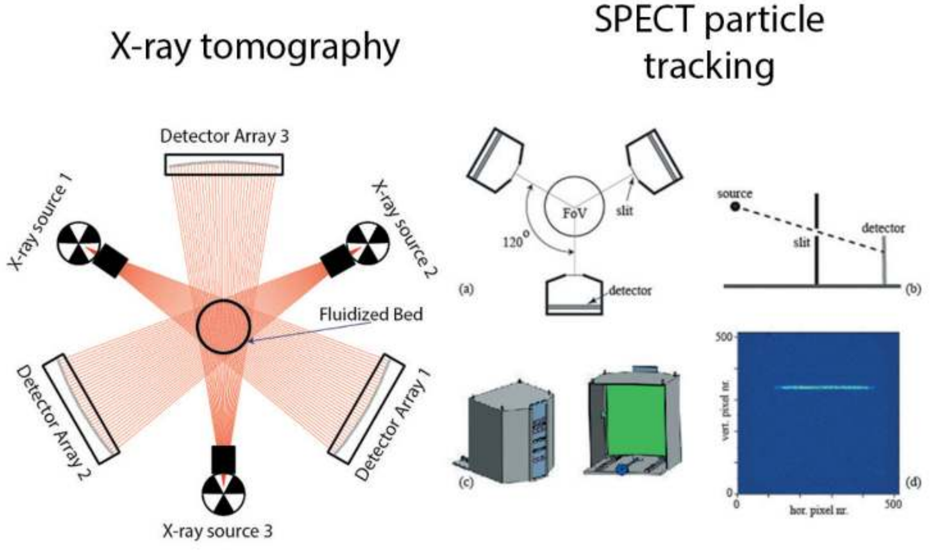
We have completed the move to a new lab, combining X-ray tomography and SPECT particle tracking in one frame. First tests with synchronous experiments planned in 2019. Advances have been made in X-ray particle tracking capabilities in liquid metal, results expected in 2019. New and ongoing collaborations with TUD-3mE (Poelma, Padding), and PSI Switzerland (Schildhauer) in experiments concerning cavitation, fluidized beds. Working on re-writing reconstruction algorithm for fast multi-CPU/GPU processing based on ASTRA toolbox.

Dissertations

-

Scientific Publications

1. F. Schillinger, J. Schildhauer, S. Maurer, E. Wagner, R.F. Mudde, J.R. van Ommen, Generation and evaluation of an artificial optical signal based on X-ray measurements from bubble characterization in fluidized beds with vertical internals. International Journal of Multiphase Flow 107 (2018) 16–32.



Project Aim

Coalescence and break-up of droplets governs numerous industrial processes. The current practice of predicting and modeling such systems lacks fundamental rigor, making the scale-up and scale-down procedures unreliable. The aim of this project is to develop a mesoscopic DNS framework to study droplet dynamics under turbulent conditions in surfactant laden emulsions. The results can help formulate more accurate coalescence and break-up models useful for macroscopic simulations.

Progress

A multi-component lattice-Boltzmann method was successfully coupled with a homogeneous, isotropic turbulence forcing scheme to study the formation of emulsions/dispersions due to turbulence. Various aspects of this system were studied, including the effect of varying volume fractions on the emulsion morphology, modification of the turbulence energy spectra below and above the Hinze scale and droplet size distributions. The quasi-equilibrium of coalescence and breakup was shown to comprise time delayed limit cycles in the state space of kinetic energy, dissipation, droplet number density and surface energy, which can have important consequences for simplified kernel models currently in use. Droplets were shown to strongly enhance vortex compression in turbulence flow topology. These results have been prepared as a manuscript to be submitted to JFM. The paper on modeling surfactants using pseudo-potential LB was accepted for publication in AIChE Journal, and the paper on inter-comparison of LB and VOF for simulating droplets was published in IJHFF.

Dissertations

-

Scientific Publications

1. Mukherjee, Siddhartha, et al. “Droplet-turbulence interactions and quasi-equilibrium dynamics in turbulent emulsions” Journal of Fluid Mechanics (to be submitted).
2. Mukherjee, Siddhartha, et. al. “A lattice Boltzmann approach to surfactant-laden emulsions.” AIChE Journal (accepted).
3. Mukherjee, Siddhartha, et al. “Simulating liquid droplets: A quantitative assessment of lattice Boltzmann and Volume of Fluid methods.” International Journal of Heat and Fluid Flow 70 (2018): 59-78. (published).

Project leaders

Dr. Saša Kenjereš, Dipl-Ing

Prof. dr. ir. H.E.A Van den Akker

Prof. dr. Robert F. Mudde

Research theme

Complex dynamics of fluids

Participants

Ir. Siddhartha Mukherjee

Cooperations

-

Funded by

ISPT

Funded %

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

Start of the project

2015

Information

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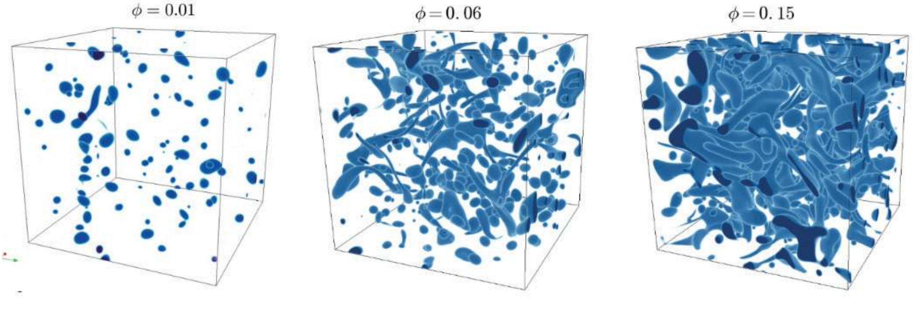

Snapshots of turbulent emulsions with varying volume fraction. The density field shows the distribution of droplet sizes in the domain

Product and process engineering

Prof.dr.ir. MT Kreutzer

Prof.dr.ir. R van Ommen

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 – led by Michiel Kreutzer – 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.

Project Aim

To develop a better understanding of agglomeration in spray drying processes, by studying the drying and subsequent collisions of solute-containing droplets. Key for this understanding is to connect drying kinetics of single droplets to agglomeration behavior of colliding droplets and particles. Additionally, by decreasing the size of droplets reduced to sub-100 µm, we aim to better mimic the conditions in the spray dryer.

Progress

A free-falling dryer is in development. Droplets between 200-500µm are dispensed using a PipeJet®

A dispensing event triggers a camera at a set delay to image the falling droplet at the desired height. Currently, this triggering system is operational. To pursue <100µm droplets, liquid-in-gas microfluidics has been used to dispense water droplets of 80µm diameter (Fig. 1.). Rapid evaporation has been observed. Addition of solute resulted in deposition on the channel wall. Future work aims to address this. Internal structure and flows in drying droplets have been investigated for whey protein and maltodextrin using Optical Coherence Tomography (OCT) (Fig. 2.).

Dissertations

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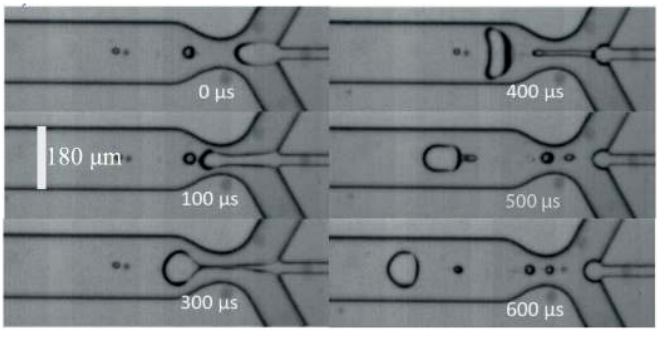
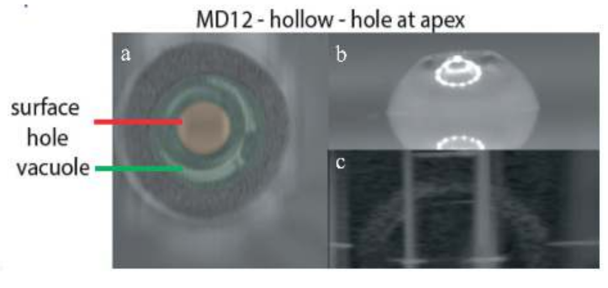
Scientific Publications

-

Dispensing of water droplets in continuous gas phase. Calculated spherical diameter ~ 80µm





a) Top-view 2D-OCT image at droplet base, surface hole and vacuole are clearly visible. b) Conventional side-view camera image. c) Side-view 2D-OCT slice of droplet, showing internal vacuole.

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

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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 AIM

While the influence of perturbations at the film interface arising from thermal fluctuations have been extensively studied in the context of planar film rupture, their influence on non-planar film with a non-zero curvature has not yet been explicitly studied. The addition of curvature introduces an additional thinning mechanism of drainage, which is not present in the planar films. The aim of the present work is to systematically explore the parameter space consisting of the strength of the drainage and the strength of thermal noise, to delineate the relevance of thermal fluctuations, or the lack thereof in describing film lifetimes in foams and emulsions.

PROGRESS

How film lifetimes depend on the strength of drainage, κ, and that of the noise strength, θ, is illustrated in figure 1. With strong drainage (κ » κtr, where κtr is the transition strength of drainage between the two regimes discussed below), film rupture occurs predominantly due to the dimple formation and the earlier established scaling rule for film lifetime with κ still holds, irrespective of the strength of noise. With weak drainage (κ « κtr), film rupture occurs due to spontaneous growth of perturbations of film interface due to fluctuations, and thereby depends only on the strength of noise, independent of κ. In this fluctuations-dominated regime, the dependence of film lifetimes on noise strength can be rationalized using a linear stability theory.

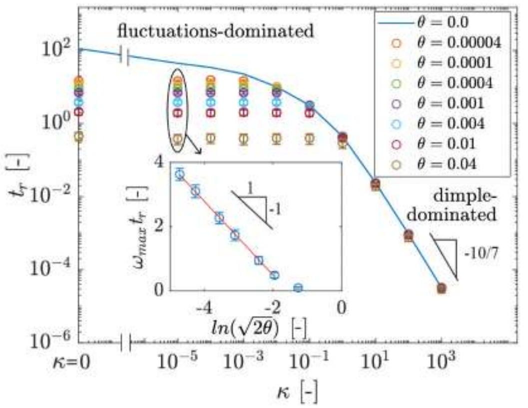
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Kreutzer, M.T., Shah, M.S., Parthiban, P., Khan, S.A., Evolution of nonconformal Landau-Levich-Bretherton films of partially wetting liquids, Phys. Rev. Fluids 3, 014203.

Dimensionless rupture times [$t/(12\pi^2\gamma\mu h0^2/A^2)$] versus dimensionless curvature (ratio of two competing pressures: laplace pressure /van der Waals disjoining pressure ($\pi h0^3\gamma/Ar$) for different values of noise strength ($k_bT/\gamma h_0^2$)



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. de Martín, L., Ottevanger, C., van Ommen, J. R., & Coppens, M. O. (2018). Universal stability curve for pattern formation in pulsed gas-solid fluidized beds of sandlike particles. Physical Review Fluids, 3(3), 034303.

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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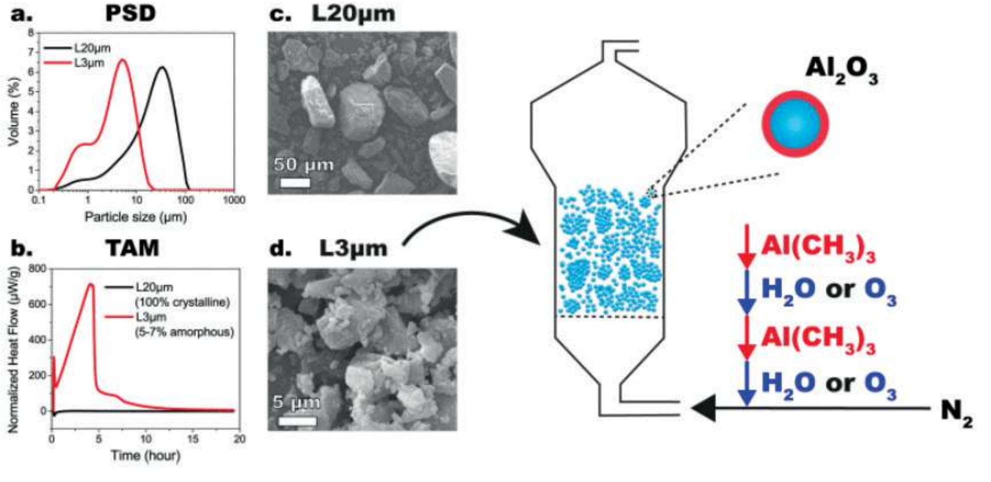

Numerical analysis

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

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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
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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. M. Baumann, Fast Iterative Solution of the Time-Harmonic Elastic Wave Equation at Multiple Frequencies 2018, 147 p.
2. Astudillo Rengifo, R, Induced Dimension Reduction algorithms for solving non-symmetric sparse matrix problems, 2018, 127 p.

SCIENTIFIC PUBLICATIONS

1. V. Gaiko and C. Vuik and H. Reijm, Bifurcation Analysis of a Multi-Parameter Lienard Polynomial System, IFAC-PapersOnLine, 51, pp. 144-149, 2018
2. C. Vuik, Krylov Subspace Solvers and Preconditioners, ESAIM: Proceedings and Surveys, 63, pp.1-43, 2018
3. V. Gaiko and C. Vuik, Global Dynamics in the Leslie-Gower Model with the Allee Effect, International Journal of Bifurcation and Chaos, 28, 1850151 pp. 1-10 (2018)
4. M. HosseiniMehr and M. Cusini and C. Vuik and H. Hajibeygi, Algebraic dynamic multilevel method for embedded discrete fracture model (F-ADM), Journal of Computational Physics, 373, pp. 324-345, 2018
5. X. He and C. Vuik and C. Klaij, Combining the Augmented Lagrangian Preconditioner with the Simple Schur Complement Approximation, SIAM Journal on Scientific Computing, 40, pp. A1362-A1385, 2018
6. Yue Qiu and Martin B. van Gijzen and Jan-Willem van Wingerden and Michel Verhaegen and Cornelis Vuik, Evaluation of multilevel sequentially semiseparable preconditioners on computational fluid dynamics benchmark problems using Incompressible Flow and Iterative Solver Software Mathematical Methods in the Applied Sciences, 41, pp. 888-903, 2018
7. G.B. Diaz Cortes and C. Vuik and J.D. Jansen, On POD-based Deflation Vectors for DPCG applied to porous media problems, Journal of Computational and Applied Mathematics, 330, pp. 193-213, 2018

8. M. HosseiniMehr and M. Cusini and C. Vuik and H. Hajibeygi, Algebraic Dynamic Multilevel Method for Single-phase Flow in Heterogeneous Geothermal Reservoirs, ECMOR XVI - 16th European Conference on the Mathematics of Oil Recovery, September 3-6, 2018. Editor: D. Gunasekera. EAGE, Barcelona, pp. 1-11, 2018
9. G.B. Diaz Cortes and J.D. Jansen and C. Vuik, On The Acceleration Of Ill-Conditioned Linear Systems: A Pod-Based Deflation Method For The Simulation Of Two-Phase Flow, ECMOR XVI - 16th European Conference on the Mathematics of Oil Recovery, September 3-6, 2018. Editor: D. Gunasekera. EAGE, Barcelona, pp. 1-22, 2018
10. R. Tielen and M. Moeller and C. Vuik, Efficient Multigrid based solvers for isogeometric analysis Proceedings of the 6th European Conference on Computational Mechanics (ECCM 6) and 7th European Conference on Computational Fluid Dynamics (ECFD 7) 1115 June 2018, Glasgow, UK Editors: R. Owen and R. de Borst and J. Reese, ECCOMAS, CIMNE, Barcelona, pp. 1-12, 2018

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	-

Start of the project
2018

Information
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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(10¬8) 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
-

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 H. Eding and M.P.L. Calus and C. Vuik , Deflated preconditioned conjugate gradient method for solving single-step BLUP models efficiently Genetics Selection Evolution, 50:51, pp. 1-17, 2018.
2. E. Brunner and C.C. de Visser and C. Vuik and M. Verhaegen, GPU implementation for spline-based wavefront reconstruction, Journal of the Optical Society of America A, 35, pp.859-872, 2018.
3. J. Vandenplas and H. Eding and M.P.L. Calus and C. Vuik, Deflated preconditioned conjugate gradient method for solving single-step single nucleotide polymorphism BLUP, Proceedings of the World Congress on Genetics Applied to Livestock Production 11.25, pp. 1-7, 2018.

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

Information

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Project leaders
C. Vuik, F.J. Vermolen
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
2007
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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

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Scientific Publications

1. J. Hinz and M. Moeller and C. Vuik, Spline-Based Parameterization Techniques for Twin-Screw Machine Geometries, IOP Conference Series: Materials Science and Engineering, 425, 012030, 2018 Discontinuous Galerkin method
2. J J. Hinz and M. Moeller and C. Vuik, Elliptic grid generation techniques in the framework of isogeometric analysis applications, Computer Aided Geometric Design, 65, pp. 48-75, 2018.
3. J. Hinz and M. Moeller and C. Vuik , Spline-based meshing techniques for industrial applications Proceedings of the 6th European Conference on Computational Mechanics (ECCM 6) and 7th European Conference on Computational Fluid Dynamics (ECFD 7) 1115 June 2018, Glasgow, UK. Editors: R. Owen and R. de Borst and J. Reese. ECCOMAS, CIMNE, Barcelona, pp. 1-12, 2018
4. E. Wobbes and M. M\"oller and V. Galavi and C. Vuik, Taylor Least Squares reconstruction technique for material point methods, Proceedings of the 6th European Conference on Computational Mechanics (ECCM 6) and 7th European Conference on Computational Fluid Dynamics (ECFD 7) 1115 June 2018, Glasgow, UK. Editors: R. Owen and R. de Borst and J. Reese. ECCOMAS, CIMNE, Barcelona, pp. 1-12, 2018

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

-

Scientific Publications

1. Palmes, C.; Funke, B.; Hosseini, B.: Nonparamtetric low-frequency Lévy copula estimation in a general framework, Journal of Nonparametric Statistics, 523-555, https://doi.org/10.1080/10485252.2018.1474215, 2018

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

Information

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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
2017
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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.

Dissertations

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Scientific Publications

1. Conservative Taylor least squares reconstruction with application to material point methods. Wobbes, E., Möller, M., Galavi, V. & Vuik, C., 2018, Delft: Delft University of Technology. 35 p. (Reports of the Delft Institute of Applied Mathematics; vol. 18-02).
2. Efficient Multigrid based solvers for isogeometric analysis. Tielen, R., Möller, M. & Vuik, K., 2018, Proceedings of the 6th European Conference on Computational Mechanics (ECCM 6) and 7th European Conference on Computational Fluid Dynamics (ECFD 7). Owen, R., de Borst, R. & Reese, J. (eds.). Barcelona: ECCOMAS, p. 1-12 12 p.
3. Taylor Least Squares reconstruction technique for material point methods Wobbes, L., Möller, M., Galavi, V. & Vuik, K., 2018, Proceedings of the 6th European Conference on Computational Mechanics (ECCM 6) and 7th European Conference on Computational Fluid Dynamics.

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 parameterisations 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.

Dissertations

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Scientific Publications

1. Elliptic grid generation techniques in the framework of isogeometric analysis applications. Hinz, J., Möller, M. & Vuik, C., 2018, In : Computer Aided Geometric Design. 65, p. 48-75 28 p.
2. Spline-Based Parameterization Techniques for Twin-Screw Machine Geometries Hinz, J., Möller, M. & Vuik, C., 2018, In : IOP Conference Series: Materials Science and Engineering. 425, p. 1-19 19 p., 012030.
3. Spline-based meshing techniques for industrial applications. Hinz, J., Möller, M. & Vuik, K., 2018, Proceedings of the 6th European Conference on Computational Mechanics (ECCM 6) and 7th European Conference on Computational Fluid Dynamics (ECFD 7). Owen, R., de Borst, R. & Reese, J. (eds.). Barcelona: ECCOMAS, p. 1-12 12 p.

Project leaders

M. Möller

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Jochen Hinz, M. Möller

Cooperations

Johannes Kepler Universität Linz, Austria; Technische Universität Dortmund, Germany; RWTH Aachen, Germany

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
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 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 obtained on the mesh generation, the non-reactive and reactive flow computation of the rotary in use by our industrial partner. In cooperation with its developers, the mesh generator cfmesh was employed to obtain quality meshes close to the inlet nozzles and on the interface between the lining and freeboard. Non-reactive and reactive flow computations for two geometries of the combustion air inlet were performed. The co-axial air inlet was shown to result in a stable flow pattern.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. El Abbassi, Lahaye, Vuik, “Simulation of Turbulent Non-Premixed Combustion and Conjugate Heat Transfer Applied to An Industrial Rotary Kiln Test Case” submitted to HTFF-2019 Lisbon, Portugal.

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 obtained in the modeling of the turbulent isothermal flow of air in a single section of an anode baking furnace.

Dissertations

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Scientific Publications

1. P. Nakate, D. Lahaye, C. Vuik, Numerical Modeling of Anode Baking Furnace with COMSOL Multiphysics, COMSOL Multiphysics Users Conference, Lausanne, Zwitserland, 2018.
2. P. Nakate, Numerical Simulation of Anode Baking Furnace: Simplified Model of 2D Turbulent Reacting Flow in the 2D Cross-Section, Combura Symposium, October 9th-10th, Soesterberg.

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 leaders
Fred Vermolen

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Bernard Meulenbroek, Menel Rahrah, Luis Antonio Lopez

Cooperations
-

Funded by
-

Funded %

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

Start of the project
2015

Information
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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. Conditions for upscalability of bioclogging in pore network models, Lopez Pena, L. A., Meulenbroek, B. & Vermolen, F., 2018, In : Computational Geosciences. 22, 6, p. 1543-1559 17 p.
2. Monte Carlo Assessment of the Impact of Oscillatory and Pulsating Boundary Conditions on the Flow Through Porous Media. Rahrah, M. & Vermolen, F., 2018, In : Transport in Porous Media. p. 1-22 22 p.

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

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Scientific Publications

1. A Discontinuous Galerkin Model for the Simulation of Chemotaxis Processes: Application to Stem Cell Injection After a Myocardial Infarction: Discontinuous Galerkin methods. Vermolen, F. J., Crapts, L. Y. D. & Ryan, J. K., 2018, Numerical Methods and Advanced Simulation in Biomechanics and Biological Processes. Cerrolaza, M., Shefelbine, S. & Garzón-Alvarado, D. (eds.). Elsevier Inc., p. 95-115 21 p.
2. A Particle Finite Element-Based Framework for Differentiation Paths of Stem Cells to Myocytes and Adipocytes: Hybrid Cell-Based and Finite Element Modeling. Vermolen, F. J., Harrevelt, S., Gefen, A. & Weihs, D., 2018, Numerical Methods and Advanced Simulation in Biomechanics and Biological Processes. Cerrolaza, M., Shefelbine, S. & Garzón-Alvarado, D. (eds.). Elsevier Inc., p. 171-185 15 p.
3. Continuum-Scale Models for the Evolution of Hypertrophic Scars and Contractions after burn injuries, F.J. Vermolen, D.C. Koppenol, Computer Methods in Biomechanics and Biomedical Engineering. Proceedings of the 14th International Symposium CMBBE, Tel Aviv, Israel, 2016.

Project leaders

Fred Vermolen

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Daniel Koppenol, Qiyao Peng

Cooperations

Beverwijk Burns Hospital

Funded by

Dutch Burns Foundation

Funded %

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

Start of the project

2012

Information

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Project leaders
Fred Vermolen
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Jiao Chen, Fred Vermolen, Daphne Weihs, Ilkka Polonen
Cooperations
Technion, Haifa, Israel
Jyvaskyla University, Finland
Funded by
-
Funded %

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

Start of the project
-
Information
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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

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Scientific Publications

1. A phenomenological model for cell and nucleus deformation during cancer metastasis. Chen, J., Weihs, D., van Dijk, M. & Vermolen, F. J., 2018, In : Biomechanics and Modeling in Mechanobiology. 17, 5, p. 1429-1450 22 p.
2. Monte Carlo uncertainty quantification in modelling cell deformation during cancer metastasis. Chen, J., Weihs, D. & Vermolen, F., 2018, CMBBE2018.
3. A model for cell migration in non-isotropic fibrin networks with an application to pancreatic tumor islets. Biomechanics an Modeling in Mechanobioloqy, 17(2), 2018, 367-386.

Prof.dr.ir. AW Heemink

Prof.dr.ir. ELC Deleersnijder

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

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SCIENTIFIC PUBLICATIONS

1. Spatially varying parameter estimation for dust emissions using reduced tangent linearization 4Dvar, J. Jin, H.X. Lin, A.W. Heemink, A.J. Segers, Atmospheric Environment, Vol. 187, 2018, pp 358-373.
2. Non-intrusive subdomain POD-TPWL for reservoir history matching, C. Xiao, O. Leeuenburch, H.X. Lin, A.W. Heemink, Computational Geosciences,, 2018, https://doi.org/10.1007/s10596-018-9803-z.

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 %

START OF THE PROJECT

2001

INFORMATION

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Project leaders
A.W. Heemink
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
W.T. van Horssen, H.M. Schuttelaars, J.L.A. Dubbeldam, A. Geyer, Y. van Gennip, T. Akkaya, M. Kumar, X. Wei, K. Xi, Y. Dijkstra, Jin Jianbing, Xiao Deng, Wang Jing, Jie Liu
Cooperations
-
Funded by
-
Funded %

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

Start of the project
2003
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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 2018 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. Power system stability and frequency control for transient performance improvement, Kaihua Xi, 2018, PhD thesis, promotor: H.X. Lin and J.H. van Schuppen, co-promotor: J.L.A. Dubbeldam.
2. Three-dimensional model for estuarine turbidity maxima in tidally dominated estuaries, Mohit Kumar, 2018, PhD thesis, promotor: H.M. Schuttelaars, co-promotor: P.C. Roos.
3. BiGlobal stability of shear flows: spanwise and streamwise analyses, Koen Groot, 2018, PhD thesis, promotor: B.W. van Oudheusden, M. Kotsonis, and H.M. Schuttelaars.
4. On boundary damping for elastic structures, Tugce Akkaya, 2018, PhD thesis, promotor: A.W. Heemink, co-promotor: W.T. van Horssen.

Scientific Publications

1. Shallow water equations for equatorial tsunami waves, Geyer, A. & Quirchmayr, R., 2018, In : Royal Society of London. Philosophical Transactions A. Mathematical, Physical and Engineering Sciences. 376, 2111, p. 1-12 12 p.
2. Traveling wave solutions of a highly nonlinear shallow water equation, Geyer, A. & Quirchmayr, R., 2018, In : Discrete and Continuous Dynamical Systems A. 38, 3, p. 1567-1604 38 p.
3. Triadic Split-Merge Sampler, van Rossum, A. C., Lin, H. X., Dubbeldam, J. & van den Herik, J., Apr 2018, Proceedings of Tenth International Conference on Machine Vision (ICMV 2017). Verikas, A., Radeva, P., Nikolaev, D. & Zhou, J. (eds.). 1 ed. SPIE, Vol. 10696. 8 p.
4. Power-Imbalance Allocation Control of Power Systems-Secondary Frequency Control, Xi, K., Dubbeldam, J. L. A., Lin, H. X. & van Schuppen, J. H., 2018, In : Automatica. 92, p. 72-85 14 p.
5. Dynamic simulation of a multi-cable driven parallel suspension platform with slack cables, Wang, Y., Cao, G. & van Horssen, W. T., 2018, In : Mechanism and Machine Theory. 126, p. 329-343 15 p.
6. On solving wave equations on fixed bounded intervals involving Robin boundary conditions with time-dependent coefficients, van Horssen, W. T., Wang, Y. & Cao, G., 2018, In : Journal of Sound and Vibration. 424, p. 263-271 9 p.

7. Resonances and vibrations in an elevator cable system due to boundary sway, Gaiko, N. V. & van Horssen, W. T., 2018, In : Journal of Sound and Vibration. 424, p. 272-292 21 p.
8. Sediment Trapping in Estuaries, Burchard, H., Schuttelaars, H. M. & Ralston, D. K., 2018, In : Annual Review of Marine Science. 10, p. 371-395 25 p.
9. The effect of geometry and tidal forcing on hydrodynamics and net sediment transport in semi-enclosed tidal basins: A 2D exploratory model, Boelens, T., Schuttelaars, H., Schramkowski, G. & De Mulder, T., 2018, In : Ocean Dynamics. 68, 10, p. 1285-1309 25 p.
10. The hyperturbid state of the water column in estuaries and rivers: The importance of hindered settling, Dijkstra, Y. M., Schuttelaars, H. M. & Winterwerp, J. C., 2018, In : Ocean Dynamics. 68, 3, p. 377-389 13 p.
11. Three-Dimensional Sediment Dynamics in Well-Mixed Estuaries: Importance of the Internally Generated Overtide, Spatial Settling Lag, and Gravitational Circulation, Wei, X., Kumar, M. & Schuttelaars, H. M., 2018, In : Journal of Geophysical Research: Oceans. 123, 2, p. 1062-1090 29 p.
12. Time Evolution of Estuarine Turbidity Maxima in Well-Mixed, Tidally Dominated Estuaries: The Role of Availability- and Erosion-Limited Conditions, Brouwer, R. L., Schramkowski, G. P., Dijkstra, Y. M. & Schuttelaars, H. M., 2018, In : Journal of Physical Oceanography. 48, 8, p. 1629-1650 22 p.

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
COOPERATIONS
TNO, CMA 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 desert 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

-

SCIENTIFIC PUBLICATIONS

1. J. Jin, H.X. Lin, A.W. Heemink, A. Segers (2018), Spatially varying parameter estimation for dust emissions using reduced-tangent-linearization 4DVar, Atmospheric Environment, Vol.187, pp. 358-373.

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.

LDA and PIV measurements of crossflow and flow-induced vibrations inside a hexagonal 7-rods bundle facility

Project Aim

Design and construction of two hexagonal 7-rods bundle facilities: one for studying flow-induced vibrations (SEEDS1), and the other for studying the flow in a rod bundle with wrapping wire (SEEDS2). Experiments study the flow inside the gap between the rods, large coherent structures occurring in the stream, and the frequency with which the structure oscillates under the influence of coherent structures. The experiments are being done with LDA, high speed camera and, eventually, with PIV.

Progress

Operation of two experimental hexagonal rod bundles, SEEDS-1 and SEEDS-2. SEEDS1: the results have contributed to a new correlation to predict the length of the periodical structures forming in the bundle, and they have shown the mutual interaction, i.e. vibrations, between the flow and some components of the setup. SEEDS2: the results of the PIV measurements have provided more insight into the flow behavior under the action of transversal pressure gradient caused by the geometry: a new equation has been derived to describe such an action.

Dissertations

-

Scientific Publications

1. F. Bertocchi, M. Rohde, C. Spaccapaniccia, P. Planquart, “Rod bundle and pool type experiments in water serving liquid metal reactors”, Chapter 3.1 in “Thermal Hydraulic Aspects of Liquid Metal Cooled Reactors”, Woodhead Publishing Series in Energy, 2018.
2. F. Bertocchi, M. Rohde, J. L. Kloosterman, “LDA measurements of coherent flow structures and cross-flow across the gap of a compound channel with two half-rods”, Nuclear Engineering and Design vol. 326, pp 17-30, 2018.
3. H. Dolfen, F. Bertocchi, M. Rohde, J. Vierendeels, J. Degroote, “Investigation of the gap vortex street in densely packed tube arrays in axial flows using cfd and experiments”, Proc. 6th European Conference on Computational Mechanics-7th European Conference on Computational Fluid Dynamics, Glasgow (UK).
4. H. Dolfen, F. Bertocchi, M. Rohde, J. Vierendeels, J. Degroote, “Numerical investigation of vortex-induced vibrations of a bundle of cylinders in axial flow”, Proc. 9th International Symposium on Fluid-Structure Interactions, Flow-Sound Interactions, Flow-Induced Vibration & Noise, Toronto (Canada), 2018.

Project leaders
M Rohde

Research theme
Complex structures of fluids

Participants
F Bertocchi, M Rohde,
J L Kloosterman

Cooperations
SESAME project (H2020)

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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Numerical study of heat transfer in supercritical fluids with a discontinuous Galerkin method

Project leaders
Dr. D. Lathouwers, dr. M. Rohde
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Aldo Hennink
Cooperations
-
Funded by
'sCO2-HeRo project', Horizon 2020 Framework Program of the European Commission under Grant Agreement No. 662116
Funded %

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

Start of the project
2015
Information
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Project Aim

Develop a discontinuous Galerkin method finite element to simulate heat transfer in a supercritical fluid. Conventional methods in computation fluid dynamics are often not suitable for flows of supercritical fluids, so I will adjust existing numerical methods to make them applicable to supercritical fluids. Turbulent flows are modeled with large eddy simulations.

Progress

I have developed an in-house computational fluid dynamics solver that is based on the discontinuous Galerkin method. I have imlpemented and validated several large eddy simulation (LES) models for isothermal flows. The LES simulations for supercritical fluids are verified. Hopefully they will soon be validated as well.

Dissertations

-

Scientific Publications

-

Three-dimensional, multi-physics simulation of a molten salt fast reactor

Project Aim

The goal of the PhD research (part of the European SAMOFAR project) is to verify the safe operations of the Gen. IV MSFR during accident scenarios. To simulate them, advanced 3D multi-physics models must be developed, taking into account the physics of radiation transport, fluid flow (turbulent) and heat transfer specific for this reactor. The high-order Discontinuous Galerkin Finite Element numerical method is used to consistently improve the accuracy of simulations.

Progress

Continuation of the development and testing of the in-house multiphysics code. Main achivements include: parallelization of CFD code (shows good scalability), implementation of high-order BDF time-schemes, addition of Doppler feedback in cross sections correction.

Completed simulations of the molten salt natural circulation loop DYNASTY. Very good agreement with partner results, all predicting the same stable/unstable behavior.

Coupled code verified with a predefined multi-physics test-case, mimicking the behavior of a MSFR (both in steady state and transient regimes), by comparison of the results obtained among partners.

Dissertations

-

Scientific Publications

1. M. Tiberga, D. Shafer, D. Lathouwers, J.L. Kloosterman, "PRELIMINARY ASSESSMENT OF THE FREE-PLUG MELTING BEHAVIOR IN THE MOLTEN SALT FAST REACTOR", PHYTRA4 - The Fourth International Conference on Physics and Technology of Reactors and Applications, Marrakech, Morocco, September 17-19, 2018.

Project leaders

Dr. D. Lathouwers, Dr. M. Rohde

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

M. Tiberga, D. Lathouwers, M. Rohde, J.L. Kloosterman

Cooperations

SAMOFAR (Horizon 2020)

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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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 aerodynamic and light scattering characteristics 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.

Progress

The flow tracing capabilities of HFSB and air-filled soap bubbles (AFSB) in wall-bounded turbulence have been assessed, retrieving a characteristic time response of 30 □s and 500 □s, respectively. Compared to the conventional micron-sized tracers (DEHS), measurements using HFSB allow estimating the boundary-layer thickness within 10%; the mean streamwise velocity profile deviated less than 2% of U_∞ across the boundary layer down to a wall distance of approximately two bubble diameters. A new measurement concept, named Coaxial Volumetric Velocimetry (CVV), has been introduced that exploits the co-axial arrangement between cameras and light source, thus enabling flow measurements even when the optical access is available only from one direction. The theory of CVV has been developed, with focus on the measurement uncertainty of the three velocity components. Furthermore, a novel approach to the measurement of large-scale complex aerodynamic flows has been introduced, based on the combination of coaxial volumetric velocimetry and robotics. The advantages of the proposed system have been demonstrated in a full-scale volumetric PIV study of a time-trialing cyclist. An unprecedented ensemble of 450 time-resolved volumetric PIV acquisitions has been conducted to compose the time-averaged velocity field on a 2 m3 domain around the cyclist replica.

Dissertations

1. Caridi GCA, Development and application of helium-filled soap bubbles for large-scale PIV experiments in aerodynamics, Delft University Press.

Scientific Publications

1. Faleiros DE, Tuinstra M, Sciacchitano A and Scarano F, Helium-filled soap bubbles tracing fidelity in wall-bounded turbulence, Exp Fluids (2018) 29:56
2. Jux C, Sciacchitano A, Schneiders JFG, Scarano F, Robotic volumetric PIV of a full-scale cyclist, Exp Fluids (2018) 59:74.
3. Schneiders JFG, Scarano F, Jux C and Sciacchitano A, Coaxial volumetric velocimetry, Meas Sci Technol 29 (2018) 065201.
4. Sciacchitano A, Giaquinta D, Schneiders JFG, Scarano F, van Rooijen BD and Funes DE, Quantitative flow visualization of a turboprop aircraft by robotic volumetric velocimetry, Proceedings of the 18th Int Symp on Flow Visualization, 26-29 June 2018, Zurich, Switzerland.

Project leaders

Dr. A. Sciacchitano
Prof. F. Scarano

Research theme

Complex structures of fluids

Participants

G.C.A. Caridi
D. Engler Faleiros
C. Jux
E. Saredi
J.F.G. Schneiders

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

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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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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 on a scaled system. A drag resolution of 30 drag counts was retrieved. An assessment of the full-scale ring of fire system has been carried out considering both indoor and outdoor configurations, and low-speed and high-speed PIV systems. A novel approach for the aerodynamic optimization of sport garments has been devised which relies upon the conservation of momentum in a control volume enclosing individual body parts of the athlete. The approach has been proved valuable to optimize the local roughness of skin suits in cycling. Flow measurements in the wake of a two-man simplified bobsleigh model have been conducted by stereoscopic PIV to characterize the wake flow field and aerodynamic drag for different rotations of the front cowling with respect to the rear cowling.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Sciacchitano A and Pattnaik P, Near Wake Analysis of a Two-Man Bobsleigh Scaled Model, Proceedings 2018 2(6) 319.
2. Spoelstra A, de Martino Norante L, Terra W, Sciacchitano A and Scarano F, An assessment of the Ring of Fire approach for indoor and outdoor on-site sports aerodynamic investigation, 19th Int Symp on the Application of Laser and Imaging Techniques to Fluid Mechanics, Lisbon, Portugal, July 16-19 2018.
3. Spoelstra A, Terra W and Sciacchitano A, The Ring of Fire for in-field sport aerodynamic investigation, Proceedings 2018 2(6) 221.
4. Terra W, Sciacchitano A and Scarano F, A novel approach for skin suit aerodynamic optimization using local momentum deficit, Proceedings 2018 2(6) 222.
5. Terra W, Sciacchitano A, Scarano F and van Oudheusden BW, Drag resolution of a PIV wake rake for transiting models, Exp Fluids (2018) 59:120.

Project Aim

Development of RANS turbulence closure models has stalled for some time, with the most useful and practical models dating from the 90s. The recent availability of large, accurate and diverse data-sets of turbulent motion, from DES, LES and tomographic PIV, encourages us to explore numerical methods to develop new closure models from data. In particular, given a reference data-set for a narrow class of flows, we want to systematically develop new RANS closure models that are highly accurate within that class. Furthermore the models should come with estimates of their own modelling uncertainty.

Progress

We have used primarily two machine-learning approaches to derive nonlinear eddy-viscosity models (NLEVMs) from LES data: (i) deterministic symbolic regression, and (ii) Bayesian random forests (BART). Both use the tensor-basis framework of Pope for representing the anisotropy tensor, and both also modify turbulence production. Method (i) has the advantage of giving open-box models of simple algebraic form. Method (ii) gives models which capture the variability within the data-set. Example predictions of anisotropy for random-forests are shown in Fig. 1. Propagating these through a solver results in significantly improved mean-fields.

Dissertations

1. Kaandorp, M. (2018). Machine learning for data-driven RANS turbulence modelling. MSc Thesis, TU Delft. uuid:f833e151-7c0f-414c-8217-5af783c88474.
2. Van Korlaar. A. (2018). Field inversion and machine learning in turbulence modeling. MSc Thesis, TU Delft. uuid:0b211690-00e2-4b7c-9469-bc43bcf49e7e.
3. Fatou Gomez, J. (2018). Multi-fidelity co-Kriging optimization using hybrid injected RANS and LES. MSc Thesis, TU Delft. uuid:c5ddec13-e103-49b4-8b84-a8ad013c753c.
4. Döpke, M. (2018). A study of global-coefficient non-linear eddy viscosity models. MSc Thesis, TU Delft. uuid:e675fadc-fd8d-4ced-b59e-45b6faba6fdd.

Scientific Publications

1. Kaandorp, M.L.A. & Dwight, R.P. (2018). Stochastic Random Forests with Invariance for RANS Turbulence Modelling. arXiv 1810.08794 [physics.comp-ph].
2. Kumar, P., Schmelzer, M. & Dwight, R.P. (2018). Stochastic Turbulence Modeling in RANS Simulations via Multilevel Monte Carlo. arXiv:1811.00872 [physics.comp-ph].
3. Edeling, W.N., Schmelzer, M., Dwight, R.P. & Cinnella, P. (2018). Bayesian Predictions of Reynolds-Averaged Navier–Stokes Uncertainties Using Maximum a Posteriori Estimates. AIAA Journal 56, (5). doi:10.2514/1.J056287.
4. Schmelzer, M., Dwight, R.P. & Cinnella, P. (2018). Data-Driven Deterministic Symbolic Regression of Nonlinear Stress-Strain Relation for RANS Turbulence Modelling. In 2018 Fluid Dynamics Conference. AIAA 2018-2900. doi:10.2514/6.2018-2900.

Project leaders

Dr. Richard P. Dwight
Dr. Steven J. Hulshoff
Prof. Stefan Hickel

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Martin Schmelzer, Prashant Kumar, Yu Zhang, Julia Steiner, Arent van Korlaar, Alexander Blauw, Micheal Kaandorp, Max Döpke, Javier Fatou Gomez

Cooperations

Prof. Paola Cinnella (ParisTech)
Marin, NRG, McLaren F1 (UK)

Funded by

EU STRP" Umrida" (FP7)
FOM-Shell CSER

Funded %

University	35 %
FOM	15 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	50 %
Scholarships	-

Start of the project

2017

Information

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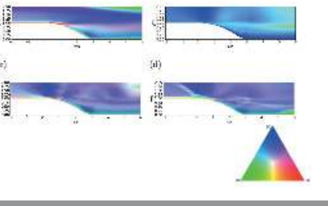

Curved backward-facing step case. Colours show anisotropy type of turbulence 3C = 3-component, etc. for (a) LES (reference), (b) RANS k-w, (c) a deep neural network, and (d) random-forest. Both (c), (d) are trained on a different, periodic hill case

PROJECT LEADERS
Dr. F.F.J. Schrijer
Dr. B.W. van Oudheusden
Prof. S. Hickel

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
A D'Aguanno, PL van Gent,
RHM Giepman, L Laguarda

COOPERATIONS
ESA, VKI, DLR, NLR, Airbus,
ArianeGroup, TNO, ONERA, UNINA

FUNDED BY
EU (TFAST, HOMER, CS2), ESA
(TRAV2)

FUNDED %

University	50 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	25 %
Scholarships	25 %

START OF THE PROJECT
2003

INFORMATION
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PROJECT AIM
Development and implementation of non-intrusive measurement techniques for high-speed compressible flows with special focus on particle image velocimetry. The measurement techniques are subsequently used to investigate flow phenomena that are pertinent to the high-speed aerospace technology domain, such as including launchers, high-speed air transport systems and reentry vehicles. Specific topics that are studied are shockwave boundary layer interaction (SWBLI), transonic buffet control, (compressible) roughness-induced boundary layer transition and compressible baseflows.

PROGRESS
1) Study and control of transonic and supersonic shock-wave boundary layer interactions.

2) Flow control of SWBLIs by means of micro-ramps and surface porosity.

3) Unsteady transonic airfoil aerodynamics (CleanSky2 project) and buffet control.

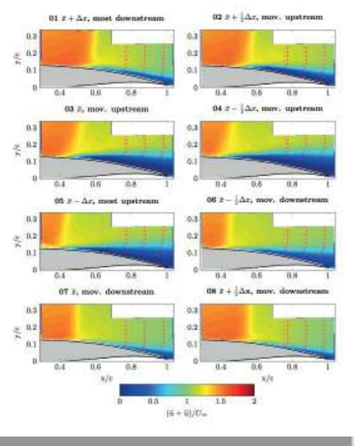
4) Launcher base flows, using (tomographic) PIV and PIV-based pressure integration.

5) Application of IR thermography for quantitative heat transfer measurements in high speed turbulent boundary layers with roughness and for roughness-induced transition.

6) Investigation of supersonic shock-shock interactions

DISSERTATIONS
1. P.L. van Gent, From particles to pressure - PIV-based pressure reconstruction for base flows, TU Delft, 26-10-2018.

SCIENTIFIC PUBLICATIONS
1. R.H.M. Giepman, F.F.J. Schrijer, B.W. van Oudheusden: A parametric study of laminar and transitional oblique shock wave reflections, Journal of Fluid Mechanics, 844 (2018), pp. 187-215.
2. P.L. van Gent, B.W. van Oudheusden, F.F.J. Schrijer: Determination of mean pressure from PIV in compressible flows using the Reynolds averaging approach. Exp. Fluids (2018) 59:41.
3. N. A. Voogt, B.W. van Oudheusden, F.F.J. Schrijer: Investigation of supersonic, large wall roughness elements with QIRT and PIV, 14th Quantitative Infrared Thermography Conference (QIRT 2018) , 25-29 June 2018, Berlin, Germany.
4. F. Schrijer, R. Solana Perez, B. van Oudheusden: Investigation of transonic buffet using high speed PIV, 5th International Conference on Experimental Fluid Mechanics (ICEFM 2018), Munich, Germany, July 2-4, 2018.
5. D. P. Ramaswamy, F.F.J Schrijer, F. Avallone: Experimental investigation of the effect of a surface protuberance on the surface heat transfer in a high speed boundary layer, 5th International Conference on Experimental Fluid Mechanics (ICEFM 2018), Munich, Germany, July 2-4, 2018.



Characterisation of transonic buffet with PIV: phase-averaged flow fields (horizontal velocity component), based on shock position, illustrating the complete buffet cycle.

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 a transonic base flow investigation with relevance to launcher-afterbody buffeting.

2) Theoretical study of PIV-based determination of instantaneous pressure in a transonic base flow, based on a numerical data set.

3) Pressure field determination for large-scale flows based on the helium-filled soap bubble PTV technique

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

Dissertations

1. P.L. van Gent, From particles to pressure - PIV-based pressure reconstruction for base flows, TU Delft, 26-10-2018.

Scientific Publications

1. P.L. van Gent, B.W. van Oudheusden, F.F.J. Schrijer: Determination of mean pressure from PIV in compressible flows using the Reynolds averaging approach. Exp. Fluids (2018) 59:41.
2. P.L. van Gent, F.F.J. Schrijer, B.W. van Oudheusden: Assessment of the pseudo-tracking approach for the calculation of material acceleration and pressure fields from time-resolved PIV: part I. Error propagation, Meas. Sci Technol. 29 (2018) 045204.
3. P.L. van Gent, F.F.J. Schrijer, B.W. van Oudheusden: Assessment of the pseudo-tracking approach for the calculation of material acceleration and pressure fields from time-resolved PIV: part II. Spatio-temporal filtering, Meas. Sci Technol. 29 (2018) 045206.
4. W. Terra, A. Sciacchitano, B.W. van Oudheusden, F. Scarano: Drag resolution of a PIV wake rake for transiting models, Exp. Fluids (2018) 59:120.
5. C. Jux, A. Sciacchitano, F. Scarano: Surface pressure visualization by 3D PTV, ISFV 18 - International Symposium on Flow Visualization, 26-29 June 2018, Zurich, Switzerland.

Project leaders

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

Research theme

Complex dynamics of fluids

Participants

PL van Gent, JFG Schneiders, W Terra, G Gonzalez, A D'Aguanno, C Jux

Cooperations

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

Funded by

EU (NIOPLEX, HOMER)

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. BW van Oudheusden
Dr. FFJ Schrijer

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
PL van Gent, M. Percin

COOPERATIONS
Uni BW Munich, KU Leuven

FUNDED BY
EU FP-7 (NIOPLEX)

FUNDED %

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

START OF THE PROJECT
2010

INFORMATION
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PROJECT AIM

The wake dynamics of truncated models is investigated experimentally, in view of their relevance to launcher afterbody unsteady loading and buffeting. Both subsonic and compressible (transonic and supersonic) conditions are considered. Similar fluid dynamic phenomena are investigated in relation to swirling jet configurations.

PROGRESS

1) Flow analysis, including PIV-based pressure determination, in high speed flows: effect of exhaust plume and nozzle length.

2) Investigation of a generic base flow model at incompressible flow conditions (subsonic flow speed): low-frequency unsteadiness, effects of afterbody presence and model angular alignment.

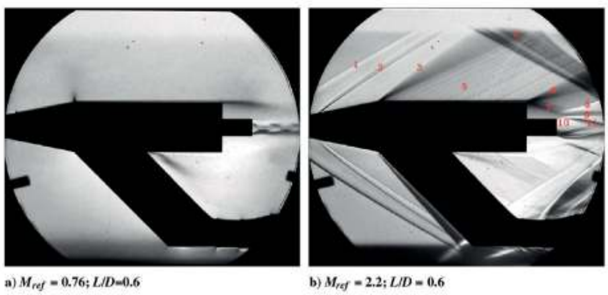
3) Experimental investigation of swirling jet flows

DISSERTATIONS

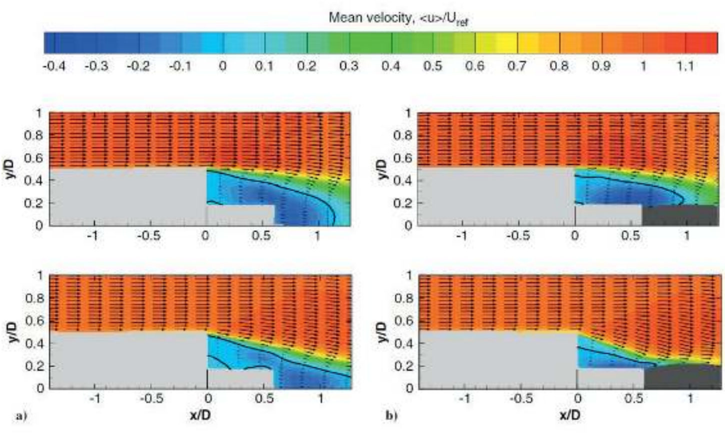
1. P.L. van Gent, From particles to pressure - PIV-based pressure reconstruction for base flows, TU Delft, 26-10-2018.

SCIENTIFIC PUBLICATIONS

1. M. Vanierschot, M. Percin, B.W. van Oudheusden: Double helix vortex breakdown in turbulent swirling jet flow, Physical Review Letters, of Physical Review Fluids 3 (2018) 034703.



Schlieren visualization of base-flow model with propulsive jet, for transonic and supersonic conditions (P.L. van Gent, PhD thesis, 2018)



Mean velocity field for base flow with (a) and without (b) exhaust plume; top: transonic flow, Mach = 0.76; bottom: supersonic flow, Mach = 2.20.

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, has now five projects finalized; the most recent one on the efficient source term modelling of vortex generators for wind turbine blades. Two new PhD projects started, focusing more on the simulation of wind turbine wakes, by using vortex methods or hybrid Eulerian Finite Volume – Lagrangian Vortex Parttcle 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

1. Florentie, L. Aspects of Source-Term Modeling for Vortex-Generator Induced Flows (2018) Delft University of Technology.

Scientific Publications

1. Florentie, L., Hulshoff, S.J., van Zuijlen, A.H., Adjoint-based optimization of a source-term representation of vortex generators (2018) Computers and Fluids, 162, pp. 139-151.
2. Berdowski, T., Ferreira, C., van Zuijlen, A., van Bussel, G., Three-dimensional free-wake vortex simulations of an actuator disc in yaw (2018) Wind Energy Symposium, 2018.

Project leaders

A.H. van Zuijlen, H. Bijl

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Carlos Baptista, Tom Berdowsky, Liesbeth Florentie, Shaafi Kaja Kamaludeen

Cooperations

ECN, Technical University München

Funded by

FOM, EU

Funded %

University	50 %
FOM	25 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	25 %
Scholarships	-

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
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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 abovementioned challenges and lead to intervention-free high-fidelity simulation methods for rigorous design assessment and optimization.

Progress

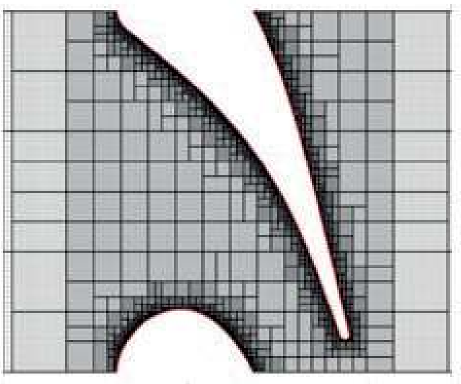
The dual solution procedure has been formulated and implemented for different representations of the primal solution and objective functions. We are currently exploring adjoint based error estimation and correction, which also form the basis of mesh adaptation criteria.

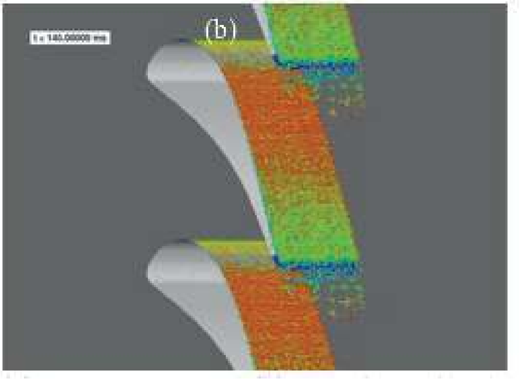
Dissertations

-

Scientific Publications

-





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

We develop methods for scalable multi-physics massively parallel high-performance computing. The new methods will be applied for performing unprecedented large-eddy simulations (LES) of high-pressure liquid-fuel injection and reacting transcritical multiphase flows in modern energy conversion systems, such as rocket engines, gas turbines and diesel engines, to provide detailed insight into high-pressure-injection phenomena and contribute to the solid physical understanding necessary to further improve the efficiency of these technical systems.

PROGRESS

In 2018, we have further improved the computational efficiency of a two-phase model based on cubic equations of state and vapor-liquid equilibrium calculations, which can represent supercritical states and multi-component subcritical two-phase states (Matheis & Hickel, 2018). This model is combined with our finite-rate chemistry solver (Diegelmann et al, 2017), which can accurately predict ignition and the transition between deflagration and detonation. The next steps are to develop dynamic multi-level parallelization for scalable high-performance multi-physics simulations.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Matheis, J., Hickel, S. (2018) Multi-component vapor-liquid equilibrium model for LES of high-pressure fuel injection and application to ECN Spray A. International Journal of Multiphase Flow 99: 294-311. doi: 10.1016/j.ijmultiphaseflow.2017.11.001

PROJECT LEADERS

Prof. Stefan Hickel

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Mohamad Fathi, Dr. Maria Chertova Dr. Nicolas Renaud, Prof. Dirk Roekaerts

COOPERATIONS

Universität der Bundeswehr München
eScience Centre Amsterdam

FUNDED BY

JCER eScience for Energy Research

FUNDED %

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

START OF THE PROJECT

2012

INFORMATION

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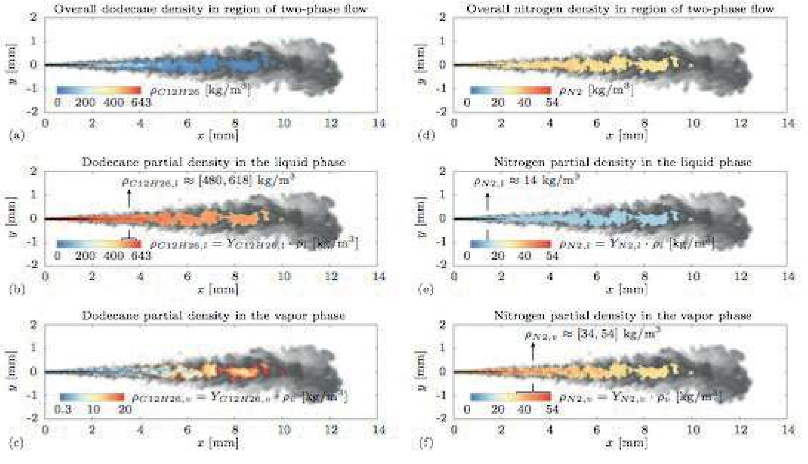
Full phase information for VLE-LES of transcritical n-dodecane jet at 60bar. Left and right column show contours of dodecane and nitrogen partial densities, respectively, from blue to red shades. All cells with 0.1% > vapor volume fraction > 99.9% are blanked out and the background contour shows the temperature field from dark to light shades (Matheis & Hickel, 2018)



Computational and experimental investigation of unsteady asymmetric interactions of shock waves and between shock waves and boundary layers over a flexible plate

Project leaders
Stefan Hickel, Bas van Oudheusden, Ferry Schrijer

Research theme
Complex dynamics of fluids

Participants
Luis Laguarda, Weibo Hu

Cooperations
-

Funded by
Self, CSC

Funded %

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

Start of the project
2017

Information
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Project Aim

Supersonic inlet diffusors and over-expanded rocket nozzles are characterized by complex shock interaction pattern, shock turbulence interactions and boundary layer separation, which result in unsteady and asymmetric loads that bend and deform thin-walled structure. As the deformed nozzle or inlet contour directly affects its internal flow field and thus the mean and dynamic flow-separation and side-load behaviour, these fluid-structure interactions can self-amplify and quickly cause structural failure. Our goal is to improve the understanding of the dynamics of these processes and the prediction capabilities of numerical tools.

Progress

Matheis & Hickel (2015) found that finite time scales of the bi-directional transition process between two-shock and three-shock interaction pattern can determine the topology of the mean flow field of shock-wave/boundary-layer interactions. We have performed a theoretical, numerical, and experimental analysis of quasi 2-D shock-shock interactions. We found that and present theory based on steady equilibrium flow assumptions fails in the practically relevant case of unsteady or non-quiescent internal flow. Our preliminary results further indicated additional geometry effects, and strong effects of free stream noise in the wind-tunnel experiments.

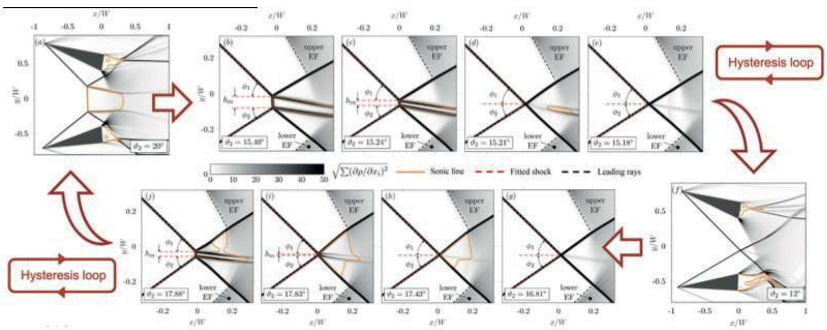
Dissertations

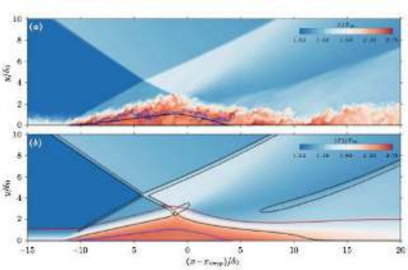
-

Scientific Publications

-

Asymmetric shock interaction hysteresis loop at M=3 (Laguarda & Hickel, 2017)





LES of shock/boundary-layer interaction at Mach 3 and Re□=200 000: (a) Instantaneous temperature contours; (b) Mean temperature contours (Pasquariello et al. 2017).

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

1. Dr. Jacopo Serpieri, Cross-Flow Instability: Flow diagnostics and control of swept wing boundary layers, March 2018.
2. Dr. Koen Groot, BiGlobal Stability of Shear Flows: Spanwise & Streamwise Analyses, December 2018.

SCIENTIFIC PUBLICATIONS

1. Groot, K. J., Serpieri, J., Pinna, F., & Kotsonis, M. (2018). Secondary crossflow instability through global analysis of measured base flows. Journal of Fluid Mechanics, 846, 605-653.
2. Yadala, S., Hehner, M. T., Serpieri, J., Benard, N., Dörr, P. C., Kloker, M. J., & Kotsonis, M. (2018). Experimental control of swept-wing transition through base-flow modification by plasma actuators. Journal of Fluid Mechanics, 844.
3. Serpieri, J., & Kotsonis, M. (2018). Conditioning of unsteady cross-flow instability modes using dielectric barrier discharge plasma actuators. Experimental Thermal and Fluid Science, 93, 305-318.
4. Rius Vidales, A. F., Kotsonis, M., Antunes, A. P., & Cosin, R. (2018). Effect of Two-Dimensional Surface Irregularities on Swept Wing Transition: Forward Facing Steps. In 2018 Fluid Dynamics Conference (p. 3075).

PROJECT LEADERS

Dr. Marios Kotsonis

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Dr. Jacopo Serpieri (promoted 2018)
Dr. Koen Groot (promoted 2018)
Srikar Yadala Venkata (defence 2020)
Alberto Felipe Rius Vidales (defence 2021)
Kaisheng Peng (defence 2023)

COOPERATIONS

Dr. Nicolas Benard (U. Poitiers)
Dr. Markus Kloker (U. Stuttgart)

FUNDED BY

NWO, Embraer

FUNDED %

University	10 %
FOM	-
STW	50 %
NWO Other	-
Industry	40 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2013

INFORMATION

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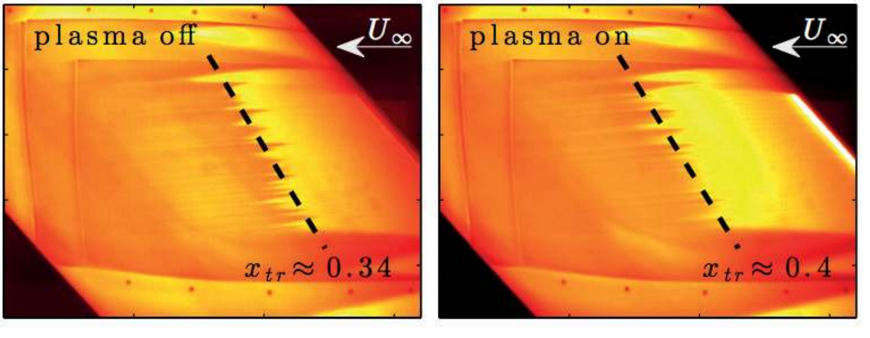
Thermal imaging of swept wing transition controlled by plasma actuators (Rec = 2.2 million)



PROJECT LEADERS
Dr. BW van Oudheusden
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
M Percin, S Deng, WB Tay
COOPERATIONS
Nanjing University of Aeronautics and Astronautics, National University of Singapore
FUNDED BY
-
FUNDED %

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

START OF THE PROJECT
2010
INFORMATION
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PROJECT AIM

The project considers fundamental and applied research on aerodynamic characterization for 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

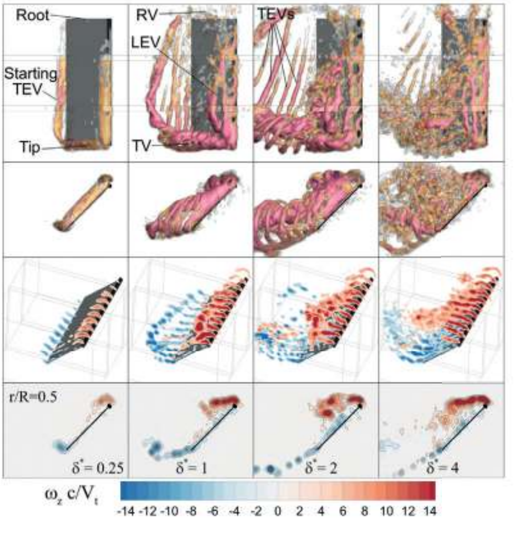
The work has two major fields of attention: 1) the study of generic aeroelastic phenomena relevant to MAV propulsion and 2) a more detailed characterization of the aerodynamic behavior of the flapping-wing DelFly MAV itself. PIV wind tunnel studies were directed towards the characterization of the DelFly 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. R. van de Meerendonk, M. Percin, B.W. van Oudheusden: Three-dimensional flow and load characteristics of flexible revolving wings, Experiments in Fluids (2018) 59:161.
2. W.B. Tay, J.H.S. de Baar, M. Percin, S. Deng, B.W. van Oudheusden: Numerical simulation of a flapping micro aerial vehicle through wing deformation capture, AIAA Journal, Vol. 56, No. 8 (2018), pp. 3257-3270.
3. A. del Estal Herrero, M. Percin, M. Karasek, B. W. van Oudheusden: Flow visualization around a flapping-wing Micro Air Vehicle in free flight using large-scale PIV, Aerospace (2018), 5(4), 99.
4. B. Martinez Gallar, B.W. van Oudheusden, A. Sciacchitano, M. Karasek: Large-scale flow visualization of a flapping-wing Micro Air Vehicle, ISFV 18 - International Symposium on Flow Visualization, 26-29 June 2018, Zurich, Switzerland.



Experimental characterization of the flow development around a revolving flat-plate wing started from rest.
(R. van de Meerendonk et al., Experiments in Fluids (2018) 59:161).

Development of mimetic spectral element methods for flow problems

Project Aim

Development and application of high order methods which identically satisfies conservation laws such as conservation of mass, momentum, angular momentum on non-orthogonal domains.

Progress

This is continuous work in progress. For the status of this project, feel free to contact theproject leader.

Dissertations

-

Scientific Publications

1. Mimetic spectral element method for anisotropic diffusion. M. Gerritsma, A Palha, V. Jain & Y Zhang. Numerical Methods for PDEs, 31-74
2. Spectral mimetic least-squares method for curl-curl systems. A. Palha & M. Gerritsma. BHRA/ Springer Verlag
3. Construction and application of algebraic dual polynomial representations for finite element methods. V. Jain, Y. Zhang, A. Palha & M. Gerritsma. arXiv:1712.09472
4. C1 continuous h-adaptive least-squares spectral element method for phase-field models. K. Park, M. Gerritsma & M. Fernandino. Computers & Mathematics with Applications 75(5), 1582 – 1594.
5. Discrete conservation properties for shallow water flows using mixed mimetic spectral elements. D. Lee, A. Palha & M. Gerritsma. Journal of Computational Phyics, 357, 282-304.
6. Algebraic dual polynomials for the equivalence of curl-curl problems M. Gerritsma, V. Jain & Y. Zhang. arXiv:1805.00114
7. A higher order equilibrium finite element method. K. Olesen, B. Gervang, J.N. Reddy & M. Gerritsma. International Journal for Numerical Methods in Engineering 114(12), 1262 – 1290.
9. Spectral element methods for parabolic interface problems. A. Khan, C.S. Upadhyay & M. Gerritsma. Computers Methods in Applied Mechanics and Engineering, 337, 66-94

Project leaders
Marc Gerritsma

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Artur Palha, Varun Jain, Yi Zhang

Cooperations
Bo Gervang (Arhus University)
Dave Lee (Los Alamos, Monash University)

Funded by
CSC, Shell FOM

Funded %

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

Start of the project
2017

Information

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Project Aim

We perform Direct Numerical Simulations (DNS) of homogeneous rotating and stratified turbulence and of turbulence generated by breaking inertia gravity waves in the atmosphere. Our objective is to better understand the physics of anisotropic turbulence and the implications on turbulence modeling. We develop and analyze new turbulence models for Large-Eddy Simulation (LES) based on SGS tensor transport equations and algebraic non-Boussinesq models.

Progress

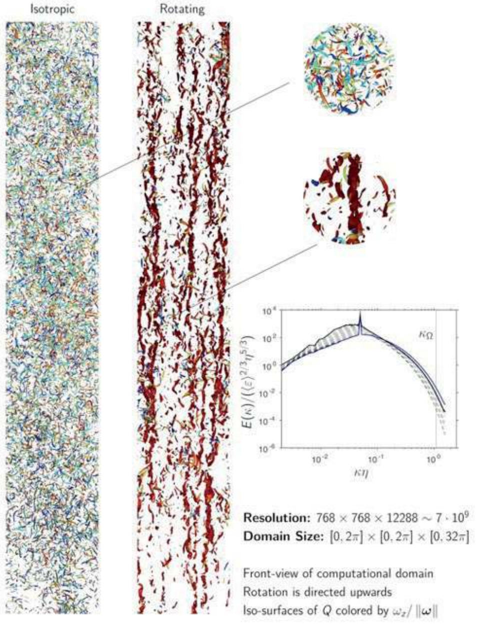
Transition from a split to a forward kinetic energy cascade system is explored in the context of rotating turbulence using DNS with a 3-D isotropic random force uncorrelated with the velocity field. Our parametric study covers confinement effects in large aspect ratio domains and a broad range of rotation rates. Results indicate that for a fixed geometry the Rossby number acts as a control parameter, whereas for a fixed Rossby number the product of the domain size along the rotation axis and forcing wavenumber governs the amount of energy that cascades inversely.

Dissertations

1. Gnanasundaram, A. (2018) Explicit Algebraic Subgrid-Scale Stress Model for Homogeneous Turbulence. MSc thesis TU Delft.

Scientific Publications

1. Pestana, T., Hickel, S. (2018) Regime Transition in the Energy Cascade of Rotating Turbulence. arXiv preprint arXiv:1811.01034.
2. Pestana, T., Thamhammer, M., Hickel, S. (2018) Energy transfer and dissipation tensor anisotropy in atmospheric turbulence. Proceedings of the ERCOFTAC Symposium on Engineering Turbulence Modelling and Measurement (ETMM12).



Project leaders

Stefan Hickel

Research theme

Complex dynamics of fluids

Participants

Tiago Pestana, Arun Gnanasundaram
Matthias Thalhammer

Cooperations

-

Funded by

TU Delft

Funded %

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

Start of the project

2015

Information

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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

In this study, an idealized eddy-resolving model is employed to examine the interplay between the downwelling, ocean convection and mesoscale eddies in the Labrador Sea and the spreading of dense water masses. The model output demonstrates a good agreement with observations with regard to the eddy field and convection characteristics. It also displays a basin mean net downwelling of 3.0 Sv. Our analysis confirms that the downwelling occurs near the west Greenland coast and that the eddies spawned from the boundary current play a major role in controlling the dynamics of the downwelling.
The magnitude of the downwelling is positively correlated to the magnitude of the applied surface heat loss. However, we argue that this connection is indirect: the heat fluxes affect the convection properties as well as the eddy field, while the latter governs the Eulerian downwelling. With a passive tracer analysis we show that dense water is transported from the interior towards the boundary, predominantly towards the Labrador coast in shallow layers and towards the Greenland coast in deeper layers. The latter transport is steered by the presence of the eddy field. The outcome that the characteristics of the downwelling in a marginal sea like the Labrador Sea depend crucially on the properties of the eddy field emphasizes that it is essential to resolve the eddies to properly represent the downwelling and overturning in the North Atlantic Ocean, and its response to changing environmental conditions.

Dissertations

-

Scientific Publications

1. Georgiou, S., van der Boog, C.G., Brüggemann, N., Ypma, S.L., Pietrzak, J.D., and Katsman, C.A., (2018). The interplay between eddies, deep convection and downwelling of dense water in an idealized model study of the Labrador Sea. Poster presentation, 2018 International AMOC Science Meeting, Miami, Florida, U.S.A.
2. Georgiou, S., van der Boog, C.G., Brüggemann, N., Pietrzak, J.D., and Katsman, C.A., (2018). The interplay between eddies, deep convection and downwelling of dense water in an idealized model study of the Labrador Sea. Oral presentation, Ocean Sciences Meeting, Portland, Oregon, U.S.A.

Project leaders

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

Research theme

Complex dynamics of fluids

Participants

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

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Project leaders
Dr.ir. B. Hofland, Prof.dr.ir. W. Uijttewaal
Research theme
Complex dynamics of fluids
Participants
Irene Rivera-Arreba
Cooperations
MARIN, BigLift
Funded by
NWO
Funded %

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

Start of the project
2018
Information
I. Rivera-Arreba
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Project Aim

To better control overtopping over coastal structures and ice accretion on ships, the formation of spray-jets from wave run-up needs to be investigated. This project focuses on how much spray is formed and how does it break up in drops under various representative storm conditions. Understanding of the physical processes, and from there, computational modelling, will be made based on different scale tests that will be performed during the PhD project.

Progress

To characterize the wave run-up and water sheet breakup in droplets in relation to the type of impact on a vertical structure, small-scale experiments were done at the WaterLab at TU Delft. Here the wave-wall interaction processes for three type of impacts (see Figure 1) were studied based on the analysis of visual material (high-speed camera).

Based on the hypothesis that turbulent instabilities such as Taylor-Görtler vortices are important in the process of water sheet breakup, Particle Image Velocimetry was used to measure the out-of-plane motion velocities of the water sheet running up. The results obtained with these experiments will serve as a basis for the next step of the research project, where large-scale tests will be performed at Marin.

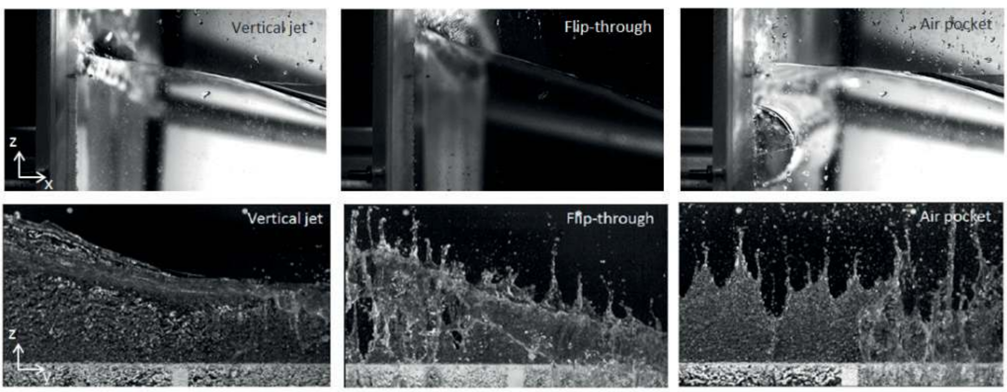
Dissertations

-

Scientific Publications

-

Top: types of wave impact (left: vertical jet; center: flip-through, right: air pocket). Bottom: water sheet run-up corresponding to the three types of impact.



Sustainable engineering of coastal systems in Regions Of Freshwater Influence (Sustainable ROFI's)

Project Aim

The overall project consists of two subprojects. This subproject of Sustainable ROFI's will focus on the interaction of stratification, turbulence and SPM within the Rhine Region of Freshwater Influence. The aim is to gain more insight into the complex phenomena in front of the Dutch coastal zone, such as the transport and dispersion of the freshwater and SPM, the hindered mixing by stratification, effect of tidal straining on the evolution of fronts. The role of turbulence in stratified flows plays a key role. In addition, high quality turbulence data will be used to improve turbulence models.

Progress

In 2014 a large dataset with e.g. salinity, temperature, velocities, turbidity and buoyancy fluxes is obtained. The dataset contains 4-6 weeks of data. The measurement site is off the Dutch coast near the Sand Engine. The data analysis has been focused on understanding the freshwater fronts which are propagating towards the coast. We investigated the impact of wind and tide on the thickness and propagation speed of these fronts. Reynolds stresses and the impact on fine sediment has been studied as well. In addition, we compared the data to a numerical model and use this model to investigate the propagation and interaction of the freshwater lenses and their frontal edges.

Dissertations

-

Scientific Publications

1. Rijnsburger, S., Flores, R. P., Pietrzak, J., Horner-Devine, A., & Souza, A. (2018). The Influence of Tide and Wind on the Propagation of Fronts in a Shallow River Plume. Journal of Geophysical Research - Oceans.
2. Flores, R., Rijnsburger, S., Meirelles, S., Horner-Devine, A., Souza, A., Pietrzak, J., et al. (2018). Wave Generation of Gravity-Driven Sediment Flows on a Predominantly Sandy Seabed. Geophysical Research Letters

Project leaders

Prof.dr. J.D. Pietrzak , Prof.dr. H.J.H. Clercx

Research theme

Complex dynamics of fluids

Participants

Sabine Rijnsburger

Cooperations

Eindhoven University of Technology
National Oceanography Centre
University of Washington
Deltares

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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Project leaders
Dr.ir. R.J. Labeur, Prof.dr.ir.W.S.J. 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
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https://www.nwo.nl/onderzoek-en-resultaten/programmas/The+New+Delta/Projecten

Project Aim

The aim is to set up a calculation tool to safely design turbines mounted in coastal infrastructure, evaluating both the energy output of the turbines and their impact on the surroundings. The Eastern Scheldt Storm Surge barrier in the Netherlands houses the world's first array of tidal turbines. The location is ideally suited to investigate the energy output of the turbines, and their influence on the local flow field. Based on field monitoring executed at this site, this research develops a theoretical model to quantify the energy production and the hydraulic resistance of free-stream turbines in barriers.

Progress

The field data analysis shows that the drag of the turbines does not simply add to that of the barrier due to so-called by-pass effects, which reduce the combined resistance. This also implies that part of the energy that is normally dissipated in turbulence swirls or eddies downstream of the barrier, becomes available to enhance the energy yield.

Dissertations

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Scientific Publications

1. M. Verbeek, R. J. Labeur, and W. Uijttewaal, "Field observations of rotor thrust and bypass-acceleration at a tidal fence," presented at the 6th Oxford Tidal Energy Workshop, Oxford, UK, 2018.

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

As a first step, we developed further the model proposed by Smit and Janssen (2015), which transports the complete second-order statistics of a wave field over variable bathymetry. The outcome of this development is that now the model is also applicable for wave-current interaction problems. The novelty of the model is that it takes into account the contribution of the cross-correlation components, and therefore, it can predict the effect of wave interference patterns. As an example, the figure below presents the contribution of the cross-correlation components in the case of obliquely incident and narrow-banded wave field over jet-like current.

Dissertations

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Scientific Publications

1. Akrish, G., Smit, P., Zijlema, M. and Reniers, A., 2018. MODELLING WAVE INTERFERENCE PATTERNS USING THE SWAN MODEL. Coastal Engineering Proceedings, 1(36), p.42.

Project leaders

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

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

G. Akrish

Cooperations

Advisor: Dr. P.B. Smit (Spoondrift technologies Inc.)

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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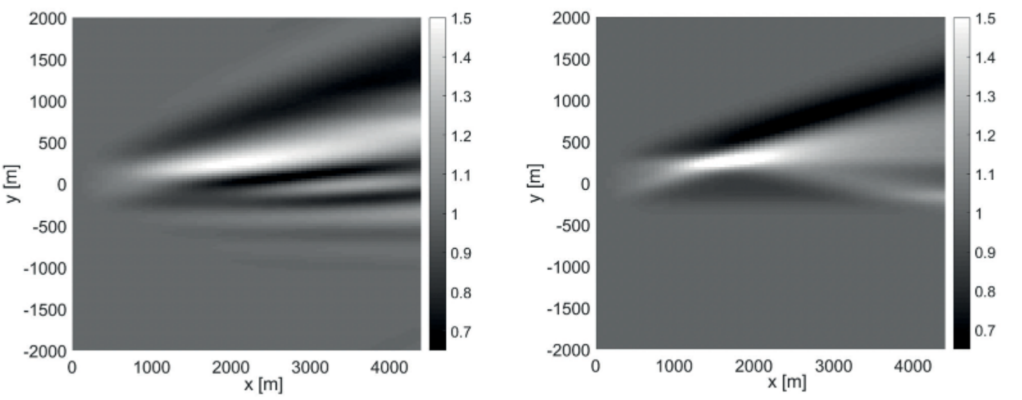

Planar view of the variations in wave height over jet-like current, for a narrow-banded wave field with incident direction of 15 degrees. Results as predicted by: Present model (left), and SWAN (right).

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, G.Ph. van Vledder, Tomohiro Suzuki
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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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

Vegetation modelling is implemented that takes into account densely spaced, vertical cylinders, like dense mangrove fields and porous brushwood groins, whereby the effect of (relatively low) porosity is optionally included. Also wave damping due to vegetation schematised as horizontal cylinders is included as an option. The associated dissipation is based exclusively on the drag force. SWASH can be downloaded from http://swash.sf.net. There were about 3,000 downloads over 100 countries by the end of 2018 since the launch of SWASH at the website (as of February 9, 2011).

Dissertations

-

Scientific Publications

1. Koen Hilgersom, Marcel Zijlema, and Nick van de Giesen. An axisymmetric non-hydrostatic model for double-diffusive water systems, Geosci. Model Dev., 11, 521–540.
2. Rong Zhang, Marcel Zijlema and Marcel J.F. Stive Laboratory validation of SWASH longshore current modelling, Coastal Engineering, 142, 95-105.

Lagrangian assessment of the boundary sinking of waters in the subpolar North Atlantic

Project Aim

To assess the pathways of the waters that sink near the boundaries of the North Atlantic seas. Previous works have associated these waters with the lower cell of the Atlantic Meridional Overturning Circulation (AMOC), but it is still unclear which are the pathways that the sinking waters follow.

Progress

As described in the 2017 annual report, the seasonal and spatial assessment of boundary sinking has already been performed with a high resolution ocean only model (paper to be submitted very soon) from an Eulerian pespective. Now we are tracking the water masses that sink near the boundaries backward and forward. It will allow us to characterize their properties (salinity, temperature) as well as to know which are the preferred pathways that they follow after sinking (see an example of backtracking in the below figure). Additionally an important remaining question is how the presence of ocean mesoscale eddies affect the trajectories of the sinking waters.

Dissertations

-

Scientific Publications

-

Project leaders

Dr. C.A. Katsman, prof. dr. J.D. Pietrzak

Research theme

Complex dynamics of fluids

Participants

Sotiria Georgiou, Steffie Ypma

Cooperations

-

Funded by

NWO

Funded %

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

Start of the project

2015 (This subproject in 11/2017)

Information

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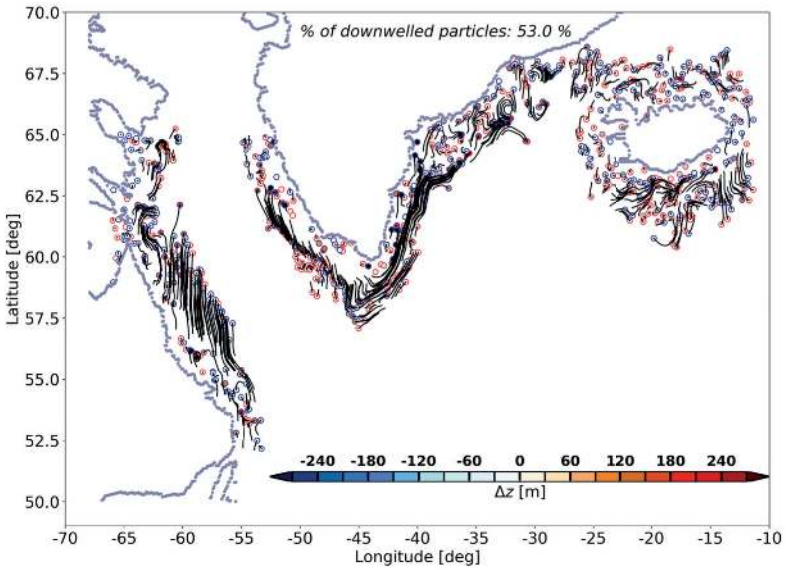

The life cycle of eddies in the Caribbean Sea

Project leaders
Dr. C.A. Katsman, Prof. dr. J.D Pietrzak, Prof.dr.ir. H.A. Dijkstra
Research theme
Complex dynamics of fluids
Participants
Carine 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
Carine van der Boog
06 33 878 152
C.G.vanderBoog@tudelft.nl

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, an 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.
- Performance and analysis of hydrographic observations of a Caribbean anticyclone.

Dissertations

-

Scientific Publications

-

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

In 2018 the second field campaign was successfully conducted. In this campaign Silke monitored the morphodynamics of a chenier (sand bar), since mangroves are observed to often recruit behind them. Alejandra studied the morphodynamic effects of brushwood structures, built in the area to enhance accretion and natural mangrove colonization. Celine focused in biologic aspects and how the abiotic factors affect the mangroves. Besides this, flume experiments have been conducted in Delft to test idealized structures in the flume, and the data from the previous field campaign was analyzed by the students. Sediment analysis tests were also conducted in Deltares, to characterize the properties of the samples brought from Indonesia.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. J.C. Winterwerp
Prof.dr.ir. W.S.J. Uijttewaal
Prof.dr. T.J. Bouma

Research theme

Complex dynamics of fluids

Participants

A Gijón Mancheño, Silke Tas, Celine 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

Alejandra Gijon
06 40 835 085
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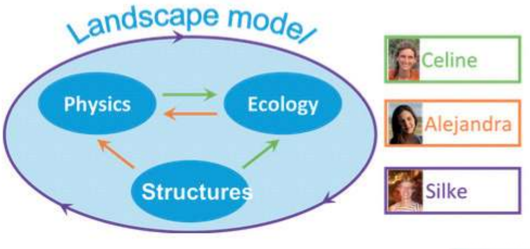
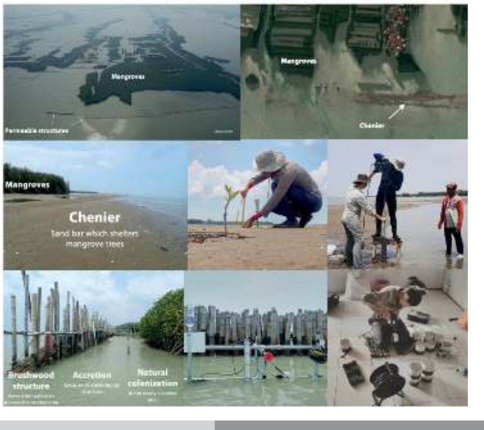
www.biomanco.org



Organisation structure of BioManCO project



Top pictures: Aerial pictures of the area. Center pictures: (left) chenier (center) Silke measuring erosion (right) Ruben and Celine drilling rods for RSETS. Bottom pictures: (left) Brushwood structure (center) frame with instruments to monitor structure (right) Alejandra preparing sediment traps to monitor sediment accretion© Silke Tas and Alejandra Gijón

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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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

Improvements were made to the numerical non-hydrostatic wave-flow model SWASH in order to run simulations with waves and (tidal) currents. Furthermore 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. A lot of time was spent on the preparation of this campaign and processing of data afterwards. Data on sediment suspension and wave nonlinearity in the vicinity of an ebb-tidal delta is analyzed.

Dissertations

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Scientific Publications

-

Project Aim

The project aims at devising numerical tools for simulating advection dominated flow problems, involving sharp transitions. In particular the aim is to simulate air-water mixtures as they occur e.g. in breaking waves. In order to achieve this a combined particle-mesh method is used which attempts to combine the advantages of Eulerian and Lagrangian methods.

Progress

The past year mainly focused on sharing research outcomes. This resulted in a number of papers, an open-source software library (https://bitbucket.org/jakob_maljaars/leopart) and various research collaborations. Contentwise, the past year focused on simulating two-fluid flows.

Dissertations

-

Scientific Publications

1. J.M. Maljaars, R.J. Labeur, N. Trask, D. Sulsky, Conservative, high-order particle-mesh scheme with applications to advection-dominated flows, Computer Methods in Applied Mechanics and Engineering 348 (2019) 443-465. https://doi.org/10.1016/j.cma.2019.01.028.
2. J.M. Maljaars, R.J. Labeur, M. Möller, A hybridized discontinuous Galerkin framework for high-order particle–mesh operator splitting of the incompressible Navier–Stokes equations, Journal of Computational Physics 358 (2018) 150–172. https://doi.org/10.1016/j.jcp.2017.12.036.

Project leaders

Dr.ir. R.J. Labeur, Prof.dr.ir. W.S.J. Uijttewaal

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

J.M. Maljaars MSc

Cooperations

-

Funded by

NWO

Funded %

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

Start of the project

2015

Information

J.M. Maljaars
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Assessing the role of eddies on deep convection and the sinking of dense waters in the Nordic Seas

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

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 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 Lagrangian study is performed using particles tracing the warm Atlantic Water inflow through Denmark Strait in two high resolution models. The connection to the Overflow Water is quantified and the strength and location of watermass transformation is studied. Further, an idealized model set-up of a marginal sea subject to buoyancy loss is used to study the role of frontal processes for watermass transformation and the spreading of dense waters.

Dissertations

-

Scientific Publications

1. Ypma, S.L., N. Brüggemann, S. Georgiou, P. Spence, H. Dijkstra, J. Pietrzak, C. Katsman, 2018: Pathways and watermass transformation of Atlantic Water entering the Nordic Seas through Denmark Strait, US CLIVAR AMOC meeting 2018, Miami.
2. Ypma, S.L., N. Brüggemann, S. Georgiou, P. Spence, H. Dijkstra, J. Pietrzak, C. Katsman, 2018: Pathways and watermass transformation of Atlantic Water entering the Nordic Seas through Denmark Strait in two high resolution models, FAMOS meeting 2018, Bergen.
3. Ypma, S.L., N. Brüggemann, S. Georgiou, P. Spence, H. Dijkstra, J. Pietrzak, C. Katsman, 2018: Pathways and watermass transformation of Atlantic Water entering the Nordic Seas through Denmark Strait, Ocean Sciences meeting 2018, Portland.

Obtaining well-posedness in mathematical modelling of fluvial morpodynamics

Project Aim

We need to account for the mixed character of sediment to be able to model important physical processes that occur in rivers. These processes are of special relevance when modelling sediment management measures. The current approach to model mixed-sediment river morphodynamics may not be physically realistic as the model becomes ill-posed under some circumstances. The aim of this project is to improve modelling of mixed-sediment river morphodynamics. We will focus on (1) an analysis of the current approach, (2) a strategy to restore well-posedness of the current model approach, and (3) the development of a new set of conservation equations.

Progress

We have studied the well-posedness of the current approach to model mixed-sediment morphodynamics in one and in two dimensional models. We have found that the domain of ill-posedness is larger than previously thought. A tool has been developed to numerically check whether the present approach is well or ill-posed. We have run a set of laboratory experiments to gain insight into the physical processes that occur when the model is ill-posed. This data set has been used to develop a regularization strategy to recover the well-posedness of the model. A new model has been developed that accounts for the short time scale processes neglected by the strategy.

Dissertations

-

Scientific Publications

1. Chavarrías, V., G. Stecca, and A. Blom (2018), Ill-posedness in modelling mixed-sediment river morphodynamics, Adv. Water Resour., 114, 219-235.
2. Chavarrías, V., A. Blom, C. Orru, J. P. Mart'in Vide, and E. Viparelli (2018), A sand-gravel Gilbert delta subject to base level change, J. Geophys. Res., Earth Surface, 123(5), 1160-1179.

Project leaders
Dr.ir. A. Blom, Prof.dr.ir. W.S.J. Uijttewaal

Research theme
Complex dynamics of fluids

Participants
Victor Chavarrias

Cooperations
RWS, Utrecht U., Twente U

Funded by
STW

Funded %

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

Start of the project
2014

Information

V Chavarrias
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PROJECT LEADERS
Dr.ir. A. Blom
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
MatthewCzapiga, Meles Siele
COOPERATIONS
University of South Carolina, Deltares, Rijkswaterstaat, BAW, BfG, BOKU University
FUNDED BY
NWO Domain Applied and Engineering Sciences (AES)
FUNDED %

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

START OF THE PROJECT
2018
INFORMATION
Matthew Czapiga
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PROJECT AIM

The upper Dutch Rhine, like other highly-engineered rivers, has experienced continued degradation for many decades. This erosion has present and future impacts that affect both ecology and economics, including disconnection of channel and its floodplain, local obstructions to navigation at fixed layers, and potential redistribution of water and sediment at bifurcations. Several factors may have caused this effect, including channel narrowing, changes to hydrology, or changes to the sediment supply; this project aims to identify the most significant factors and measure schemes that may mitigate the degradation problem. Many mitigation options have been suggested, but their short and long-term effectiveness is unknown.

PROGRESS

An article is in preparation on the primary causes of river degradation following engineering practices, e.g. dams, emplacement of levees and groynes. Various scenarios are modelled and suggest that width narrowing has the largest influence on channel degradation rates. Another journal article is in preparation regarding the relative effectiveness of sediment nourishments subject to different dispersal patterns. Results can quantify the effective net-aggradation rate and short term bed level and texture response; all these are influential for selecting an appropriate application measure for sediment nourishments.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Shallow lateral non-uniform flows over a streamwise depth-increase: application to scour holes at the Eastern Scheldt storm surge barrier

Project Aim

To understand the interaction between large-scale local erosion (scour) downstream of the Eastern Scheldt storm surge barrier and the flow. To understand why the erosion is growing far larger than foreseen during the design phase. To provide possible mitigation strategies based on a fundamental understanding of the flow phenomena in the vicinity of the barrier.

Progress

An extensive analysis of field data revealed the possibility that there is a positive feedback between the flow and the ongoing erosion. The flow at the barrier is characterized by large horizontal velocity differences, and the combination of this and the local increase in depth induces a strong convergence towards the deepest part of the scour hole. Due to this convergence, the adverse pressure gradient is suppressed, and flow was observed to stay attached to the bed. This was verified in a schematized lab-experiment, where the presence of lateral non-uniformity led to the flow staying attached to the bed for slopes of up to 1 in 2 (26 degrees).

Dissertations

-

Scientific Publications

1. Y.B. Broekema, R.J. Labeur, and W.S.J. Uijttewaal. Analysis and observations of the horizontal structure of a tidal jet at deep scour holes. Journal of Geophysical Research: Earth Surface, 123(12):3162{3189, 2018.

Project leaders

Dr.ir. R.J. Labeur
Prof.dr.ir. W.S.J. Uijttewaal

Research theme

Complex dynamics of fluids

Participants

Yorick Broekema

Cooperations

A. Maghsoudloo

Funded by

Rijkswaterstaat

Funded %

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

Start of the project

2015

Information

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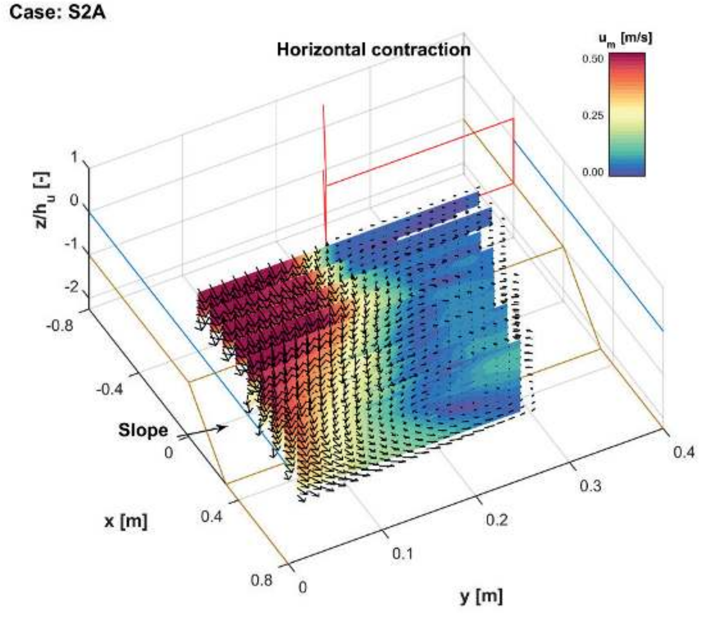
Example of a vertically attaching, horizontally converging flow, as observed in a simple geometry in a laboratoy experiment



PROJECT LEADERS
Dr.ir. A. Blom
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
Claudia Ylla Arbos
COOPERATIONS
Rijkswaterstaat, Deltares
FUNDED BY
Rijkswaterstaat, DGWB
FUNDED %

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

START OF THE PROJECT
2018
INFORMATION
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PROJECT AIM

In the upper Rhine-Meuse Delta (RMD), the river bed is incising at a rate of 2 cm/year, and by that, decreasing its slope towards a new state of equilibrium. River bed degradation hinders several river functions: flood safety, navigation, ecology, and more. Climate change (sea-level rise and changes in discharge distribution) and anthropogenic interference (such as the Room for the River measures) influence this ongoing morphodynamic trend. Within the research program Rivers2Morrow, the aim of this project is to understand how the upper RMD will respond to climate change and anthropogenic interference in the long term, and with which consequences.

PROGRESS

The project started in December 2018. Currently, research questions with the accompanying research plan are being defined.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Versatile hydrodynamics: the Rhine outflow area & MBES-derived salinity/temperature profiles

Project Aim

Understanding the baroclinic contribution to water levels is critical at the mouth of the Rotterdam Waterway, an area of significant economic activity and importance. Consequently, we investigate the key physical processes that need to be understood and resolved in models near the mouth of the Rotterdam Waterway. Here freshwater discharges into the coastal sea and forms a major river plume. In the vicinity of the river mouth we find a significant freshwater jet that forms a tidal plume front each tidal cycle. We develop a methodology to determine salinity and temperature profiles from multi-beam echo sounding (MBES) data, and use these data to understand the fronts.

Progress

A literature review has been performed and first model output has been compared with ADCP and CTD measurements from the STRAINS field experiment near the Sand Engine. During the first year, the main focus will be on understanding the dominant physical processes in the Rhine ROFI controlling the water level, in particular near the Port of Rotterdam. Knowledge of these processes are key to understanding the MBES data. In addition the plan is to start collecting MBES data as soon as possible, and to learn how to process the collected data. Together the model and MBES data will be used to assess the role of stratification on water levels along the Dutch coast.

Dissertations

-

Scientific Publications

-

Project leaders

Dr. C. Slobbe, Dr. M. Snellen,
Prof.dr.ir. M. Verlaan,
Prof.dr. J.D. Pietrzak

Research theme

Complex dynamics of fluids

Participants

Lennart Keyzer

Cooperations

Deltares

Funded by

NWO Applied and Engineering Sciences

Funded %

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

Start of the project

2018

Information

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Understanding soil-water interaction as relevant to breaching flow slides

Project leaders
Dr.ir. R.J. Labeur, Prof.dr.ir. Wim Uijttewaal
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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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. Therefore, laboratory experiments are being conducted in the water lab of Delft University of Technology.

Progress

The experimental setup has been recently constructed. As yet, two preliminary experiments have been conducted to check the functionality of the setup. The preliminary results and observations show that the sand erosion rate increases in the downstream direction of the slope due to acceleration of the turbidity current. We will conduct a series of experiments with different slope angles in the near future. We plan to obtain velocity and concentration measurements of turbidity currents to understand the coupling of the breaching process and the associated turbidity current.

Dissertations

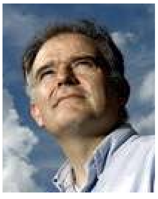
-

Scientific Publications

-

3D diagram of the experimental setup

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)

Vortex Dynamics and Turbulence (AP-WDY)
Mesoscopic Transport Phenomema (AP-MST)
Transport in Porous Media (AP-TPM)
Plasma Physics (AP-PP)

MECHANICAL ENGINEERING (ME)

Energy Technology (ME-ET)
Multiphase and Reactive Flows (ME-MRF)
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)

Prof.dr. HJH Clercx

Prof.dr.ir. GJF van Heijst

Prof.dr. F Toschi

Prof.dr.ir. AA Darhuber

Vortex dynamics and turbulence

The research in this section concerns transport phenomena, in particular as occurring in turbulent flows. An important line of approach is that vortex dynamics, in which elementary processes are studied in rather isolated configurations. Special attention is given to the influence of body forces associated with background rotation and density stratification. Such situations are met in industrial settings and also within the framework of geophysical fluid dynamics. In addition to transport in turbulent flows, the dynamics of granular media and 3D viscous mixing is studied.

The following main lines of research can be distinguished:

1. Spectral and transport properties of 3D turbulence
2. Dispersion in quasi-2D turbulence
3. Atmospheric physics
4. Granular media and viscous mixing

In most of these themes the research approach is a combination of laboratory experiments, numerical simulation, and theoretical modelling.

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 investigate the (rotation-dominated) geostrophic regime of rotating Rayleigh-Bénard convection for fluid properties (Prandtl number Pr) that are relevant to geo-/astrophysical settings. We characterize the flow via mean temperature distribution, boundary layer thicknesses, heat transport efficiency, among other statistical quantities. We also study the boundaries of this regime with the rotation-affected regime. Our results allow to distinguish between the two regimes. The transition occurs at distinct parameter values for the different Pr cases studied here, indicating a strong dependence on the fluid properties.

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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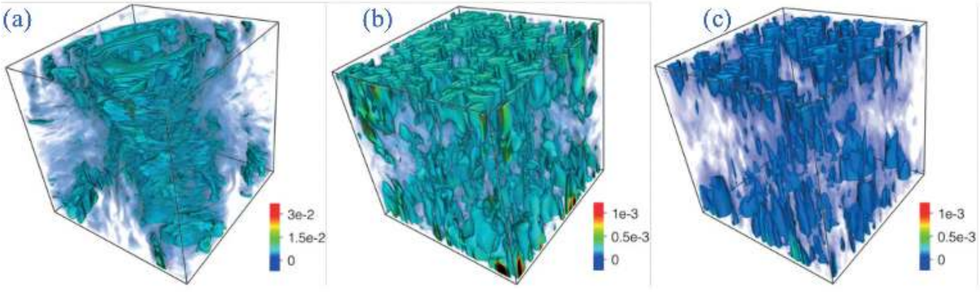

Horizontal kinetic energy at (a) Pr = 0.1, (b) 5 and (c) 100. All cases depict the geostrophic regime of rotating Rayleigh-Bénard convection. The direct numerical simulations are performed in a horizontally periodic domain with no-slip boundaries at top/bottom.

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

We study the dynamics of inertial particles in Rayleigh-Bénard convection numerically, where both particles and fluid exhibit thermal expansion. Particles have a larger thermal expansion coefficient than the fluid and become lighter (heavier) than the fluid at the hot bottom (cold top) plate. Particles with a small thermal response time, τT, have a temperature close to that of the fluid and at the hot bottom plate only colder particles clustered in colder plumes remain (figure 1a). For lager τT, the number of particles at the plate is increased and particle and fluid temperature become de-correlated (figure 1b).

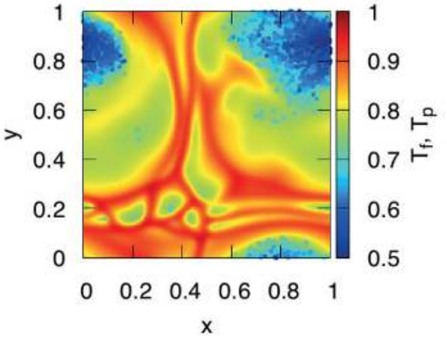
DISSERTATIONS

1. Alards, K. M. J. (2018). Lagrangian characterization of rotating Rayleigh-Bénard convection Eindhoven: Technische Universiteit Eindhoven.

SCIENTIFIC PUBLICATIONS

1. Rajaei, H., Alards, K. M. J., Kunnen, R. P. J., & Clercx, H. J. H. (2018). Velocity and acceleration statistics in rapidly rotating Rayleigh-Bénard convection. Journal of Fluid Mechanics, 857, 374-397.
2. Alards, K. M. J., Rajaei, H., Kunnen, R. P. J., Toschi, F., & Clercx, H. J. H. (2018). Directional change of tracer trajectories in rotating Rayleigh-Bénard convection. Physical Review E, 97(6).

A A snapshot of the temperature field in Rayleigh-Bénard convection close to the hot bottom plate, together with thermally inertial particles with a thermal response time of (a) τT =0.1 and (b) τT =4. The color of particles represents their temperature. Particles have a thermal expansion coefficient that is ten per cent larger than that of the fluid.



Particle fluid particle interaction project 2.2 of Perspectief MDS

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

This project has started in October 2016 and in the summer of 2017 the first experiments were made to measure the interaction of spheres with each other in a water tank. A master student is involved since February 2018 to develop the motion of plastic spheres in a water tank. Particle tracking methods were used to follow the spheres in the tank and compare the speed and acceleration with the equations of motion developed by Maxey-Riley. Also collisions by two spheres have been studied. Furthermore magnetic field analysis was made with COMSOL for Halbach types of magnet arrays and such systems have been built by using commercial magnets. The magnetic field of these systems was measured and is in good agreement with the computed field. During the last months of 2018 a $MnCl_2$ solution was chemically prepared and now neutral buoyancy tests are made with spheres that are dynamically followed in a MnCl2 solution under magnetic field forcing. Also collisions of two spheres are studied in this paramagnetic fluid. Results are being analyzed at the moment.

Dissertations

-

Scientific Publications

-

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

This project has started in October 2016. A small scale windtunnel has been designed and built. It was delivered in February 2018. Measurements are started up in March 2018 using Laser Doppler Anemometry (LDA) to study the decay of turbulence behind honeycombs. This information is relevant for the operation of MDS machines. Laser Doppler velocity measurements are being made to study the development of fluctuations behind plastic printed honeycombs. After some preliminary issues with the set-up the turbulence can now be monitored in x, y and z direction downstream of the honeycombs. A large measurement plan is now being in progress that by the summer of 2019 will yield all insight for the behavior of flow fluctuations downstream of the honeycombs.Parallel to the Laser Doppler wind tunnel system a second study was made in an independent wind tunnel where similar studies were made now using LaVision PIV. These studies give a more overall picture of the flow and indicate that vortex shedding takes place downstream of the honeycomb cells. Various effects of Reynolds number, cell thickness, and turbulence level were investigated. The picture that emerges has a close correspondence with the ongoing LD Velocimetry work. Work will be presented in the ICMF conference in May 2019.

Dissertations

-

Scientific Publications

-

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 large exhibits. Targeting a major step forward in their fundamental understanding, we develop tools for quantitative monitoring, analysis and experience management. These include real-time individuals and crowds tracking, as well as visual automated sentiments analysis.

Progress

The third year of the project focused on pedestrian tracking algorithm development, analysis of experimental data previously acquired, and pedestrian dynamics modeling. We modified the well-known Histogram of Oriented Gradients feature extractor to deliver highly accurate pedestrian localization in overhead depth maps. Moreover, we measured with high statistics the capability of visual cues (signage/illumination) of steering crowd flows. Finally, we extended our quantitative Langevin-like model for diluted pedestrian dynamics to include pairwise avoidance interactions (validated vs. millions of trajectories acquired at Eindhoven station. Cf. depth map in Figure).

Dissertations

-

Scientific Publications

1. A. Corbetta, J.A. Meeusen, C. Lee, R. Benzi, F. Toschi. Physics-based modeling and data representation of pairwise interactions among pedestrians. Phys. Rev. E. 98, 062310, 2018.

Project leaders

F Toschi

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

A Corbetta, F Toschi

Cooperations

Shenzhen Institutes of Advanced Technology (SIAT), China.
Philips Lighting Research

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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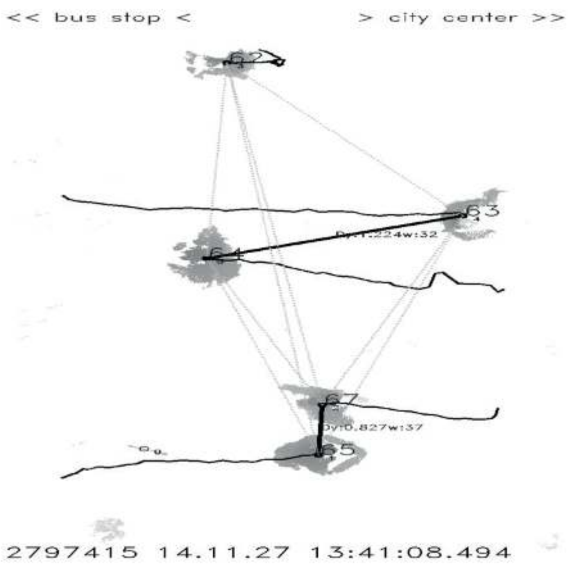

Project leaders
RPJ Kunnen, HJH Clercx
Research theme
Complex dynamics of fluids
Participants
JS Cheng, AJ Aguirre Guzman, M Madonia, HJH Clercx, RPJ Kunnen
Cooperations
-
Funded by
ERC
Funded %

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

Start of the project
2016
Information
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Project Aim
The goal of the TROCONVEX project is to explore the physics of extreme rotating Rayleigh-Bénard convection in a laboratory setting. My role in the project involves aiding in the design process and collecting and analyzing thermal data. I will use thermal measurements to characterize the modes of heat transfer occurring in geostrophic turbulence, locate the transitions between different flow regimes, and, in combination with numerical simulations and velocity measurements, gain insight into the underlying flow dynamics.

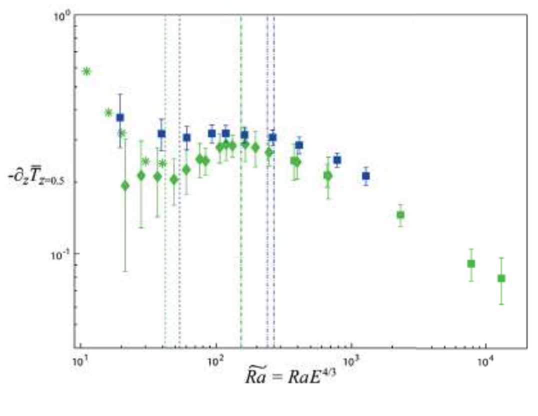
Progress
Primary: Completed construction and made various design improvements to the experimental rotating convection setup. Data in tanks of 0.8m and 2.0m height have been collected: heat transfer results showing marked agreement with previous studies and with numerical simulations. We are developing a novel method of characterizing disparate flow regimes via temperature profiles. Currently acquiring images and movies of the flow field and preparing to set up the 4.0m high tank, which will reach more extreme conditions than any existing rotating convection study.

Secondary: Conducted numerical rotating convection simulations with varying centrifugal forcing. Currently analyzing results and exploring literature for physical interpretation ideas.

Dissertations
-

Scientific Publications
1. Cheng, J.S., Aurnou, J.M., Julien, K., and Kunnen, R.P.J. (2018). A heuristic framework for next-generation models of geostrophic convective turbulence. Geophys. Astrophys. Fluid Dyn., 112(4), 277–300.

Midplane temperature gradient shows significant changes in trend as the flow reaches different behavioral regimes.



Flow field in nonrotating convection visualized by homemade rheoscopic particles.

PROJECT AIM

The main aim of the project is the development of numerical tools to characterize transport of particle debris under combined effects of fluid dynamics and plasma. We want to study when and how particles are released from surfaces under the conditions present in EUV lithography tool (hydrodynamic and rarefied gas flows, in presence of harsh and weak plasma environment). This will lead to a clear picture of what occurs inside the tool's plasma and main chambers and how it is possible to influence and, in perspective, prevent potential damaging dust to be released from surfaces.

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PROGRESS

The hybrid Direct Simulation Monte Carlo-Lattice Boltzmann Method (DSMC-LBM) methodology for the study of flows with variable non-equilibrium effects, recently developed and validated for a 1D flow set-up has been extended to a complex 3D flow set-up relevant for industrial applications. The very good results both in terms of accuracy and reduction of computational cost achieved for the 1D case have been confirmed also for a more complex flow. The main result is the drastical reduction of computational time (a more than 4x speed-up with respect to a full DSMC simulation is achieved) while maitaining an accurate solution.

DISSERTATIONS

1. G. Di Staso, PhD dissertation, Hybrid discretizations of the Boltzmann equation for the dilute gas flow regime.

SCIENTIFIC PUBLICATIONS

1. G. Di Staso, S. Srivastava, E. Arlemark, H.J.H. Clercx, and F. Toschi, Hybrid lattice Boltzmann-direct simulation Monte Carlo approach for flows in three-dimensional geometries, Comput. Fluids 172, 492.
2. Di Staso, G., Srivastava, S., Arlemark, E., Clercx, H. J. H. & Toschi, F., 2018, Hybrid lattice Boltzmann-Direct Simulation Monte Carlo approach for non-equilibrium flows in complex geometries, Proceedings of the 5th European Conference on Microfluidics - mFlu18 & 3rd European Conference on Non-Equilibrium Gas Flows - NEGF18, February 28-March 2, 2018, Strasbourg, France. p. 1-4 4 p.

PROJECT LEADERS

HJH Clercx, F Toschi

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

G Di Staso, S Nijdam, GMW Kroesen, F Toschi, HJH Clercx

COOPERATIONS

ASML

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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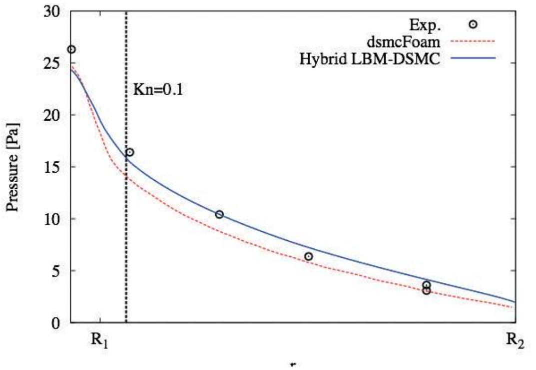

Comparison of the static pressure profiles obtained by the reference DSMC method (red dashed line), the hybrid method (blue line), experimental data (black dots).

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

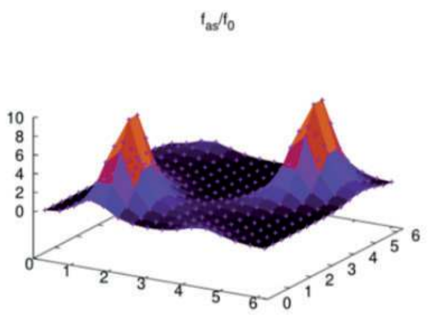
Thanks to the numerical study we discover that flow can significantly diminish the effect of selective advantage on fixation probabilities. However, because of number fluctuations, a relatively small selective advantage may not be successful since the characteristic time scale is much smaller than the one associated with turbulent effects. From the pictures it is clearly shown that the average of the asymptotic value of f is about ten times its initial value near the source. We can conclude that for 2-D system how much the probability distribution is going to increase depends on the initial position.

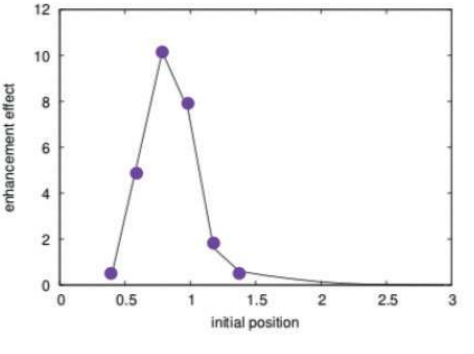
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-





Left side: Shape of the asymptotic fraction $f_\infty = \lim_{t\to\infty}$ 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_∞ f(0) (continuous black line).

PROJECT AIM

Understand the underlying physics and improve the modeling of how barotropic vortices and sediment interact.

PROGRESS

Our research on sediment transport under a spin-down flow has been successfully concluded. Currently, we are studying the transport of sediment by a translating monopolar vortex. Measurements are done simultaneously for the surface flow velocity field and region of high sediment suspension in the water column. Additionally, we perform measurements of the changes in the bed. For this last measurement, we have developed a new photogrammetric technique that allows for measurements through a deformed and changing water surface. Additionally, we are performing a numerical study of the sediment transport by large-scale, tidal dipolar vortices.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. González-Vera, A. S., Duran-Matute, M., & van Heijst, G. J. F. (2018). Morphodynamics of a sediment bed in a fluid-filled cylinder during spin-down: An experimental study. Physical Review Fluids, 3(12), 124306.

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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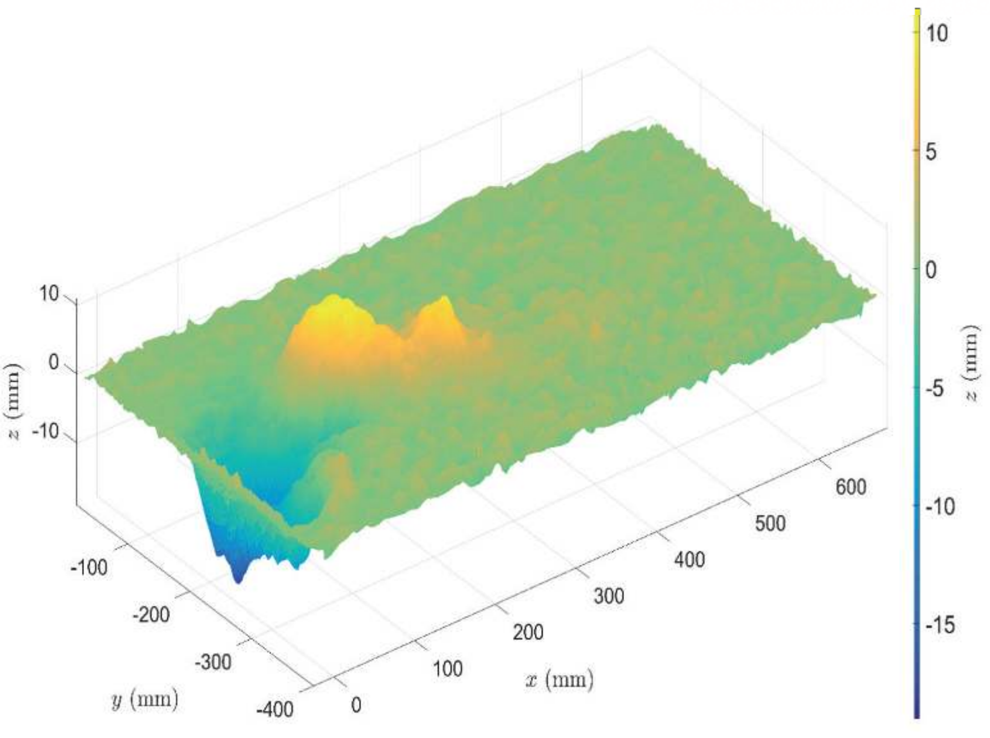

Study of non-isothermal rarefied gas flows with hybrid DSMC-LBM simulations

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

Understanding of the rarefied gas dynamics and the Direct Simulation of Monte Carlo method, writing example simulation codes for the basic problems, (e,g, lid-driven cavity). Understand the principles of Lattice-Boltzmann method, writing example codes (e.g. Kelvin Helmholtz instability). Rayleigh-Benard flow in rarefied gas dynamics, understanding the heat-transfer behavior of unsteady flows.

Dissertations

-

Scientific Publications

-

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 to the substrate: We studied the effect of substrate wetting on the phase separation dynamics near to the substrate in comparison to the bulk. Effect of wetting potential on the morphology of the domain is under investigation. Solvent evaporation modelling: Preliminary analysis of modelling solvent evaporation using LBM was conducted. We propose a lattice Boltzmann method to treat bulk evaporation of multi-component fluid system. Bulk evaporation is modelled as a moving boundary problem and the resultant domain shrinkage is accounted by coordinate transformation.

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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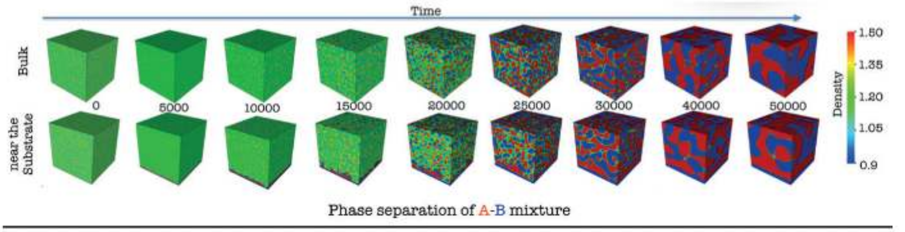
Simulation snapshots of time evolution of an A-B symmetric fluid mixture undergoing phase separation by spinodal decomposition in bulk (top row) and on a substrate preferentially wet by B-component (bottom row) from an initially well-mixed state. Domain growth in bulk is isotropic while substrate wetting leads to formation of a B-rich layer (wetting layer) next to the substrate from early times



Project leaders
F Toschi, HJH Clercx
Research theme
Complex Dynamics of Fluids
Participants
A Gupta, F Toschi, HJH Clercx
Cooperations
Shell-NWO/FOM, Univ. of Almeria, Spain
Funded by
Shell-NWO/FOM
Funded %

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

Start of the project
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Information
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Project Aim

The aim of the present project is to investigate numerically and develop models for the statistical properties of hydrodynamics stresses on algae in turbulent environments at different cell concentrations. In the recent past the small-scale statistical properties of (point-wise) particles in turbulence, like e.g. their acceleration, have been investigated experimentally and numerically. Numerical methods have been developed and employed to study the rheological properties of very dense suspensions of cells in simple laminar flows. Here we will need to combine the physics and the numerical methods of these previous studies and push both considerably further to challenge the turbulence transport and the statistical properties of (non)-Newtonian dense cell suspensions.

Progress

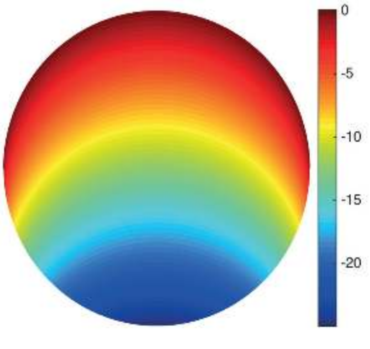
We coupled the DNS of particle laden turbulent pipe with a light regime analysis. Using the particle trajectories, we calculated the power spectral density of the irradiance signal and the circulation frequencies of particles. Subsequently, the stresslet distribution and the fragmentation rate of particles with different shapes were discussed. Finally, we showed a comparison of particle trajectories computed from DNS using LBM against LES using ANSYS Fluent. Overall, we attempted to develop a framework for modeling, understanding and optimizing the particle migration and cell damage due to turbulent flow in tubular photo- bioreactors. With the incorporation of these works, the PhD thesis is finalized.

Dissertations

-

Scientific Publications

1. Tauzin, G., Biferale, L., Sbragaglia, M., Gupta, A., Toschi, F., Bartel, A. & Ehrhardt, M., 2018, A numerical tool for the study of the hydrodynamic recovery of the Lattice Boltzmann Method. Computers and Fluids. 172, p. 241-250 10 p.
2. Gupta, A., Clercx, H. J. H. & Toschi, F., 2018. Effect of particle shape on fluid statistics and particle dynamics in turbulent pipe flow. European Physical Journal E : Soft Matter. 41, 10, 15 p., 116.
3. Gupta, A., Clercx, H. J. H. & Toschi, F., 2018, Simulation of finite-size particles in turbulent flows using the lattice Boltzmann method. Communications in Computational Physics. 23, 3, p. 665-684 20 p.



Average irradiance profiles (Iav) inside the tubular photo-bioreactor as a function of the radial coordinates, normalized by the external direct irradiance (Io,direct = 1000µmol/m2s) for a pipe radius of 0.03m.

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

1. van Houwelingen, J. (2018). Optimizing propulsion in human swim. Eindhoven: Technische Universiteit Eindhoven. ((Co-)promot.; Clercx, H.J.H., P.J. van Beek en W. van de Water).

Scientific Publications

1. van Houwelingen, J., Antwerpen, R. M., Holten, A. P. C., Grift, E. J., Westerweel, J. & Clercx, H. J.H. Automated LED tracking to measure instantaneous velocities in swimming. 2018, Sports Engineering. 21, p. 419-427 9 p.

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

Starting focus on the learning of Lattice-Boltzmann Method (LBM) and Direct Simulation Monte Carlo (DSMC) numerical models for solving the Boltzmann equation of a gas flow by developing 2D codes, used also as testing environment for novel implementations, later to be ported in the 3D production code. Implemented interpolated 2nd-order accurate fluid-solid interaction algorithm in the 3D production code LBE3D for the description of the transport of arbitrary shaped particles. Performing systematic analysis of the error reduction provided by the new algorithm with respect to the standard 1st-order accurate bounce-back method.

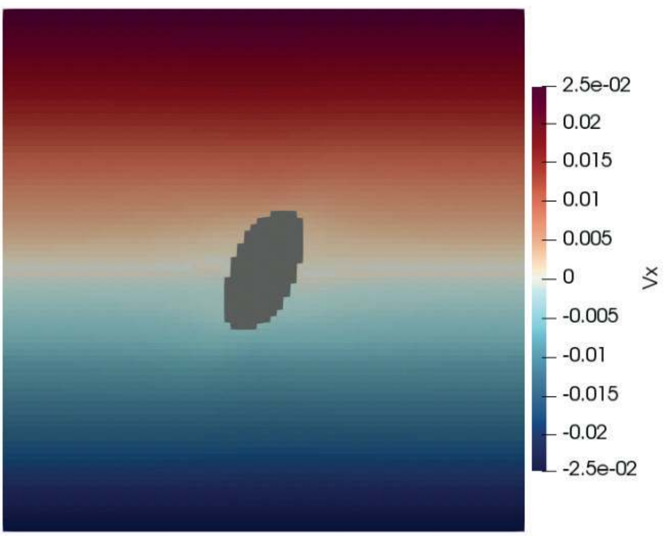
Dissertations

-

Scientific Publications

-

Snapshot from a Lattice-Boltzmann Method simulation of an ellipsoid set into motion by a shear flow



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.

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

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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-WDY

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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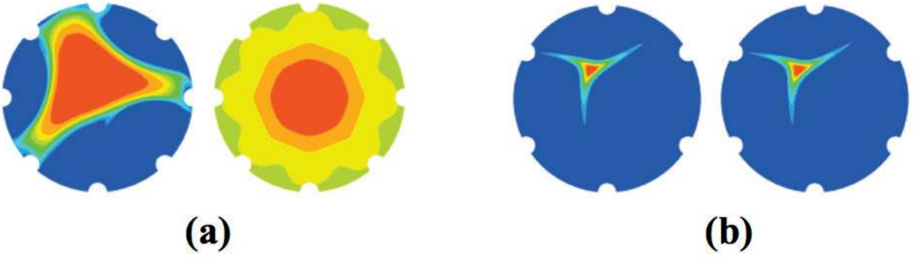
Project Aim
The study investigates scalar transport in enhanced subsurface flows driven by injection and production wells for 3 generic transport problems: (i) rapid scalar extraction; (ii) confinement of a scalar quantity for in situ processing; (iii) targeted delivery of a scalar quantity to a designated 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
Investigation of (scalar) thermal transport by the subsurface flow was investigated using Local Thermal Non-Equilibrium (LTNE) model for Darcy-type flows in 2018. The impact of diffusion and internal heat exchange between fluid and porous matrix on the subsurface scalar transport is investigated. This revealed that scalar extraction is slower in RPM flows compared to the base flow due to the entrapment of heat in a central warm region of the reservoir domain. The scalar entrapment however is effective for the other two transport goals thereby enabling well-controlled confinement (Fig a) and/or targeted delivery (Fig b) using a carefully chosen pumping scheme.

Dissertations
-

Scientific Publications
-



Fluid phase (left) and Solid phase (right) temperature field distribution enabling a) confinement of scalars towards the central region of the reservoir domain and b) targeted delivery of a scalar to isolated designated sub-regions of the reservoir

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

During 2019, previous investigations on the turbulent oscillating boundary layer lead to two submitted papers. The first deals with the influence of a reduced water-depth on the structure of the turbulent boundary layer (submitted to EFM) and the second discussed its implications for the existence and properties of the logarithmic layer (submitted to JHR). Investigations about the density driven flow have resulted in an improved 1DV model for highly stratified flows. This 1DV model has been implemented as forcing for DNS simulations allowing for the simulation of turbulent density driven flows with periodic boundary conditions.

Dissertations

-

Scientific Publications

-

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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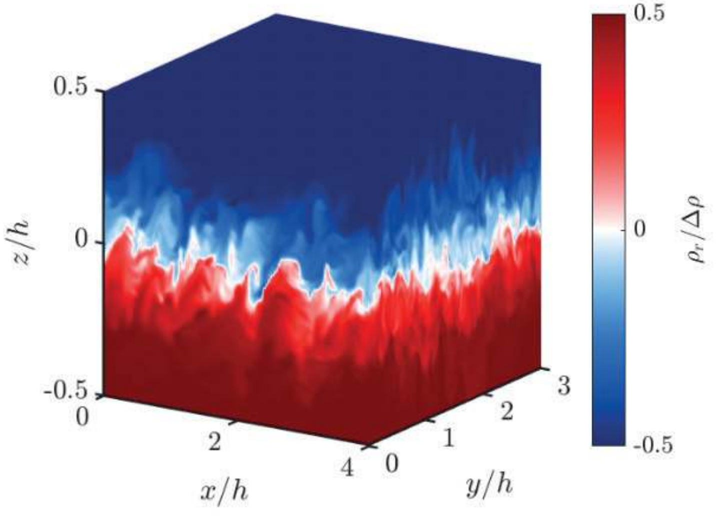

Project leaders
HJH Clercx, RPJ Kunnen
Research theme
Complex dynamics of fluids
Participants
A Kozhevnikov, RPJ Kunnen, HJH Clercx
Cooperations
TNO
Funded by
TKI
Funded %

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

Start of the project
2017
Information
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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

Systematic CFD simulations of the recoating process in additive manufacturing have been executed over the topography with the rectangular shape. The influence of the cavity length and depth on the free-surface deformation was investigated as well as the different values of the recoater width were considered. It was shown that the resin level in the cavity mostly depends on the penetration depth of the Couette-like flow. Experiments have been carried out to verify the results of numerical simulations. Comparison showed a good qualitative agreement with the CFD model.

Dissertations

-

Scientific Publications

-

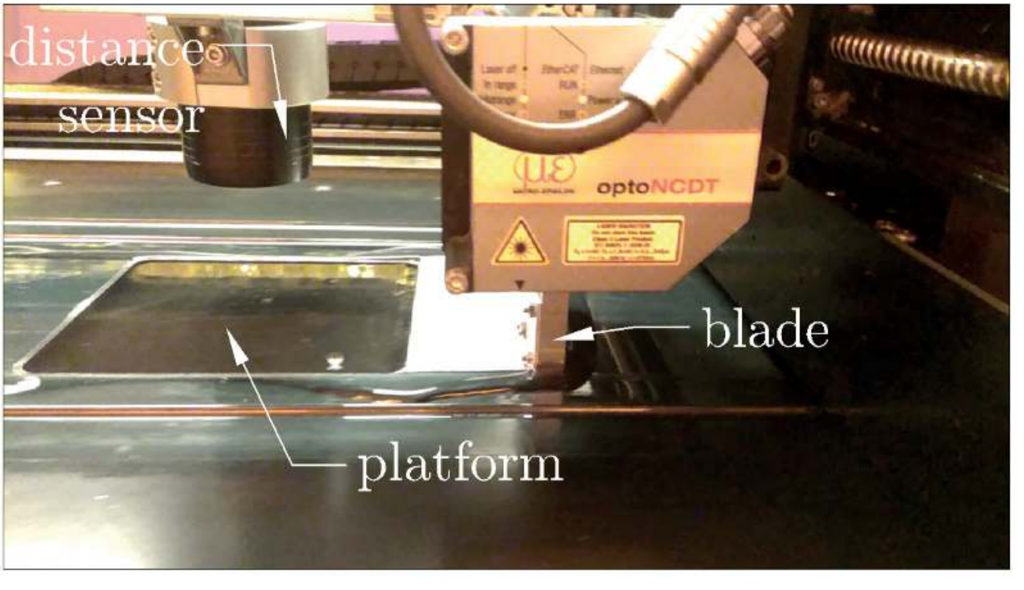

Photo of the experimental setup to investigate the resin surface height profile as a function of the cavity depth

PROJECT AIM

The aim of the project is to develop a quantitative connection between the physics of complex soft-glassy materials below yield stress and the dynamics of stick-slip faulting events leading to earthquakes. A novel formulation based on the multicomponent Lattice Boltzmann method is used to investigate fundamental issues related to natural seismicity, to find the interaction between spatially and temporally separated faulting events, as well as to determining the response of faults to external perturbations (i.e. induced seismicity) mimicking natural gas extraction and activities in injection wells.

PROGRESS

- We developed a mechanism for arresting topological re-arrangements in our soft-glassy model, and using it, we created a database of events where causality between event-pairs can be established.
- Using this database, we are also able to compute statistics which can differentiate between the mechanisms (pressure wave vs elastic wave) of triggering subsequent events.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Haans, A., Corbetta, A., Kumar, P.P. & Toschi, F. (2017). Measuring the effect of dynamic lighting on pedestrian speed by means of overhead kinectTM sensors and continuous pedestrian tracking algorithms.

PROJECT LEADERS

F Toschi, J Trampert

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

PP Kumar, F Toschi, J Trampert, R Benzi

COOPERATIONS

Shell-NWO/FOM

FUNDED BY

Shell-NWO/FOM

FUNDED %

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

START OF THE PROJECT

2015

INFORMATION

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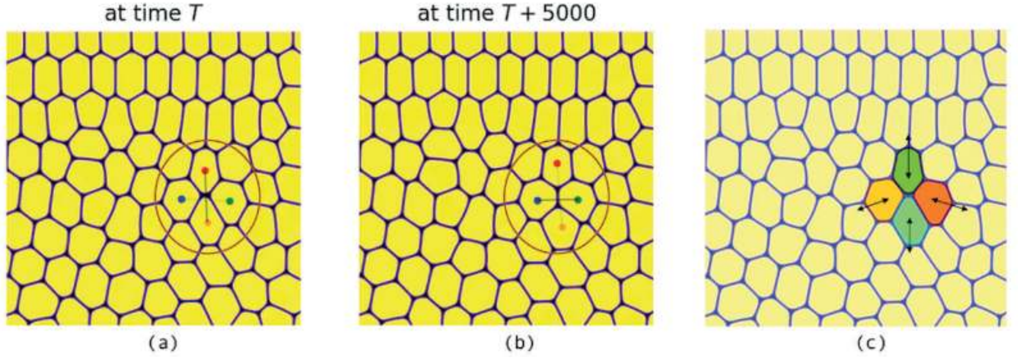

The figure shows a typical topological plastic re-arrangement in our LB simulation of a dense emulsion. Fig (a) and (b) highlight a cluster of 4 droplets, which undergo this neighbor switching. In Fig (c), we isolate the four using techniques from image processing literature and apply vibrations (along the axes shown by arrows), which stops this event from occurring

Project leaders
F Toschi, J. van Dijk
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
H Li, F Toschi, J van Dijk, GMW Kroesen
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

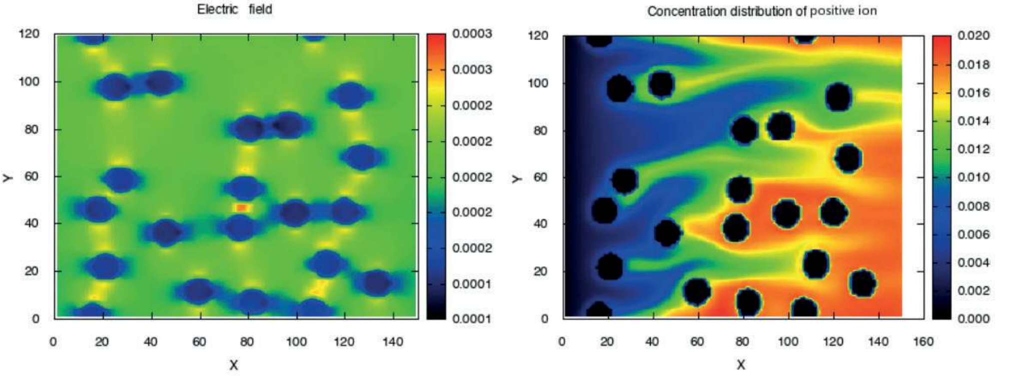
A 2D Lattice Boltzmann (LB) model is developed for plasma/flow problems in a packed sphere structures. Navier-Stokes equations for the fluid, Nernst-Planck equations for the electrokinetic and Poisson equation for the electrokinetic potential were applied to study the total density and velocity fields, the concentration of reactants and products, the electric potential and the interaction forces of the simplified reactive plasma fluid. Preliminary result shows that the packing beads can help to enhance the reaction efficiency by enhancing the local electric filed in the bed, but meanwhile, too many beads will result in higher flow velocity and leave less time for the reactants to react.

Dissertations

-

Scientific Publications

-



An illustrative example from our model. A fluid with only neutral species, A, flows through a packed sphere bed, with the reaction A0 -> B+ + C- takes place with reaction rate coefficient k which is a function of the local electric field. (a) Distribution of the electric field (dimensionless). Positive electrode at y=120 and negative electrode at y=0. (b) Concentration distribution of positive ion (dimensionless).

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

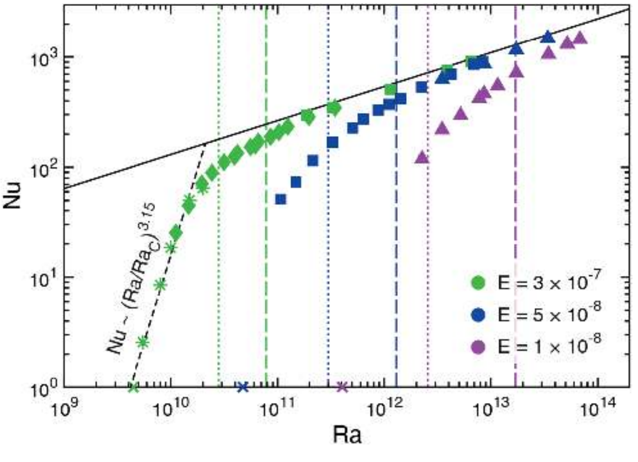
Collection of data from 2 m tank covering two different Ekman numbers. Calculation of heat transfer efficiency at different regimes, with temperature profile analysis. Upgrade and repair of the setup in order to get better performances at wider range of parameters. Calculation of heat loss of the setup. Progress in optical measurement setup. Design and realization of a new transparent segment to perform Stereo PIV, including a calibration grid system and illumination. Attendance of various courses related to PIV and general fluid dynamics.

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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Current size of the tank (2 m)

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

1) Investigation of simple shear an elongational flow droplet break employing both fully resolved Lattice Boltzmann SCMC simulations and the Maffettone-Minale model as a comparison

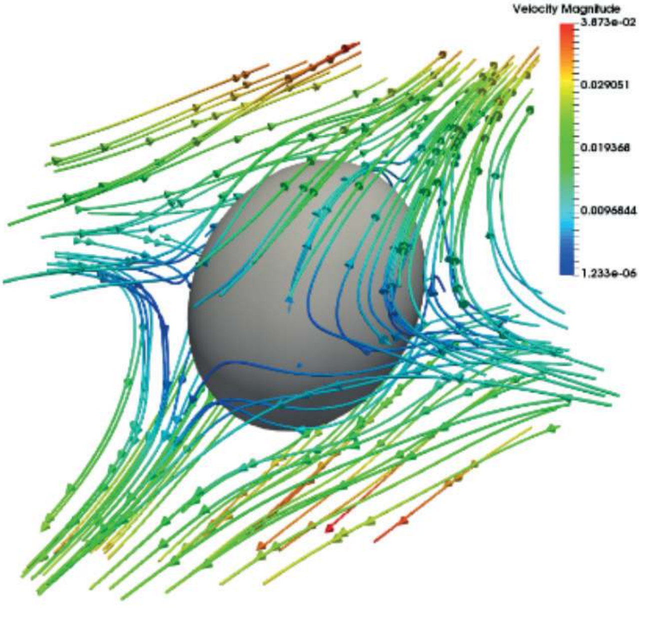
2) Set up for the study of sub-Kolmogorov droplets in isotropic turbulence finished and tested. The turbulent flow in the LB simulations is established via Lagrangian trajectories of passive tracer particles obtained from a pseudo spectral code.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Milan, F., Sbragaglia, M., Biferale, L. & Toschi, F. Lattice Boltzmann simulations of droplet dynamics in time-dependent flows (2018), European Physical Journal E. 41, 1, 6.



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 performed lattice Boltzmann simulations to study the imbibition of suspensions with varying particle interactions in model pores. Furthermore, we studied the spreading of soluble surfactant on a liquid thin film and developed a computational model. The model is able to reproduce key features such as the nucleation of a dry zone and dewetting induced by autophobing. At last, we studied and developed a 2D time dependent numerical model for droplet deposition (see figure). It is apparent that the line roughness diminishes in time. Moreover, the horizontal and vertical levelling proceed according to different time scales.

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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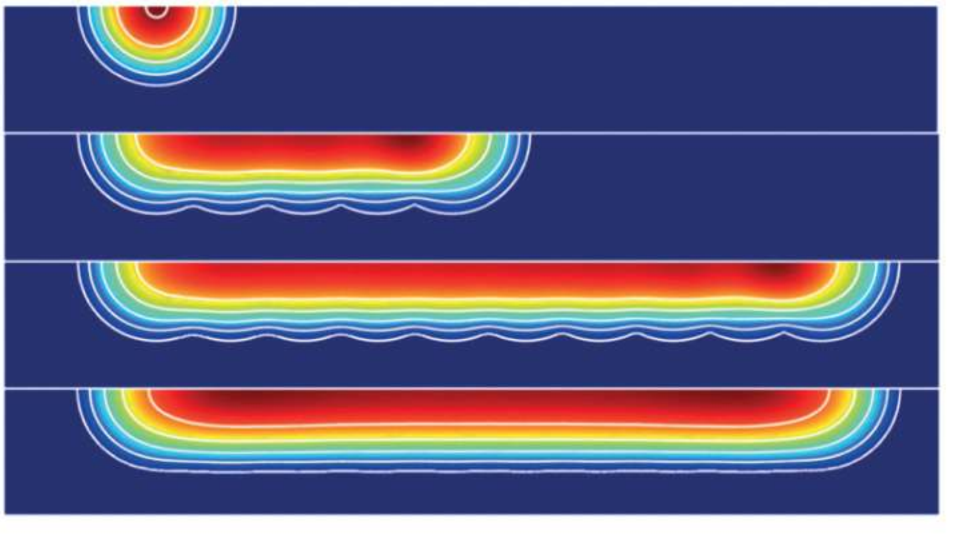

Top view of a printed line deposited as a one-dimensional array of droplets. Due to mirror symmetry, only one half of the line is shown.

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	100 %
STW	-
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

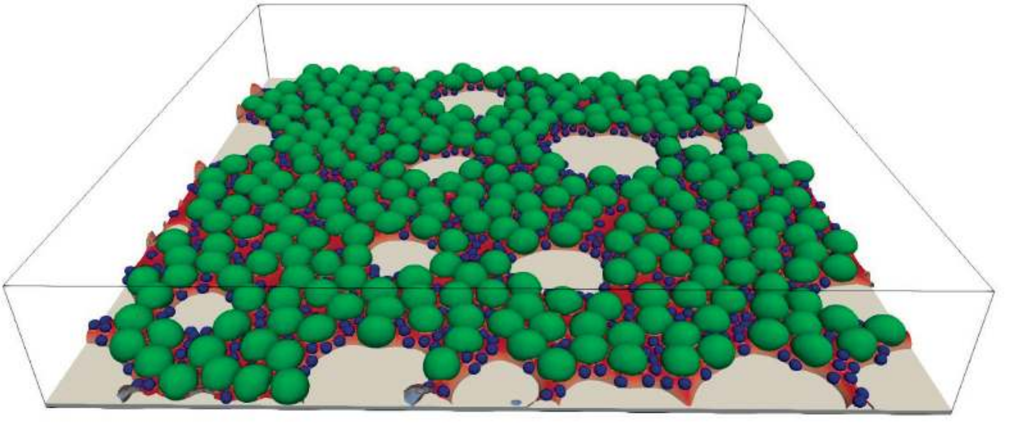
We developed a novel simulation method which is able to accurately model soft capsules in an evaporating fluid. The method has been implemented in 3D and is fully parallelized, allowing us to simulate large systems with dense suspensions of soft capsules, such as shown in the image below. Currently the capillary interaction between soft particles in thin films above a substrate are being studied.

Dissertations

-

Scientific Publications

-



Snapshot of a drying film with 300 large soft particles (green) and 600 rigid small particles (blue). The liquid interface (red) has partially de-wetted from the substrate (grey).

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, both numerically and theoretically, the effect of the thickness of the surrounding liquid layer on the lifetime of dissolving surface droplets. We performed 3D lattice Boltzmann simulations (as shown in Fig.1) and found that the lifetime is proportional to the thickness of the liquid layer. We proposed a theoretical model based on a quasi-static diffusion equation which confirms the numerical results.

2. We extended our lattice Boltzmann method code to study systems containing three fluid components and obtained preliminary results on the behavior of droplets deposited on a lubricated surface.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Q. Xie and J. Harting. From dot to ring: the role of friction on the deposition pattern of a drying colloidal suspension droplet. Langmuir 34, 5303-5311 (2018).
2. O. Aouane, Q. Xie, A. Scagliarini, J. Harting. Mesoscale simulations of Janus particles and deformable capsules in flow, in High Performance Computing in Science and Engineering '17, ed. W. Nagel, D. Kröner, M. Resch, Springer, 369-385 (2018).

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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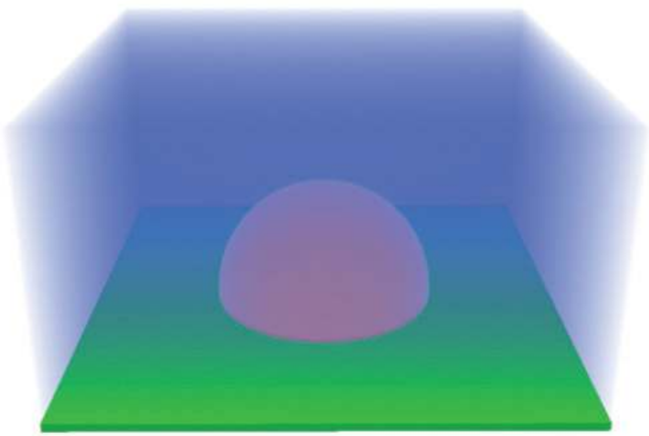

Project leaders
F Toschi
Research theme
Complex dynamics of fluids
Participants
X Xue, F Toschi, M Sbragaglia (Rome), L. Biferale (Rome)
Cooperations
University of Rome, Tor Vergata, HPC-LEAP Program, Eurotech (changed to Nvidia)
Funded by
HPC-LEAP(Marie Curie Fellowhsip), Horizon 2020
Funded %

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

1. Finalize and publish the Effects of thermal fluctuations on the fragmentation of a nanoligament.
2. Understand difference between SRT operator and MRT operation for Lattice Boltzmann methods in the multicomponent simulations.
3. Validate the wetted particle in the multicomponent fluctuating fluids. The particle is able to do Brownian motion with the correction of wall effect.
4. Study the influence of thermal fluctuations on the settling particle the confined geometry.

Dissertations

-

Scientific Publications

1. X.Xue, M. Sbragaglia, L. Biferale, F. Toschi, Effects of thermal uctuations in the fragmentation of a nanoligament, Physical Review E 98, 1. 9p 012802 (2018).
2. D. Chiappini, X. Xue, G. Falcucci, M. Sbragaglia, Ligament break-up simulation through pseudo-potential Lattice Boltzmann Method, AIP conference proceedings, , 4p 420003 (2018).

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

Inside an inkjet nozzle non-homogeneous wetting conditions may be present and result in asymmetric jetting when part of the nozzle is more hydrophobic or hydrophylic than other parts. In which manner and to what degree this impacts the jetting process is being investigated through simulations. Currently two multi-phase Lattice Boltzmann models are being considered; a free-energy and color-gradient model. Benchmarking and validating these approaches is underway. Numerically stable 3D simulations with high density ratios (order of 1000) have been achieved using the free-energy model, including non-uniform wetting conditions inside the nozzle.

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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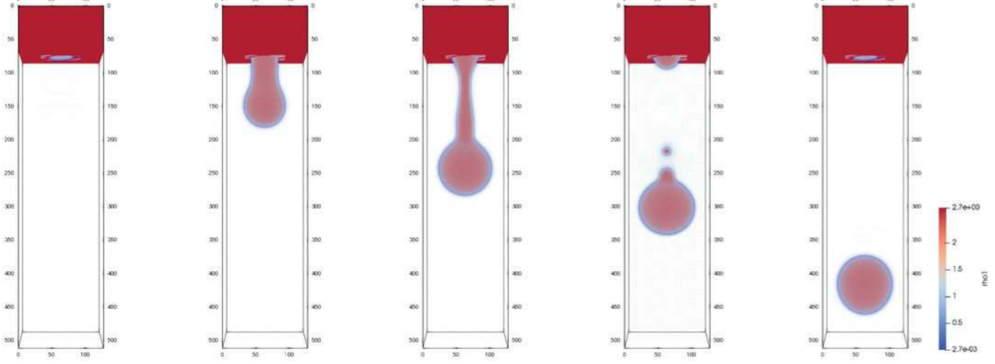

Visualization of the density field of a LBM jetting simulation for a density ratio of 1000 between the jetted fluid and ambient.

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

Funded %

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

Start of the project
2015

Information
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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

A manuscript concerning electrically controllable adhesion has been drafted. Dynamical features of dewetting of thin liquid films between unpatterned soft substrates have been studied systematically by experiments and numerical simulations.

Dissertations

-

Scientific Publications

-

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

Study the stabilization of inorganic crystal hydrates in order to:

- Obtain a thermochemical material which can be applied over 20 years for heat storage purpose in the built environment.

- Understand the hydration and solid-state changes during use of the thermochemical material.

Progress

Thermochemical materials K2CO3, MgCl2 and Na2S have been investigated in depth on energy density, power output and chemical stability in view of domestic heat storage application, presenting a critical assessment of potential chemical side reactions in an open and closed reactor concept.

Dissertations

-

Scientific Publications

1. Sögütoglu, L. C., Donkers, P. A. J., Fischer, H. R., Huinink, H. P., & Adan, O. C. G. (2018). In-depth investigation of thermochemical performance in a heat battery: Cyclic analysis of K2CO3, MgCl2 and Na2S. Applied Energy, 215, 159-173.

Project leaders
H.P Huinink

Research theme
Complex dynamics of fluids

Participants
Dr.ir. H.P. Huinink
Prof.dr. O.C.G. Adan
Dr. H.F. Fischer (TNO)

Cooperations
TNO, DOW, CALDIC

Funded by
EU H2020 project CREATE

Funded %

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

Start of the project
2015

Information
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Project leaders
L. Pel, O.C. Adan

Research theme
Complex dynamics of fluids

Participants
Dr.ir. L. Pel, Prof.dr. O.C.G. Adan

Cooperations
TNO, TU-Delft, Rijkswaterstaat, ConSensor, BAM, ENCI

Funded by
STW

Funded %

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

Start of the project
2012

Information
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https://www.tue.nl/universiteit/faculteiten/technische-natuurkunde/onderzoek/onderzoeksgroepen/transport-in-permeabele-media-tpm/transport-in-permeable-media-tpm/

Project Aim
One of the main causes of corrosion of steel bars in concrete is present of chloride in the concrete which penetrates together with moisture in to the porous structure of concrete. In cementitious materials part of the chloride ions will be bound (physically or chemically) to the structure. The corrosion of steel bars is caused by free chloride ions. The aim of this project is to study chloride ingress in concrete by Nuclear Magnetic Resonance (NMR). The main focus is on a situation where there is a permanent supply of moisture and ions on one side of materials, whereas the other side is exposed to drying in the open air, the so-called wick action.

Progress
- Salt diffusion in brick and concrete has been measured with two different method of radial diffusion and axial ion profile measurement. The results shows very well matching with simulation
- Sodium and Chloride profile during wick action has been measured by 4.7T NMR setup
- Comparison of resistivity sensor output during hydration of cement with Hydrogen relaxation measurement from NMR.

Dissertations
-

Scientific Publications
1. A simplified model for the combined wicking and evaporation of NaCl solution in limestone; L.Pel, R.Pishkari, M.Casti Journal of Materials and Structures.
2. L. Pel, R. Pishkari, Combined wicking and drying of NaCI solution in concrete, ConMod 2018, August, Delft, The Netherlands.

True Solvent Free (TSoF): Towards the next generation of waterborne coatings

Project Aim

The aim of the study described in this thesis is to determine the role of carboxylic acid functionalities in latex polymer particles on the drying behavior and coating end properties of latex dispersions with varying methacrylic acid (MAA) content. The drying rate decreases at MAA concentrations ≥10 wt%. With dilatational rheology it is shown that particle accumulation on the latex surface during drying can account for this behavior. Moreover, using 1H NMR relaxometry and increased interaction of water with the polymer phase with increasing MAA content is observed.

A correlation between the glass transition temperature Tg and polymer mobility, expressed as a T2 relaxation time, is found as a function of water uptake. This clearly shows the effect of water on polymer mobility in relation with the polymer polarity. With FTIR-ATR analyses, the role of carboxylic acid groups and the dimerization of these substituents in the dry coating is underlined. Water absorption by the coating results in the formation of "open" dimers, i.e. dimers connected through water molecules and a decrease of the polymer Tg.

Progress

Extensive studies have been done on the drying behavior of polymer dispersions in water ("latex") containing polymer particles with various amounts of methacrylic acid groups.

Dissertations

-

Scientific Publications

1. B. Voogt, H.P. Huinink, S.J.F. Erich, J. Scheerder, P. Venema, O.C.G. Adan, ''Water mobility during drying of hard and soft type latex: Systematic GARField 1H NMR relaxometry studies'', Progress in Organic Coatings. 123, 111-119, 2018.

Project leaders

H. P. Huinink

Research theme

Complex dynamics of fluids

Participants

Dr. H.P. Huinink, Dr. S.J.F. Erich, Prof. Dr. O.C.G. Adan, Dr. P. Venema (Wageningen University), Priv.-Doz. Dr. J.D.R. Harting, Prof. Dr. J. Keddie (University of Surrey), B. Voogt, MSc. M.P.J. Wouters, MSc.

Cooperations

DSM Coating Resins, Teknos-Drywood, AkzoNobel, TNO, NVVT, SHR, Océ-Technologies

Funded by

STW/NWO

Funded %

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

Start of the project

2014

Information

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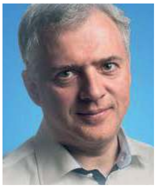
Prof.dr.ir. GWM Kroesen



Prof.dr.ir. V Banine

Prof.dr.ir. U Ebert

Prof.dr.ir. GJ van Rooij

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!

PROJECT AIM

It has been known since many years that cold atmospheric discharges like coronas, streamers and dielectric barrier discharges can induce a gas flow. This effect is generally called corona wind or ion wind. Many groups have investigated corona wind with empiric methods, but insight in the microscopic principles is very limited. The project will make the connection between microscopic quantities like ion drift velocity and macroscopic quantities like flow velocity by investigating them both. This will lead to a detailed understanding of ion wind, thus enabling large steps in the optimization of its applications.

PROGRESS

The ion wind is generated in needle-cylinder electrode by corona discharge. Hot-wire anemometry method is used to measure the wind velocity downward the electrode. When the voltage is above the corona inception level, the flow increases linearly with the voltage. The rising of relative humidity from 40% to 70% can severely inhibit the flow velocity. Using the Schlieren technique to gain flow patterns, it was found that flow patterns can be measured. Furthermore, a three-species corona model coupled with gas dynamics is built. The drift-diffusion equation of plasma together with the Navier-stokes momentum equation are solved in Comsol Multiphysics.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Chen, S.; van den Berg, R. & Nijdam, S., The effect of DC voltage polarity on ionic wind in ambient air for cooling purposes, Plasma Sources Sci. T., 2018, 27, 055021.
2. Chen, S.; Li, K. & Nijdam, S., Transition mechanism of negative DC corona modes in atmospheric air: from Trichel pulses to pulseless glow, Plasma Sources Sci. T., 2018 (accepted)

PROJECT LEADERS

S. Nijdam

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

She Chen

COOPERATIONS

Together with Turbulence Vortex Dynamics group, TU/e, H.J.H. Clercx and A.P.C. Holten.

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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PlasmaPower2Gas (PP2G) - Efficient Electrical to Chemical Energy Conversion via Synergy Effects in Plasma- and Catalytic Technology

Project leaders
prof. dr. ir. G. M. W. (Gerrit) Kroesen
dr.ir. J. (Jan) van Dijk

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
S. (Samaneh) Tadayon Mousavi
ir. P. M. J. (Peter) Koelman

Cooperations
This project is part of STW project 13581. The other participants are: dr. W.A.Bongers of the Dutch Institute for Fundamental Energy Research. Prof.dr.L.Lefferts from University of Twente.

Funded by
STW/Alliander

Funded %

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

Start of the project
2015

Information
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Project Aim

Transformation of CO2 into fuels that are transportable with current infrastructure seems a promising idea to solve one part of global warming. In this project, a multi-disciplinary approach is pursued to cover the entire process chain from CO2 and H2O to CH4 by advanced microwave plasma source design, diagnostics, modeling, and catalytic follow up chemistry. Dissociation of CO2 is a non-equilibrium electrical gas discharge is the first section of this triple part project, and maximization of the whole process efficiently through admixture of water in the first part is the final aim of the project. Our project is to investigate numerically the effect of adding H2O to CO2 dissociation in microwave plasma.

Progress

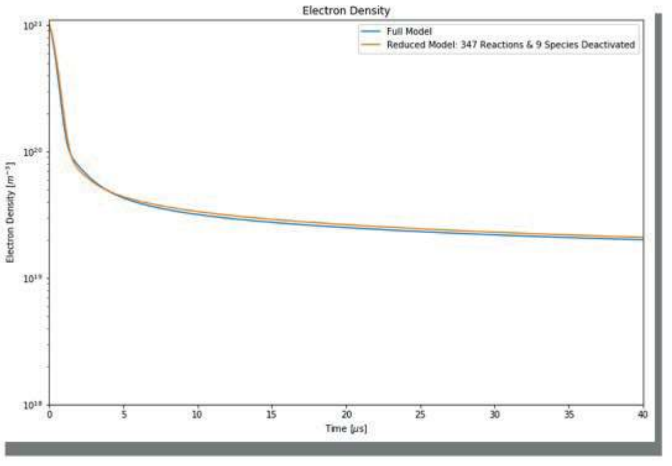
In order to achieve the goal of the project, we need a thorough understanding of the H2O chemistry. Therefore, we made, verified, and validated a global model for H2O-He mixture. The results of this model have been compared with measured electron density in a microwave reactor in DIFFER. In order to understand the underlying chemical mechanism, the so-called reaction pathway algorithm has been implemented, and the performance of the algorithm for complex chemistry has been tested by designing a variety of test cases. This algorithm has been used to develop a semi-automated reduction method for non-equilibrium, complex chemical reaction networks. In the below figure, the result of electron density variation with time for a full H2O-He model, which mimics the microwave reactor conditions, is compared with reduced model.

Dissertations

-

Scientific Publications

-



PROJECT AIM

As the shapes of the illumination optics become increasingly more complex, with typical feature sizes ranging from several tens of microns to a millimeter, new measurement techniques to profile these surfaces have to be developed. The proposed method is based on so-called plasma bullets, which are fast moving ionization fronts generated in a gas flow. The physics of plasma bullets, of which more detailed understanding is important in the development of novel applications, are experimentally investigated by fast imaging and (nonlinear) laser spectroscopic diagnostics.

PROGRESS

New insights in the spatial and temporal development of plasma bullets have been obtained by imaging the plasma bullets with a high frame rate camera with image intensifier when the setup is first turned on. It has been found that flow plays an important role in the development of plasma bullet generated in nitrogen and argon. Electric field measurements by means of four-wave mixing have been successfully performed and an Abel-like inversion method to obtain spatially resolved data from these measurements has been demonstrated for the first time.

DISSERTATIONS

1. van der Schans, M. (2018). Experiments on the physics of pulsed plasma jets Eindhoven: Technische Universiteit Eindhoven.

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

S. Nijdam, W.L. IJzerman

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

M. van der Schans

COOPERATIONS

-

FUNDED BY

Philips

FUNDED %

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

START OF THE PROJECT

2014

INFORMATION

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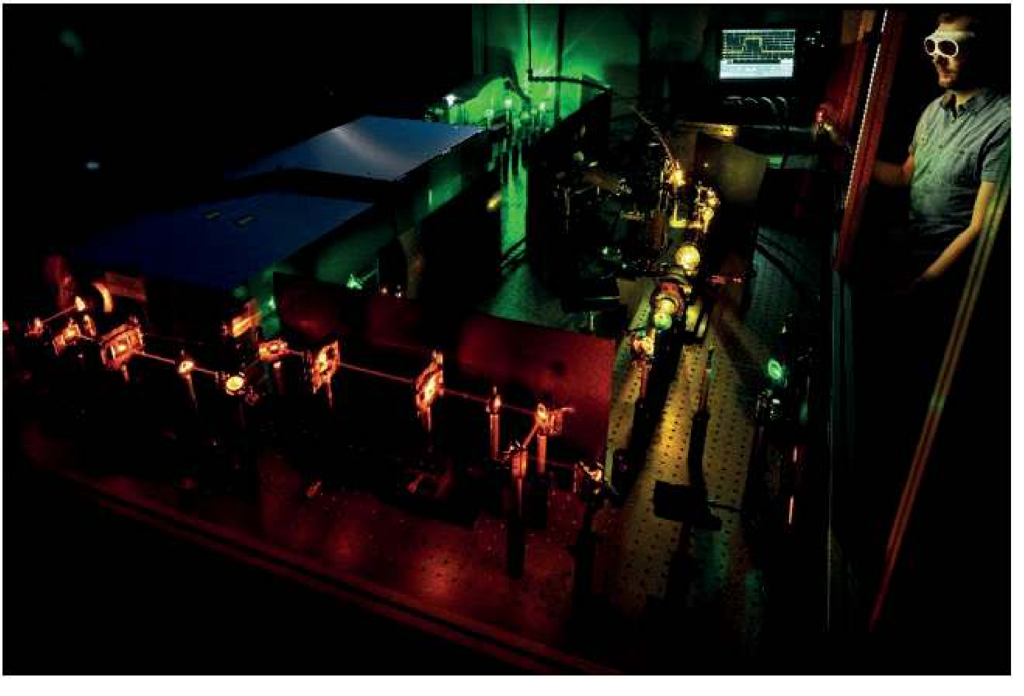

PROJECT LEADERS
prof.dr.ir. G.M.W. (Gerrit) Kroesen
dr.ir. J. (Jan) van Dijk

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
This project is part of STW project 13584. The other participants are: dr. W.A. Bongers of the Dutch Institute for Fundamental Energy Research, prof. dr. D.C. Nijmeijer from the Eindhoven University of Technology.

COOPERATIONS
dr. Emile Carbone (IPP Garching)

FUNDED BY
STW/Alliander

FUNDED %

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

START OF THE PROJECT
2015

INFORMATION
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PROJECT AIM

The nature of renewable energy sources is typically intermittent and does not match with the energy demand. When the energy production does exceed the demand of energy, the surplus is stored in batteries, which is an inefficient and expensive process. One idea is to store this energy by reversing the process of burning fossil fuel. By plasma assisted CO2 dissociation CO is produced, where after fuels are produced. The goal of this project is to improve the efficiency of the plasma assisted CO2 dissociation. This will be done by numerical simulations of CO2 microwave plasmas.

PROGRESS

A method for uncertainty analysis for large global models is presented.

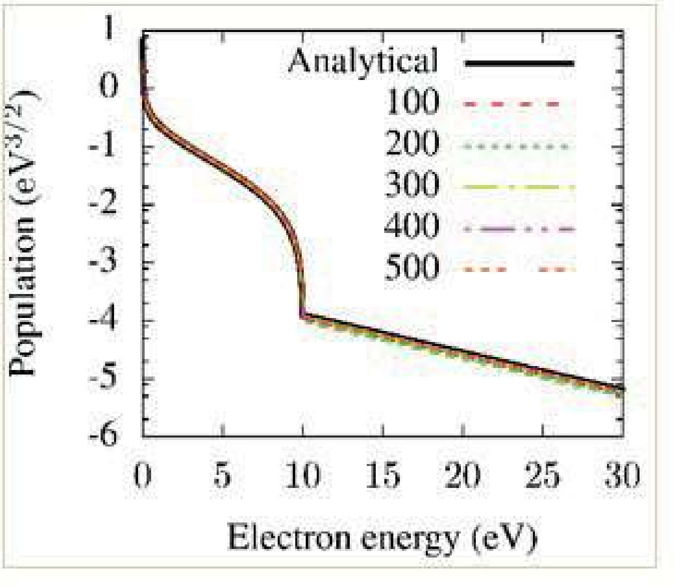
Analytical solutions for the two term approximation of the Boltzmann equation with inelastic source terms are presented, and being compared to numerical solutions. The figure below shows the analytical solution for a Dirac delta peaked excitation cross section at 10 eV, with a Maxwell-Boltzmann like shaped tail. In color the numerical solutions are presented.

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

Project Aim

Enhanced subsurface flows for geothermal heat recovery, in situ minerals mining or groundwater remediation from/in underground reservoirs typically employ a static system of injector-producer wells. This usually leads to inefficient distribution of the production fluid throughout the reservoir, resulting in suboptimal performance. Recent studies in literature have shown that designing pumping schemes for time-periodic activation of pairs of injector-producer wells on the basis of Lagrangian dynamics and chaos theory can substantially enhance the performance of the subsurface process. However, effects as reservoir anisotropy and the non-trivial link between flow of the production fluid and scalar transport due to diffusion must be adequately incorporated in these design and optimization procedures. The project aims at deepening fundamental insights into these phenomena.

Progress

Investigations concentrated on the role of Lagrangian coherent structures (LCSs) in advective-diffusive scalar transport. They namely strongly impact advective-diffusive scalar transport in that certain LCSs essentially "shape" the fundamental dynamic states (the so-called "eigenmodes") that govern the Eulerian evolution of scalar fields. The link between LCSs and eigenmodes was investigated in the time-periodic Darcy flow within a 2D circular domain driven by periodically reoriented diametrically opposite source-sink pairs (2D RPM flow). LCSs are visualized by stroboscopic maps of tracers released in the flow and compared with the dominant eigenmodes of a scalar field obtained by Dynamic Mode Decomposition (DMD). Application to a case study on heat extraction from a hot reservoir by injection of cold fluid reveals an intimate connection between dominant eigenmodes (fig. a) and island-like LCSs (fig. b). Connections thus exposed can be exploited for e.g. creation of subsurface reaction zones and fronts via LCS-based flow control.

Dissertations

1. Scalar transport in enhanced subsurface flows, S. Varghese, PhD thesis TU/e (defence May 2019).

Scientific Publications

1. Lagrangian transport in a class of (anisotropic) subsurface reservoirs, Speetjens, M.F.M., Varghese, S., Trieling, R.R. (2018). EGU General Assembly 2018, Vienna, Austria.
2. Lagrangian transport in a class of (anisotropic) subsurface reservoirs, Speetjens, M.F.M., Varghese, S., Trieling, R.R. (2018). Interpore 2018, New Orleans, USA
3. Subsurface in situ processing by Lagrangian coherent structures, Speetjens, M.F.M., Varghese, S., Trieling, R.R. (2018). 12th Euromech Fluid Mechanics Conference, Vienna, Austria.

Project leaders

MFM Speetjens

Research theme

Complex dynamics of fluids

Participants

S Varghese (PhD candidate)
MFM Speetjens (TU/e-ET; 2nd promotor)
RR Trieling (TU/e-WDY; co-promotor)
F Toschi (TU/e-WDY; 1st promotor)

Cooperations

collaborative project of TU/e-ET and TU/e-WDY

Funded by

FOM (CSER program; project 13CSER032)

Funded %

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

Start of the project

2014

Information

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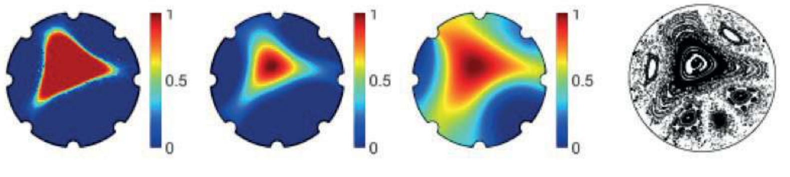
Dominant modes in temperature field (cold=0; hot=1) visualized by DMD versus LCSs in fluid transport visualized by stroboscopic map in a typical 2D time-periodic RPM flow



(a) Dominant modes with increasing diffusion (from left to right). (b) Stroboscopic map.

Project leaders
MFM Speetjens
Research theme
Complex dynamics of fluids
Participants
PS Contreras (PhD candidate)
MFM Speetjens (TU/e-ET; 2nd advisor)
HJH Clercx (TU/e-WDY; 1st advisor)
Cooperations
Collaborative project between TU/e-ET and TU/e-WDY
Funded by
CONACYT (Mexico)
Funded %

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

Start of the project
2015
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Project Aim

Studies on transport phenomena so far concentrated mainly on chaotic advection in two-dimensional (2D) flows. However, insight into chaotic advection in three-dimensional (3D) flows, crucial for further technological development, remains limited. Principal objective of the proposed PhD project is to deepen the understanding of transport mechanisms in 3D laminar flows by investigation of representative systems: 3D lid-driven cylinder flows and a buoyancy-driven flow in a differentially-heated cavity.

Progress

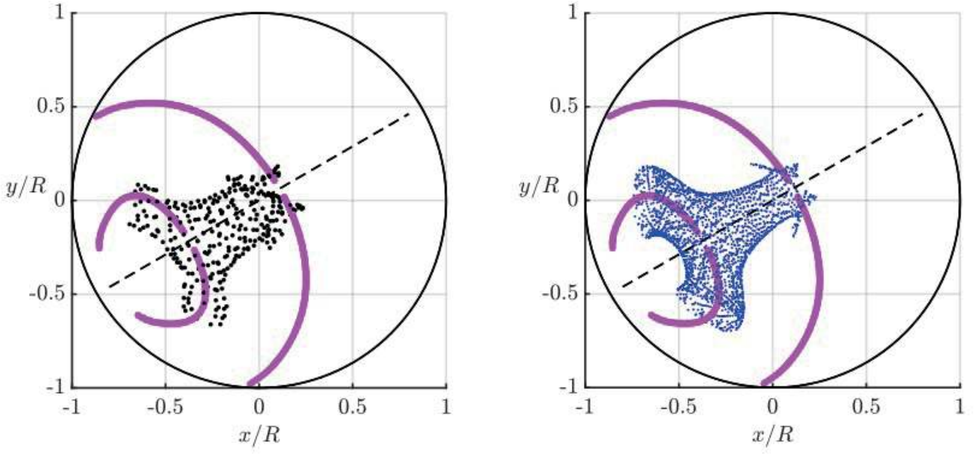
The comparative experimental-numerical analyses of the 3D time-periodic lid-driven cylinder flow showed a close agreement between the predicted and measured perturbed Lagrangian flow topology (see figure). The results conclusively demonstrate 'resonance-induced-merger' (RIM) and the associated coherent structures (shells and tubes and merger of these structures) by way of experimental 3D Lagrangian studies using 3D particle-tracking velocimetry (3D PTV). A journal publication of these results is currently in preparation. The research was presented at the 2018 Burgers Symposium and at the 2018 APS-DFD meeting (Atlanta, USA). Moreover, a comparative numerical-experimental study of the steady buoyancy-driven flow has started. This includes a comparison between the previously investigated flow topology of the buoyancy-driven system and the dynamics of a double-lid-driven cylinder flow.

Dissertations

-

Scientific Publications

1. P. S. Contreras, M. F. M. Speetjens & H. J. H. Clercx. 2018 Chaotic advection in 3D unsteady flows: not the tori way. Annual Meeting of the American Physical Society Division of Fluid Dynamics, Atlanta, Georgia, USA.



3D experimental (left) and simulated (right) stroboscopic map of single tracer showing a tube bifurcation in lid-driven flow. Curves represent simulated period-2 lines of unperturbed flow

Preconditioned iterative solution techniques for immersed finite element methods - with applications in immersed isogeometric analysis for solid and fluid mechanics

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

We have submitted a manuscript on a versatile preconditioning technique for immersed finite element methods (which is accepted and will be published in 2019). We have continued the collaboration with the Technical University of Munich on robust solvers for the hp-adaptive finite cell method and submitted a manuscript on this (which is also accepted and will be published in 2019). We have collaborated with the University of Colorado Boulder on multigrid preconditioners for immersed finite element methods, and are currently writing a manuscript about this. We have published a paper on the behavior of Nitsche's method for boundary condition imposition.

Dissertations

-

Scientific Publications

1. F. de Prenter, C. Lehrenfeld & A. Massing. A note on the stability parameter in Nitsche's method for unfitted boundary value problems. Computers and Mathematics with Applications. (2018).

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

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PROJECT LEADERS
Prof. H.A. Zondag, Dr. C.C.M. Rindt

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Mohammadreza Gaeini

COOPERATIONS
ECN

FUNDED BY
University, Provincie NB

FUNDED %

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

START OF THE PROJECT
2013

INFORMATION
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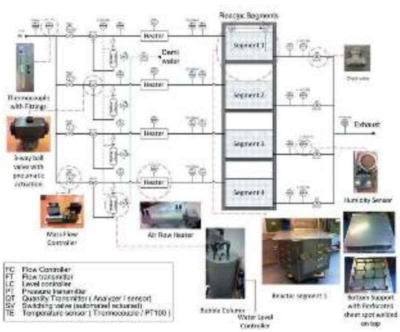

PROJECT AIM

Heat is stored by an endothermic reaction in thermochemical material in summer, and in winter the released energy from an exothermic reaction is used to provide hot tap water and space heating. The goal of the project is to develop and optimize a prototype for thermochemical heat storage system at the scale of 0.25 m3. The problem can be described on three levels; various materials should be examined to find the most suitable one for seasonal heat storage; the reactor as the main part of the setup should be technically optimized; all the other parts of the system, such as humidifier and heat exchangers, should be designed and integrated all together as a system.

PROGRESS

A pilot setup is successfully built in order to demonstrate the feasibility of the thermochemical heat storage concept for application in the built environment. The system consists of four reactor segments of 62.5L each. It can provide a maximum power of around 4kW for 10 hours, or a stable average power of 1kW for 40 hours. By upscaling this system from 4 to 150 segments, this system can provide a heating demand of almost 6 GJ, which is enough for a typical 110m2 passive house.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Gaeini, M., Rouws, A. L., Salari, J. W. O., Zondag, H. A., & Rindt, C. C. M. (2018). Characterization of microencapsulated and impregnated porous host materials based on calcium chloride for thermochemical energy storage. Applied Energy, 212, 1165-1177. DOI: 10.1016/j.apenergy.2017.12.131.
2. Lan, S., Gaeini, M., Zondag, H. A., van Steenhoven, A. A., & Rindt, C. C. M. (2018). Direct numerical simulation of the thermal dehydration reaction in a TGA experiment. Applied Thermal Engineering, 128, 1175-1185. DOI: 10.1016/j.applthermaleng.2017.08.073.
3. Gaeini, M., van Alebeek, R., Scapino, L., Zondag, H. A., & Rindt, C. C. M. (2018). Hot tap water production by a 4 kW sorption segmented reactor in household scale for seasonal heat storage. Journal of Energy Storage, 17, 118-128. DOI: 10.1016/j.est.2018.02.014.
4. van Alebeek, R., Scapino, L., Beving, M. A. J. M., Gaeini, M., Rindt, C. C. M., & Zondag, H. A. (2018). Investigation of a household-scale open sorption energy storage system based on the Zeolite 13X/water reacting pair. Applied Thermal Engineering, 139, 325-333. DOI: 10.1016/j.applthermaleng.2018.04.092.

PROJECT AIM

The promising concept for seasonal solar heat storage in the built environment is based on the reversible sorption process of water vapor into the crystalline structure of salt hydrates (MgSO4, MgCl2, LiSO4, K2CO3 etc.). Their main advantages are a high energy density, a reaction temperature in the proper range for domestic applications and their low price. The goal of this project is to create a numerical model at grain-scale that describes the hydration and dehydration reactions of thermochemical materials. The output of this model is used as input for a reactor-scale model. This model simulates a heat battery that can be installed in residential buildings to serve as an energy storage solution. The material studied is K2CO3 due to its promising characteristics for built environment heat storage applications.

PROGRESS

A stochastic model simulating the fractional conversion of grain-scale sorption material has been established. This model has been extended to include crack formation and grain growth introduced because of the hydration/ dehydration process. Extensive TGA/DSC experiments on K2CO3 have been performed and it is concluded that crack formation greatly enhances moisture transport and thus the performance of the TCM.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

prof.dr.ir. D.M.J.Smeulders
dr.ir.C.C.M.Rindt, dr.ir. A.J.H.Frijns

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

M.A.J.M. Beving

COOPERATIONS

ADEM

FUNDED BY

ADEM

FUNDED %

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

START OF THE PROJECT

2016

INFORMATION

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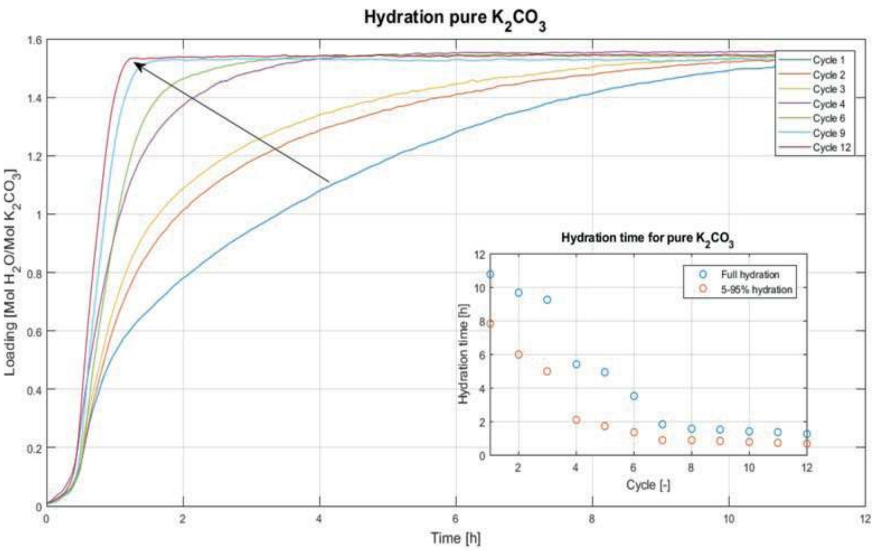

Experimentally determined loading of K2CO3 particles. The hydration time is dramatically reduced after subsequent hydration/dehydration cycles.

Project leaders
AJH Frijns
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
M. Wolf, S. Mohammad Nejad, S.V. Nedea, D.M.J. Smeulders, I Graur (AMU, F), R. Enright (Nokia Bell Labs, IR), E. Arlemark (ASML)
Cooperations
MIGRATE, RARETRANS, ASML, Nokia Bell Labs, Aix-Marseille Université
Funded by
H2020, NWO
Funded %

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

Start of the project
2005
Information
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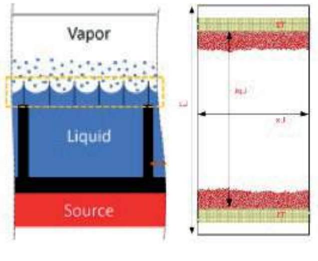


Project Aim

For microchannel gas flows the Knudsen number is that high that CFD methods breaks down. Therefore particle-based models have to be used. The goal of this project is to study the convective heat transfer and evaporative cooling in micro-devices by Molecular Dynamics (MD) and Direct Simulation Monte Carlo (DSMC) techniques and to develop a multi-scale simulation method.

Progress

The development of microscale cooling systems becomes important due to the increasing heat transfer density within electrical devices. These systems need to be more energy-efficient, i.e. to evacuate higher heat fluxes than the existing cooling systems. This can be achieved by new generation of two phase flow evaporative systems. Such device contains a nanopores structure through which the liquid evaporates and the latent heat of vaporization is the dominant mode of heat transfer. Therefore, the understanding of evaporation/ condensation process and corresponding vapor flow behaviors is important for the development of these cooling systems. The applicability of the S-model kinetic equation to describe these processes will be investigated by comparing its results with those of the MD simulations. The order of the pressure and temperature jumps at the liquid-vapor interface, provided by both approaches is also analyzed and evaporation coefficients are derived. Also the gas-wall interactions are studied with respect to thermal and momentum accommodation coefficients.

Dissertations

-

Scientific Publications

1. Wolf, M. C. W., Polikarpov, A., Frijns, A. J. H., Graur, I., Nedea, S. V., & Enright, R. (2018). Comparison of numerical results of molecular dynamics simulations and S- model kinetic equations for evaporation and condensation of Argon. In: A. Frijns, S. Le Calvé, & D. Valougeorgis (Eds.), Proceedings of the 3rd European Conference on Non-Equilibrium Gas Flows (pp. 275-278). Paris: SHF.
2. Wolf, M., Polikarpov, A., Frijns, A., Graur, I., Nedea, S., Enright, R. (2018): Numerical comparison between s-model kinetic equation and molecular dynamics simulations for heat transfer through argon vapor. 10th International Conference on Boiling and Condensation Heat Transfer. March 12th-15th, 2018. Nagasaki, Japan.
3. Wolf, M. C. W., Enright, R., Frijns, A. J. H., Nedea, S. V., Graur, I., & Polikarpov, A. (2018). The position of the liquid and vapor boundaries and its influence on the evaporation/condensation coefficients. In: L. Baldas, S. Colin, I. Graur, P. Perrier, J. Brandner, K. Haas-Santo, & M. Knapp (Eds.), Proceedings of the 3rd MIGRATE International Workshop, Bastia, France (pp. 56-59). MIGRATE2018:210706.
4. Eggink, H. J., Frijns, A. J. H., Janssen, T. W. M., & Martin, G. (2018). Numerical and experimental feasibility study of vapor chambers for LED applications. In 34th Annual Semiconductor Thermal Measurement and Management Symposium, SEMI-THERM 2018 - Proceedings (pp. 71-80). Institute of Electrical and Electronics Engineers (IEEE). DOI: 10.1109/SEMI-THERM.2018.8357355.

Project Aim

The occurrence of acute and chronic cardiovascular complications in dialysis patients is high. Insufficient correction of uremic state by conventional dialysis plays an important underlying role. Conventional hemodialysis uses a 'one size fits all' approach with a fixed dialysate concentration of electrolytes. Individualization of dialysate prescription is hampered because no suitable on-line ion-selective electrolyte monitoring is available. This project aims to develop and compare novel optical sensor technologies for continuous ion-selective monitoring of electrolytes in dialysate.

Progress

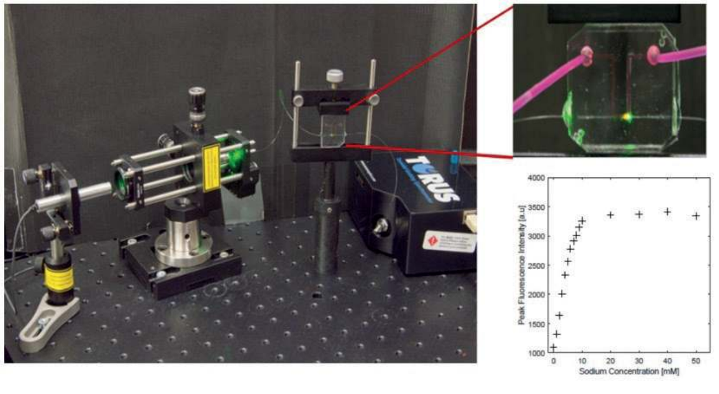
Optical sensors offer intrinsic electrical safety (no galvanic contact), good miniaturization perspective, improved biocompatibility (contactless sensing), less fouling and simultaneous measurement of multiple ions. We have created a micro-optofluidic device for in-line electrolyte measurement pertaining to application in dialysis. As a proof-of-concept, we determined sodium concentrations in a flowing medium. Besides sodium, the sensor system can also be used for pH measurements. The measurement range for sodium can be extended to a physiological range (120-150 mM) by slightly changing the PET sensor molecule. Also, the measurement approach can be extended to determine other essential electrolytes (potassium, calcium) by using their respective PET sensor molecules.

Dissertations

1. Sharma, M. K. (2018). Development of a micro-optofluidic sensor for in-line electrolyte monitoring : towards individualized dialysis treatment PhD thesis, Eindhoven: Technische Universiteit Eindhoven.

Scientific Publications

1. Sharma, M. K., Gostl, R., Frijns, A. J. H., Wieringa, F. P., Kooman, J. P., Sijbesma, R. P., & Smeulders, D. M. J. (2018). A fluorescent micro-optofluidic sensor for in-line ion selective electrolyte monitoring. IEEE Sensors Journal, 18(10), 3946-3951. DOI: 10.1109/JSEN.2018.2816986.
2. Sharma, M. K., Frijns, A. J. H., Kooman, J. P., & Smeulders, D. M. J. (2018). A micro-optofluidic sensor system based on PET sensing for real time sodium concentration measurement. In J. Brandner, S. Colin, D. Newport, & C. Serra (Eds.), Proceedings of the 5th European Conference on Microfluidics (pp. 89-92). Paris: SHF.



Project leaders
AJH Frijns

Research theme
Complex structures of fluids

Participants
M. Sharma, DMJ Smeulders, F.P. Wieringa (IMEC), R. Mandamparambil (TNO), J.P. Kooman (MUMC+)

Cooperations
TNO, MUMC+

Funded by
Dutch Kidney Foundation

Funded %

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

Start of the project
2013

Information
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PROJECT LEADERS
AJH Frijns
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
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COOPERATIONS
UM, MUMC+, Philips, TNO
FUNDED BY
RVO, STW, TU/e
FUNDED %

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

START OF THE PROJECT
1999
INFORMATION
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PROJECT AIM

The goal of this project is to develop dynamic and human specific thermo-physiological model to predict the heat transfer and temperature distribution in the human body, the local thermal sensation and thermal comfort. This model can be used to optimize the HVAC systems in the built environment.

PROGRESS

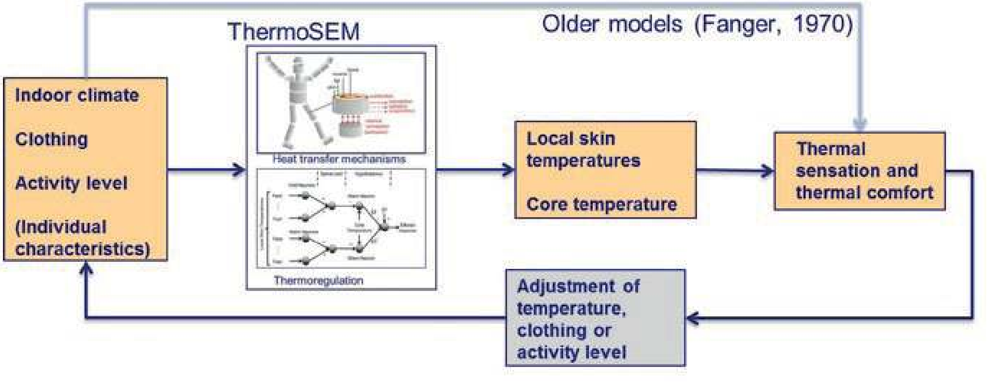
Recent research on local heating and cooling design show improvements in thermal comfort and energy consumption of office buildings. The impact of these measures on the occupants' local thermal sensation (LTS) the most important factors in the thermal modelling concept are studied and analysed using our thermophysiological model ThermoSEM: 1) the effects of the accuracy of the input data for local clothing properties and local muscular metabolic heat distribution, 2) the deviations between computed and measured local skin temperatures, and 3) neurophysiological and dynamic aspects that are missing in present LTS models. To fill this gaps, measurements are done to determine local clothing resistances and local metabolic rates and a re-evaluation of local heat balances in the thermophysiological models is done.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Veselá, S., Psikuta, A., & Frijns, A. J. H. (2018). Local clothing thermal properties of typical office ensembles under realistic static and dynamic conditions. International Journal of Biometeorology, 62(12), 2215–2229. DOI: 10.1007/s00484-018-1625-0
2. Veselá, Stephanie; Frijns, Arjan JH; Kingma, Boris RM; van Marken Lichtenbelt, Wouter D (2018) Comparison of measured and simulated local skin blood flow during light and medium activities and their effect on local skin temperature prediction, In: proceedings of BAUSIM2018, Karlsruhe, gemany.
3. Vervoort, J. W. P., Boerstra, A. C., Virta, M., Mishra, A. K., Frijns, A. J. H., Loomans, M. G. L. C., & Hensen, J. L. M. (2018). Healthy low energy redesigns for schools in Delhi. Air Conditioning and Refrigeration Journal, 21(6), 56-62.
4. Vervoort, J. W. P., Boerstra, A. C., Virta, M., Mishra, A. K., Loomans, M. G. L. C., Frijns, A. J. H., & Hensen, J. L. M. (2018). Healthy low energy redesigns for schools in Delhi: inventory of the current conditions. In: Proceedings of Roomvent&Ventilation 2018 Helsinki: REHVA.



Project Aim

The main scientific goal of the program is to create insight into unresolved issues in the current inkjet process and to improve and extend the functionality of the inkjet printing process 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 over droplet evaporation and absorption processes.

Progress

Meanwhile, almost all FIP positions are filled and a lot of related side projects are involved. On the numerical side, different methods like Navier-Stokes-Cahn-Hilliard and ALE finite element simulations are developed and improved by e.g. by mesh adaptivity. Furthermore, a pore network simulator for imbibition in porous media has be developed to predict the absorption in real porous media. The ALE-FEM method is now applied for jetting of surfactant-laden or multi-component droplets.

Dissertations

-

Scientific Publications

1. Y. Li, P. Lv, C. Diddens, H. Tan, H. Wijshoff, M. Versluis & D. Lohse, Evaporation triggered segregation of sessile binary droplets, Phys. Rev. Lett. 120(22):224501, (2018).

Project leaders

D Lohse

Research theme

Complex dynamics of fluids

Participants

Detlef Lohse
Harald van Brummelen
Herman Wijshoff
Christian Diddens
Tim Segers
Tristan Demont
Chaozhong Qin
Ioannis Zakiros
et al. (from other groups)

Cooperations

University of Twente, Technical University of Eindhoven, Océ Technologies B.V.

Funded by

NWO and Océ Technologies B.V. (A Cannon company)

Funded %

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

Start of the project

2017

Information

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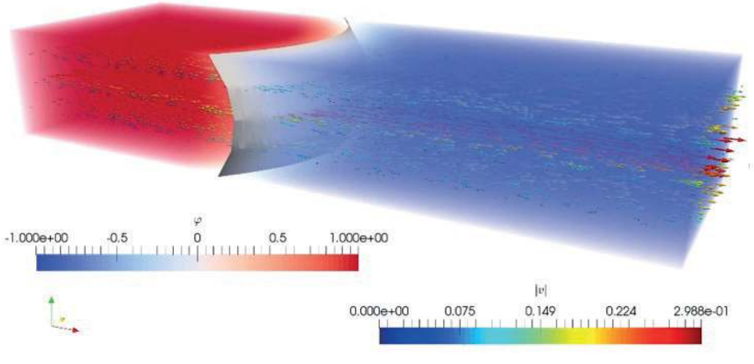

PROJECT LEADERS
MFM Speetjens
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
R. Lensvelt (PhD candidate)
H Nijmeijer (TU/e-DC; 1st promotor)
MFM Speetjens (TU/e-ET; 2nd promotor)
COOPERATIONS
collaborative project of TU/e-ET and TU/e-DC
FUNDED BY
FOM (CSER program; project 15CSER15)
FUNDED %

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

START OF THE PROJECT
2018
INFORMATION
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PROJECT AIM

Scope is enhanced recovery of underground natural resources (gas/oil/heat) by circulation of production fluids through the reservoir via a system of wells. Active control of this circulation by so-called reservoir management ("smart fields") may significantly improve performance and efficiency of this process. However, existing reservoir-management schemes typically concentrate on the Eulerian flow field and thereby insufficiently incorporate relevant transport phenomena. A key factor in subsurface transport namely is the Lagrangian dynamics of the fluid; phenomena as chaotic advection of fluid parcels or Lagrangian transport barriers are crucial to the scalar transport yet are non-trivially connected with the flow field. The project seeks to take reservoir management to the next level by a new approach that explicitly incorporates the Lagrangian fluid motion. To this end state-of-the-art methods from dynamical-systems theory (Dynamic Mode Decomposition (DMD) and Koopman operator theory) are to be employed for data-based analysis and (compact) modelling of the (generically nonlinear) process dynamics in terms of equivalent linear representations. Thus first prototype reservoir-management schemes are to be developed using representative reservoir (CFD) data.

PROGRESS

Considered as a first case study is heat-transfer enhancement by reorientations of a laminar base flow. Reorientation generally follows a fixed protocol (typically periodic in space or time) designed to accomplish chaotic advection. The present study explores an alternative approach: pro-active reorientation based on the state of the scalar field. The control strategy concerns step-wise activation of the specific reorientation that gives optimal scalar transport for a certain time horizon. Key enabler is a compact model for efficient prediction of the scalar evolution based on its spectral decomposition in the base flow. The control strategy is investigated for a representative problem: enhanced heating of a cold fluid in a 2D circular domain by an unsteady flow consisting of reorientations of a steady base flow (black/blue/red streamlines in Fig. 1a). This reveals that pro-active reorientation using the above control strategy can substantially accelerate the heating compared to sequential flow reorientation optimized for chaos (Fig. 1b) and thus demonstrates its potential for attaining optimal scalar transport in reoriented flows..

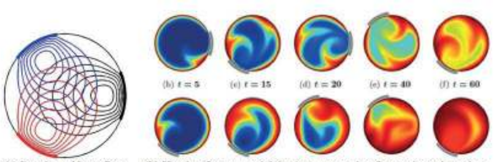
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Pro-active engineering of scalar transport in reoriented fluid flows, M.F.M. Speetjens, R. Lensvelt, H. Nijmeijer. Abstract accepted for presentation at SIAM Conference on Applications of Dynamical Systems 2019, Snowbird, USA.
2. Enhanced scalar transport for reoriented flow systems, R. Lensvelt, M.F.M. Speetjens, H. Nijmeijer. Extended abstract accepted for presentation at Benelux Meeting on Systems and Control 2019, Lommel, Belgium.

Enhanced heating of a cold fluid in a 2D circular domain by an unsteady flow consisting of reorientations of a steady base flow (black/blue/red streamlines in panel a).



(a) Reoriented base flow. (b) Heating for sequential (top) vs. pro-active (bottom) reorientation.

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.

Effect of rotor-stator interaction on rotating stall of water pump

Project leaders
BPM Esch

Research theme
Complex dynamics of fluids

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

Obtained the reasonable grid and time scale by investigating the grid and time scale sensitivity of the computational model. Based on the experimental results, two-dimensional computations was proved Reasonably.

Validated the necessity of rotation and curvature correction for transition prediction. The transition location changed when the curvature factor was adjusted, which indicated the prediction of curvature influence the transition. [Figure (a) & (b)]

Calculated and analyzed the flow around hydrofoil at three angular velocities (40°/s, 80°/s and 160°/s) in order to study the effect of angular velocity on the stall and lift drag of hydrofoil at dynamic angle of attack. [Figure (c)].

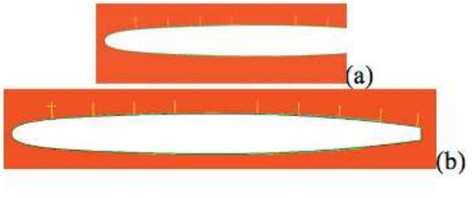
Dissertations

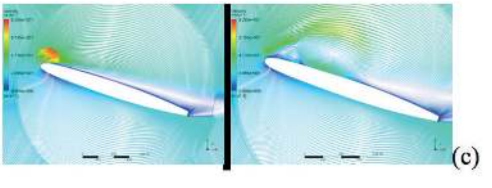
-

Scientific Publications

-

For dynamic hydrofoils, the increase of angular velocity and Reynolds number will delay the occurrence of complete stall of hydrofoils. The occurrence of complete stall predicted by full turbulence model is earlier than that predicted by transition turbulence 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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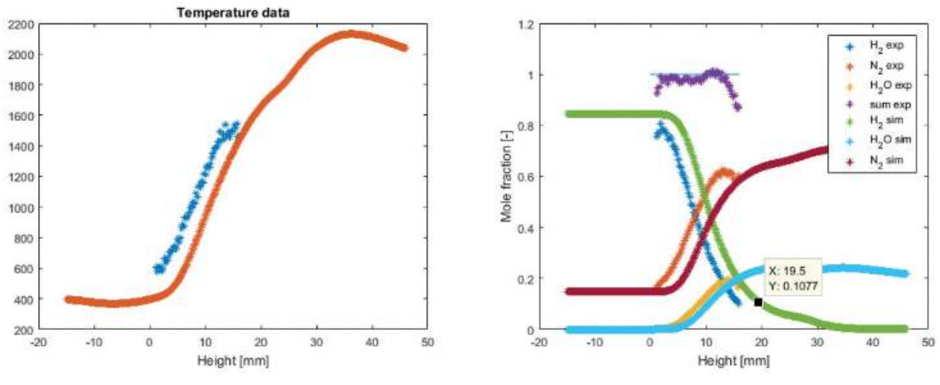
(left) Temperature derived from Raman scattering data in comparison to numerical calculations, (right), major species mole fractions from experiment and simulation.



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

Several optical and laser-based diagnostic techniques were applied to free jet and wall-impinging configurations. A novel strategy for imaging formaldehyde was successfully applied for different injection strategies, resulting in well-defined flame structure characterizations. Optical results of low- and high-temperature combustion products reveal how heavy-duty Diesel spray flame structures change significantly compared to previous studies. Analysis of the pressure-based apparent heat release rate shows how the presence of either a flat wall surface or a confined shape that resembles the piston bowl-rim shape decreases the time required to establish a quasi-steady combustion regime, and the burn-out duration. Several thermocouple assemblies were tested for durability and optimization such that future studies will allow for gas temperature measurements in the boundary layer of the wall.

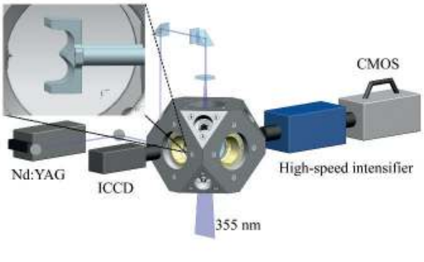
DISSERTATIONS

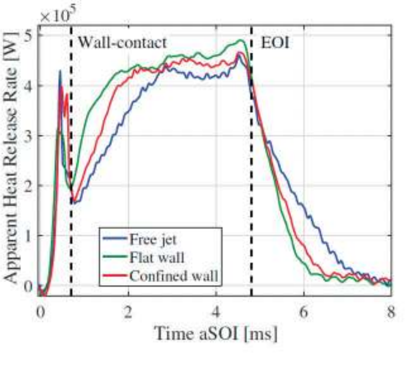
-

SCIENTIFIC PUBLICATIONS

1. H. Kahila, A. Wehrfritz, O. Kaario, M. G. Masouleh, N. Maes, B. Somers, V. Vuorinen, “Large-eddy simulation on the influence of injection pressure in reacting Spray A,” combust. Flame 191:142-159, 2018, https://doi.org/10.1016/j.combustflame.2018.01.004
2. Maes, N., Dam, N., Somers, B., Lucchini, T. et al., “Heavy-Duty Diesel Engine Spray Combustion Processes: Experiments and Numerical Simulations,” SAE Technical Paper 2018-01-1689, 2018, https://doi.org/10.4271/2018-01-1689.

Left: schematic overview of the constant volume combustion vessel with simultaneous high speed OH* chemiluminescence and laser-induced formaldehyde fluorescence detection. Right: different apparent heat release-rate curves illustrating differences obtained by placing either a flat-or a curved wall inside the combustion vessel





Project Aim

This research targets a premixed combustion concept called reactivity-controlled compression ignition (RCCI), which potentially facilitates high gross indicated efficiency and low levels of nitrogen oxides (NOx) and soot emissions. The main goals of this project are to maximize both thermal and combustion efficiencies, and investigate control possibilities for this future combustion concept.

Progress

Experimental campaigns have been run to maximize RCCI gross indicated efficiency. Optimization has been performed using gasoline and diesel as fuel mix. Figure 1 shows the projected gross indicated efficiency as function of boost pressure and port fuel injection (PFI) fraction (here gasoline) in mass percent. Clearly, highest efficiency is obtained at elevated boost pressures and high amounts of gasoline. Proper phasing of the combustion event proved to be the bottleneck for further improvements to efficiency. Experiments were continued using E85 as port fuel and direct injection of diesel. Figure 2 depicts optimization results for the E85 tests, which show significantly higher efficiencies compared to gasoline use. This is mainly ascribed to use of lower exhaust gas recirculation rates and higher tolerance to boost pressure increase.

Dissertations

-

Scientific Publications

1. Willems, Robbert, Bakker, P.C., Dreezen, Robbert and Somers, Bart (2018). The impact of operating conditions on post-injection efficacy; a study using design-of-experiments. SAE Technical Papers, 2018-01-0229.

Project leaders

L.M.T. Somers, F.P.T. Willems

Research theme

Complex dynamics of fluids

Participants

RC Willems, ME Oom, L Xia, A Maghbouli, 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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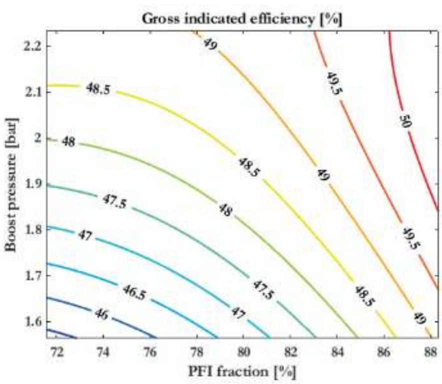
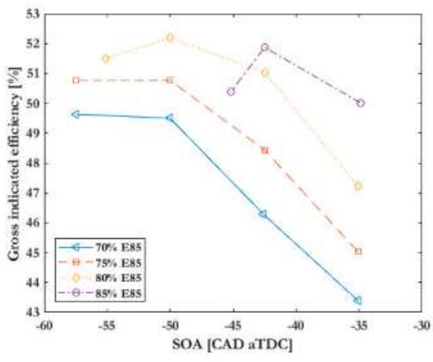


Gross indicated efficiency as function of boost pressure and PFI mass fraction



Gross indicated efficiency as function of start of actuation of the diesel injection

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
NWO/TTW
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. The Diffuse interface Model is based on the Navier-Stokes-Korteweg equations and also uses the Van der Waals equation of state.

PROGRESS

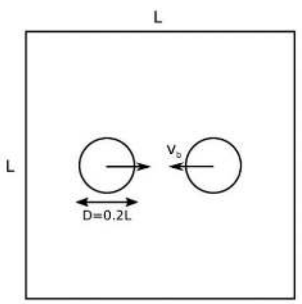
The results from the simulations of droplet collisions have been summarized in a research article which has been submitted to the International Journal of Multiphase Flow. The first round of peer-review in the publishing process has already been completed. The effect of gravitational acceleration has been included in the NSK equations and a new dimensionless number, the Eötvös number, was introduced in the equations. The first results from simulations of flow boiling in 2D have been produced. Technique for artificial enlargement of the liquid-vapor interface (Jamet et al. 2001) has been successfully implemented. First results with simulations at high mass density ratios in both 2D and 3D have been produced. A modified equation of state (Serrin 2007), more accurate than the Van der Waals equation, has been implemented. Extension of the solid wall boundary condition: first attempt to include the effects of surface roughness on the spreading behavior of liquid droplets when colliding with a solid wall.

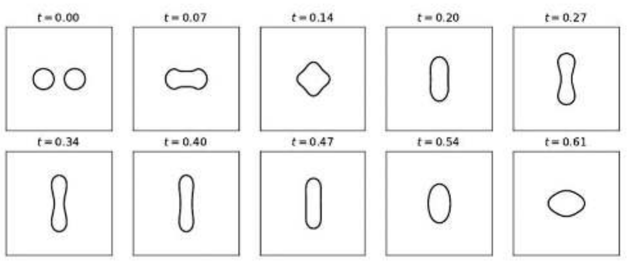
DISSERTATIONS

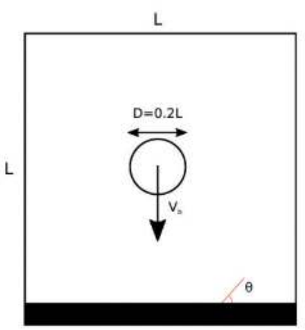
-

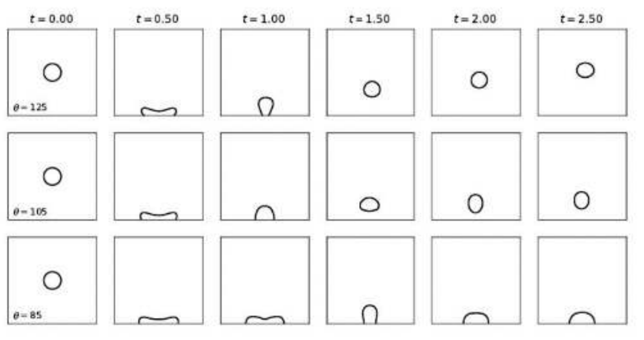
SCIENTIFIC PUBLICATIONS

1. Gelissen, E.J., van der Geld, C.W.M., Kuipers, J.A.M., Kuerten, J.G.M. (2018). Simulations of Droplet Collisions with a Diffuse Interface Model near the Critical Point. International Journal of Multiphase Flow.









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

Experiments on stationary surfaces allowed to observe explosive boiling behavior during quenching by water jets. If rewetting occurs at temperatures above the water superheating limit (312 °C), explosive boiling and bubble mitigation by subcooled water contact are observed at frequencies up to 10 kHz. This phenomenon acts as a contact mechanism, allowing rewetting at temperatures above the limits set by thermodynamics. A new experimental setup has been designed to allow plate motion up to 10 m/s, which is comparable to industrial values and higher than ever reported in lab studies. Measurements of heat flux will allow the development of improved heat transfer correlations.

Dissertations

-

Scientific Publications

-

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

C.F. Gomez
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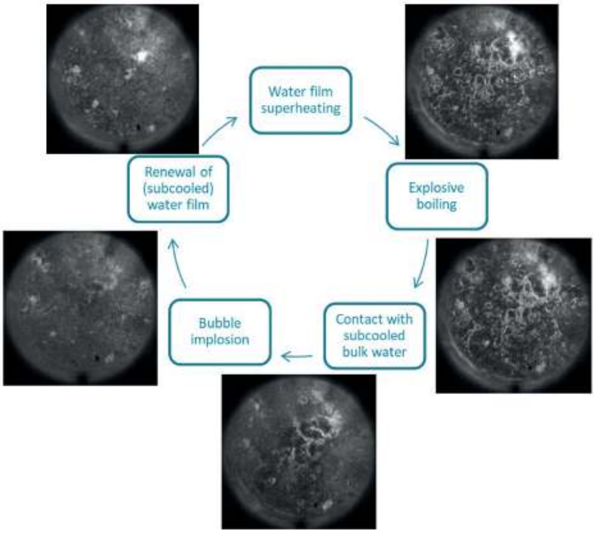
Cycle of successive explosive boiling and bubble mitigation by subcooled water contact when quenching above the water superheating limit. Images obtained by high speed recordings of the jet stagnation zone at 30k fps.



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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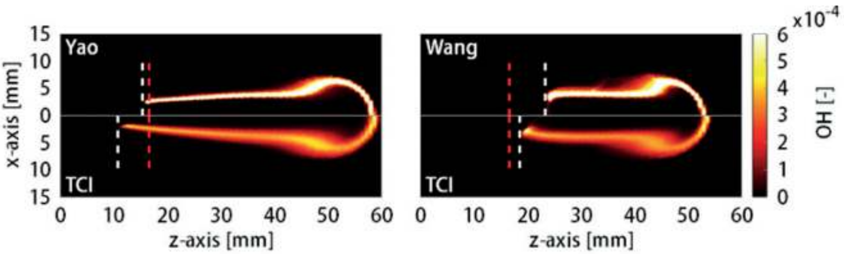
PROJECT AIM
This research project focuses on the development of new modeling technique for high EGR diesel combustion concepts with multiple injection fueling systems, which is seen as an essential step towards future RCCI concepts. The CFD-FGM model, which will be extended for multi-pulse injection strategies, will be extensively validated with experimental data.

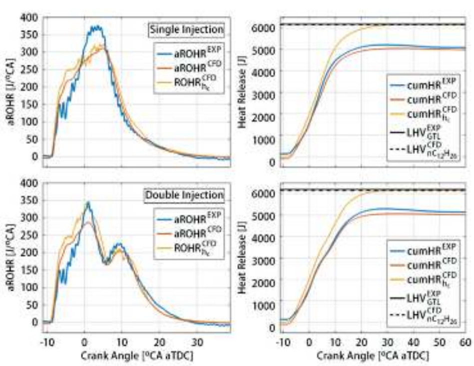
PROGRESS
The combustion modelling part of the project is continued with model validation. Prior to engine simulations and analysis of the results, Turbulence-Chemistry interaction (TCI) is studied with the constant volume application. In this manner, Spray-A simulations are repeated with the FGM tables 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
-

SCIENTIFIC PUBLICATIONS
1. Maghbouli, A., Akkurt, B., Lucchini, T., D'Errico, G., Deen, N. and Somers, B. (2018). Modelling compression ignition engines by incorporation of the flamelet generated manifold combustion closure. Combustion Theory and Modelling. DOI: 10.1080/13647830.2018.1537522.



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 a Volume-of-Fluid method.

3. The development of effective heat pipes with unconventional geometries and compatible with LED lighting systems.

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 smooth the liquid volume fraction 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.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

J.G.M. Kuerten, B.P.M. van Esch

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

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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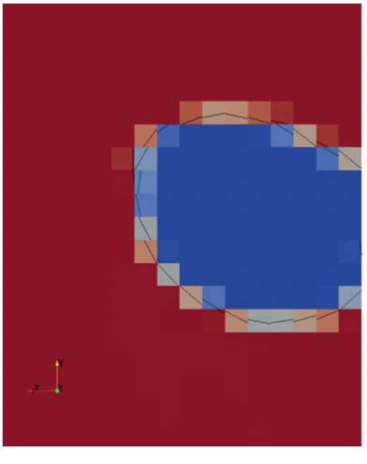
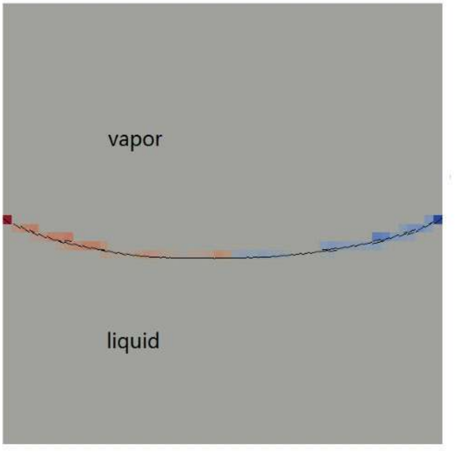
A bubble resolved by PLIC



Phase transition on a sharp interface



PROJECT LEADERS
NG Deen, LMT Somers
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Jinlin Han
COOPERATIONS
-
FUNDED BY
China Scholarship Council
FUNDED %

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

START OF THE PROJECT
2016
INFORMATION
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PROJECT AIM

1. Metal engine tests applying special fuels like PRF, alcohol fuels and cycloalkanes (Anisole and benzaldehyde) to investigate the effects of different fuels' properties on thermal efficiency and satisfaction with the Euro VI emissions standard. Best working points and engine parameters with applying these specific fuels would be selected.
2. Intensive study on emission soot size, particulate matters numbers concentration and distribution with these specific fuels will be conducted.
3. Comparison with different combustion strategies (PPC and RCCI) with the same fuel to investigate on board mixing and already mixed fuel blend.

PROGRESS

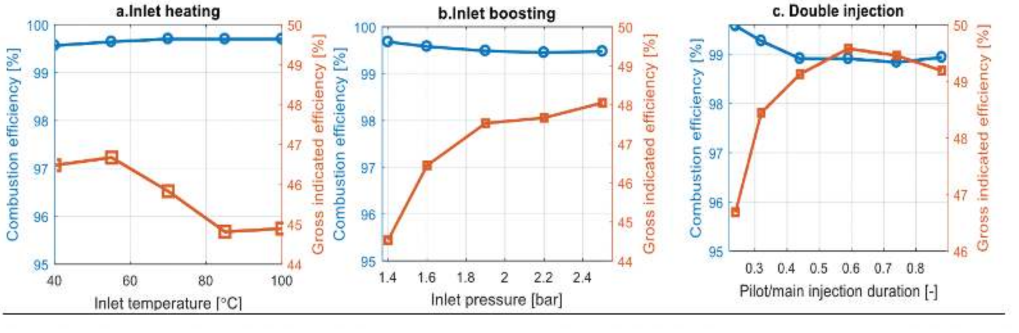
BH80 (80vol% n-butanol+20%vol n-heptane) is blended and tested at 4bar, 6 bar and 8 bar gIMEP with a heavy duty diesel engine in PPC mode. The results show that BH80 can achieve negligible soot emission and very high pressure rise rate. Compared with inlet heating and inlet boosting, double injection can achieve lower NOx emission and much stable combustion (slower heat release much lower pressure rise rate) at 8 bar gIMEP. At 6 bar, more fuel injected in the pilot results in higher gross indicated efficiency and less NOx emission. Although high inlet boosting pressure benefits the combustion stability at 4 bar, the combustion efficiency and CO emission deteriorates significantly. Inlet boosting is a better option at 4 bar.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Han, Jinlin, Shuli Wang, and Bart Somers. Effects of Different Injection Strategies and EGR on Partially Premixed Combustion. No. 2018-01-1798. SAE Technical Paper, 2018.



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.

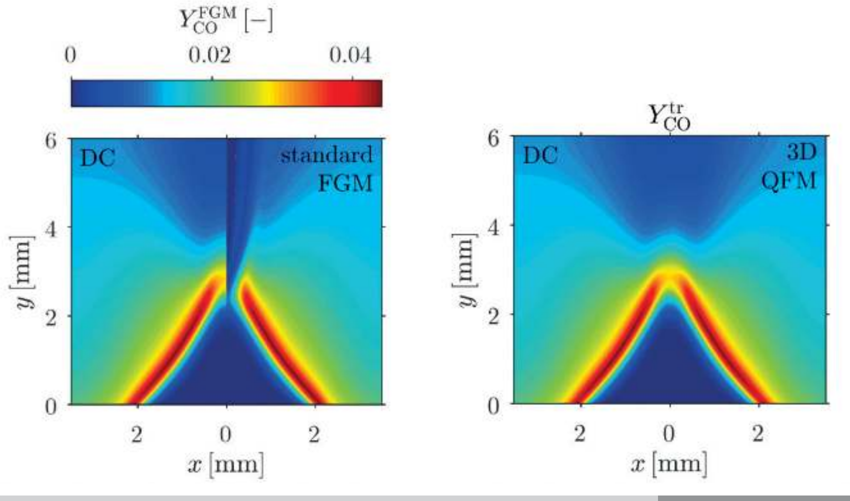
Dissertations

-

Scientific Publications

1. D.V. Efimov, P. de Goey and J.A. van Oijen, "FGM with REDx: chemically reactive dimensionality extension", Combustion Theory and Modelling, 22:6, 2018.

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.



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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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
DJEM Roekaerts

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 strain rate in the cylinder has great effect on emissions. An extended FGM table with respect to different strain rates is established. The performance of the new extended table is analysed in detail on the flamelet level and lateron on the ECN Spray A database. The PV (progress variable) definition is evaluated for the large range of strain rates.

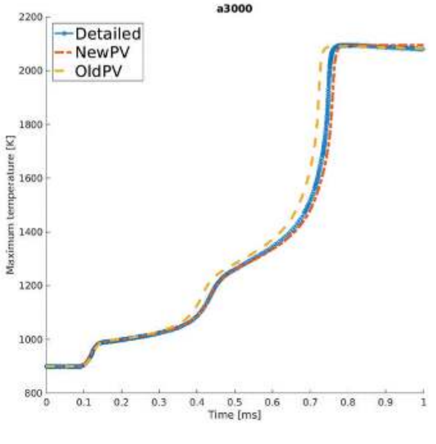
Dissertations

-

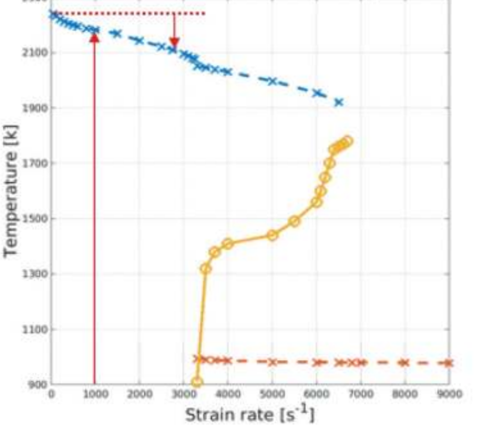
Scientific Publications

-

Temperature tendency predicted by two PV under the strain rate of 3000



S-shape curve (arrows represent ignition process and transient distinguishing process respectively)



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

The electrostatics dispersion burner was initially designed by Y. Shoshin for studying the aerosol flames. It is modified recently to shoot iron particles. The burner includes a dispersion chamber where iron powder is aerosolized by a high voltage DC electrical field, a syringe needle with an inner diameter of 0.5mm that can guide the particle carrier (central jet) and a shroud flow channel which can stabilize the central jet and keep a particle vertically flying up with a relatively high velocity.

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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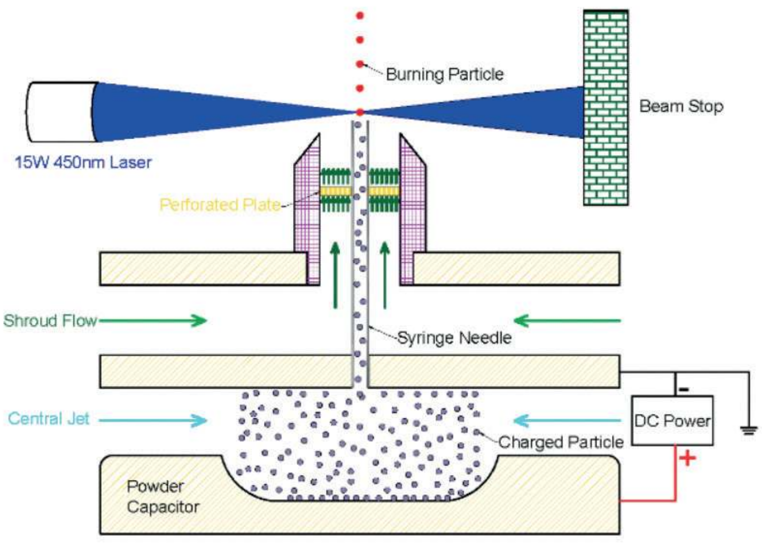
Schematic of the single particle combustion burner



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/burners are fully described by the transfer function, transfer matrix, temperature and flow area jumps. Direct measurement of the acoustic transfer matrix of hot burners is a challenging task because it needs performing acoustic measurements in the stream of very hot combustion products. However, the special symmetry of the burner characteristic matrix allows a reduction of the number of unknown matrix entries. In this case a simplified measurement strategy is elaborated by performing only measurements on the cold side of the burner to show (in)-conditional stability and intrinsic (in)-stability of flames/burners. It is needed to say that the thermo-acoustic instabilities can be due, not only to unstable acoustic modes but also due to unstable intrinsic modes. So, defining transfer matrix elements and (in)-stability of flames/burners in combustion systems are in progress.

Dissertations

-

Scientific Publications

-

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

- Comparison of the reduction performance when using different reducing agents (including H2, CH4, CO and CH3OH).
- Thermodynamic analysis of the feasibility of reducing iron oxide with methanol.
- Mathematical modeling of the reduction reaction of single iron oxide particle.
- Design and develop an experimental plan about TGA.

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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040 247 5995
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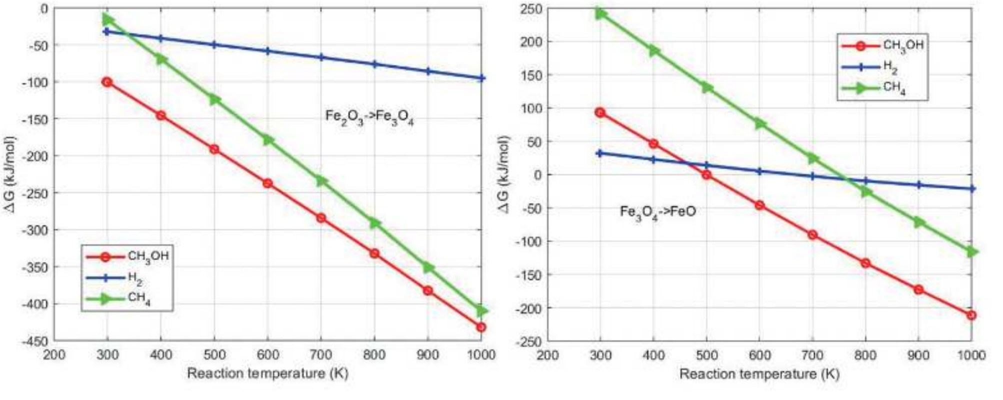

evolution of the ΔGT by using H2, CH4 and CH3OH as a function of temperature in the reduction step of Fe2O3 to Fe3O4 and Fe3O4 to FeO

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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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.

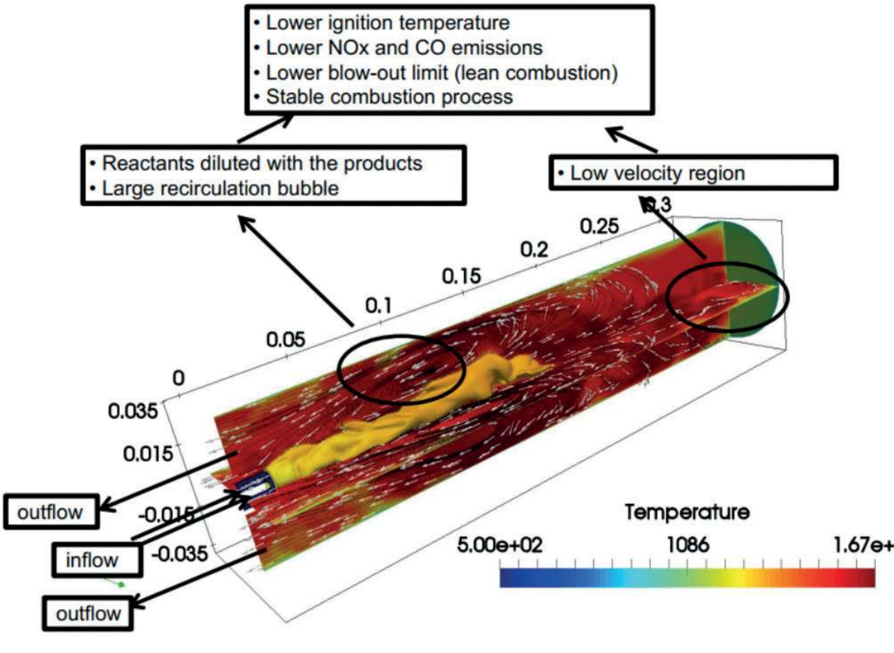
Dissertations

-

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

EZK, Nouryon

Funded %

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

Start of the project

2018

Information

A.W. Vreman
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www.tue.nl/power-flow

Experimental and numerical study on hydrogen reduction of combusted iron

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
C.J.M. Hessels
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www.tue.nl/power-flow

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 (a.o. spectroscopic) techniques will be used.

Progress

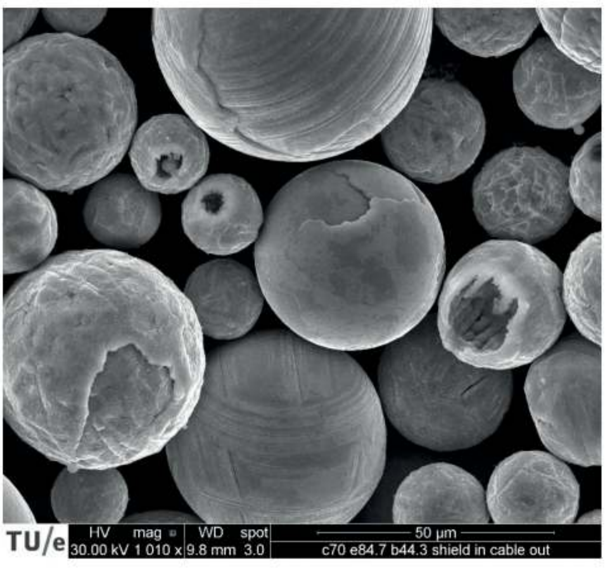
The focus of the first year lays on determining the reaction kinetics of a single iron oxide particle. On the numerical side a 1D single particle reduction model is being developed, based on the shrinking core model. An analytical solution is derived and the influence of hydrogen on fluid properties 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. A student project is carried out to investigate the use of tunable diode laser absorption spectroscopy, applying frequency modulation, for later research. An absorbance limit of 0.013 cm-1 was found.

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

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 existing lubrication model has been expanded to incorporate the presence and influence of surfactants in the bulk of the fluid and on the liquid-air interface. Furthermore, several improvements have been done to the pre-existing lubrication model regarding stability and physical consistency. Also, most of the code (including the pre-existing parts) has been documented (which was only done in a very limited way before).

Dissertations

-

Scientific Publications

Project leaders

J.G.M. Kuerten

Research theme

Complex dynamics of fluids

Participants

RT van Gaalen, C Diddens, HMA Wijshoff, JGM Kuerten

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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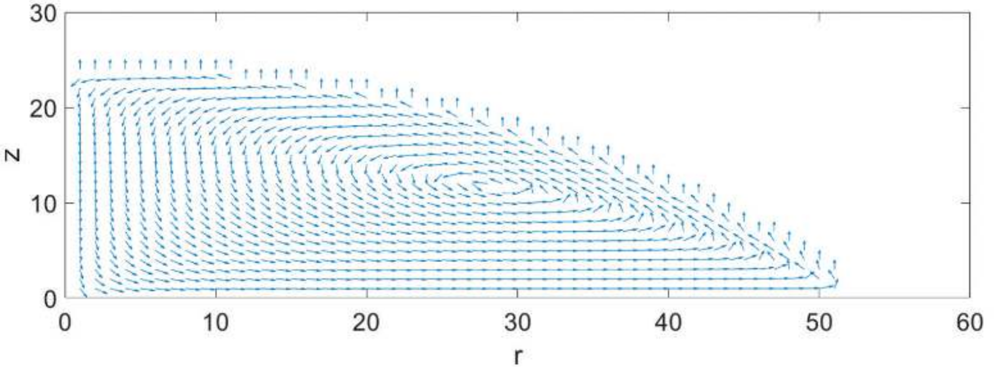

Circulating Marangoni flow in an evaporating droplet with soluble surfactants

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
A.W. Vreman
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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

A publication on the turbulence kinetic energy budgets in the laboratory frame and the particle frame for a turbulent channel flow past a moving particle array has been finalized.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. A.W. Vreman and J.G.M. Kuerten, Turbulent channel flow past a moving array of spheres. J. Fluid. Mech. 856, 580-632 (2018).

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 2018, we have developed a chip that enables to precisely generate and control an oxygen gradient between hypoxic (<1%) and ambient (21%) conditions. We tracked the migration of MDA-MB-231 breast cancer cells in this gradient. Surprisingly, we found that the cells migrate towards low oxygen levels, in contrast with an earlier study. We hypothesize that in our device, migration is exclusively due to the pure oxygen gradient, whereas the effects of oxygen in earlier work were obscured by additional cues from the tumor microenvironment (e.g., nutrients and metabolites).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Sleeboom, J.J.F., Eslami Amirabadi, H., Nair, P., Sahlgren, C.M., & Toonder, J.M.J. den (2018). Metastasis in context: Modeling the tumor microenvironment with cancer-on-a-chip approaches. Disease Models & Mechanisms 11. dmm033100. doi:10.1242/dmm.033100.
2. Sleeboom, J.J.F., Toonder, J.M.J. den & Sahlgren, C.M. (2018). MDA-MB-231 Breast Cancer Cells and Their CSC Population Migrate Towards Low Oxygen in a Microfluidic Gradient Device. Int. J. Mol. Sci. 19, 3047. doi:10.3390/ijms19103047.

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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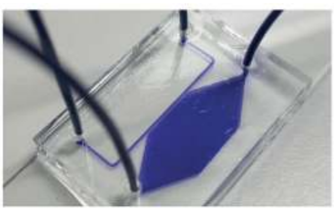

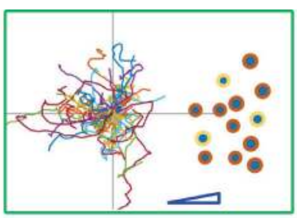

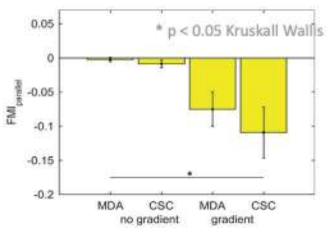

Magnetic control of micro-particles and integrated micro-actuators for high precision handheld diagnostics /

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
Eriola Shanko
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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

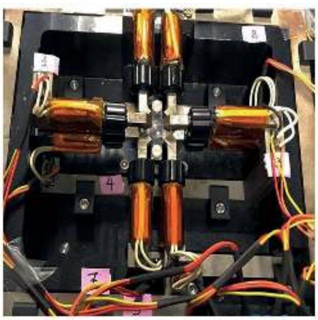
We have studied the combination of active magnetic mixing with passive staggered herringbone structures, aiming for increased mixing efficiency in no-flow-through microreaction chambers. Microfluidic chips with circular microchambers having various passive mixing patters were fabricated. Experiments were carried out by placing the chip in the center of an octopolar electormagnetic set-up, to actuate magnetic beads suspended in water in the microchamber. As a next step, the effect of this strategy on the speed of a biochemical assay will be investigated.

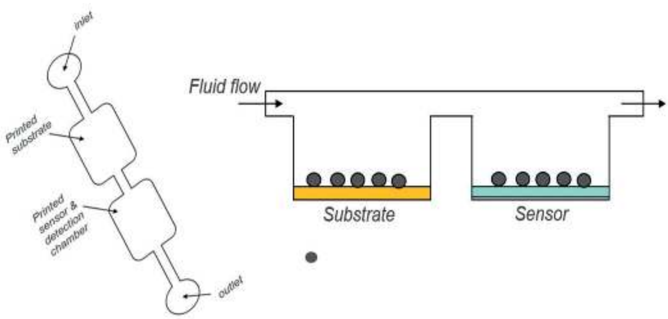
Dissertations

-

Scientific Publications

1. Eriola Sophia Shanko, Yoeri van de Burgt, Patrick Anderson and Jaap den Toonder, “STUDY OF SYNERGETIC MICROMIXING IN MICROREACTION CHAMBERS BY COMBINING ACTIVE MAGNETIC MIXING AND PASSIVE MIXING GEOMETRIES”. microTAS 2018, Kaohsiung, Taiwan.





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

We have developed a new fabrication process based on micro-moulding to manufacture MAC, in which we can vary the magnetic particle distribution within the cilia from (1) a random distribution, to (2) a linearly aligned distribution to (3) a concentrated distribution in the tips of the cilia. Magnetization measurements show that the aligned distribution leads to a substantial increase of magnetic susceptibility, which dramatically enhances their response to an applied magnetic field. When integrated in a microfluidic channel, the improved MAC can induce versatile flows, for example (i) circulatory fluid flows with flow speeds up to 250 μm/s, (ii) direction-reversible flows, (iii) oscillating flows, and (iv) pulsatile flows, by changing the magnetic actuation mode.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Zhang, S., Wang, Y., Lavrijsen, R., Onck, P.R. & Toonder, J.M.J. den (2018). Versatile microfluidic flow generated by moulded magnetic artificial cilia. Sensors & Actuators B 263, 614-624.
2. Zhang, S., Wang, Y., Onck, P.R. & Toonder, J.M.J. den (2018). Removal of Microparticles by Ciliated Surfaces—an Experimental Study. Adv. Funct. Mater., 1806434.

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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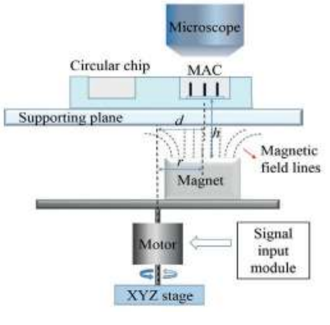

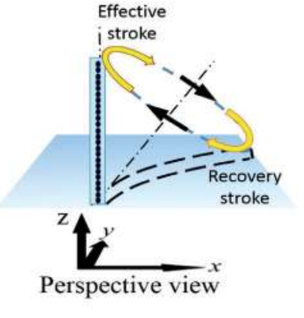

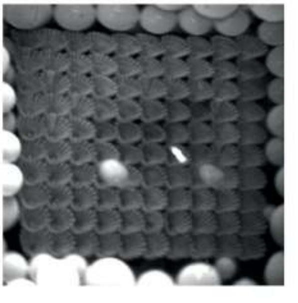

Project leaders
JMJ den Toonder, AJH Frijns
Research theme
Complex structures of fluids
Participants
S van Pelt
Cooperations
-
Funded by
CATRENE, PASTEUR
Funded %
University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

Start of the project
2009
Information
Jaap den Toonder
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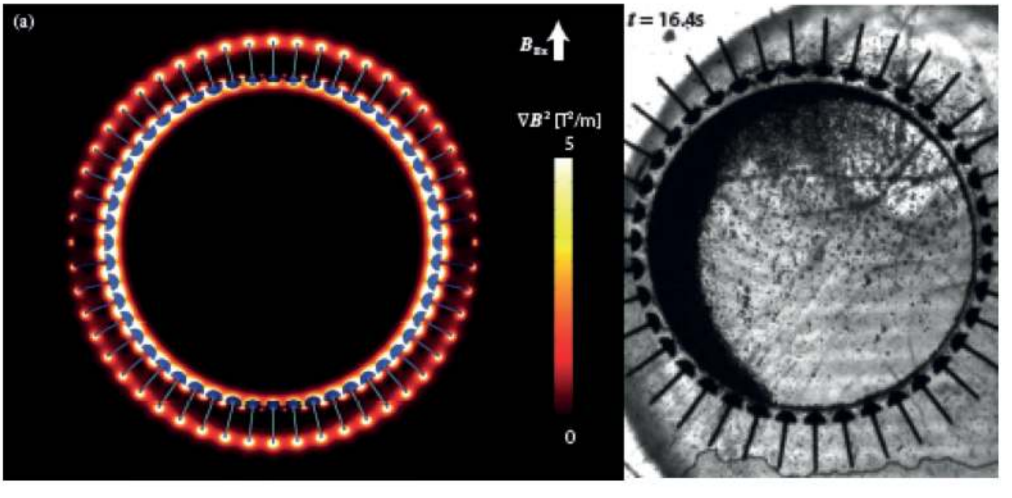
Project Aim
Magnetic beads play an important role in the miniaturization of medical diagnostic devices. They can be used to manipulate and detect target molecules at the microscale. With this project we investigate actuation based on soft-magnetic structures in an external rotating field. Additionally, we want to investigate how we can use this method to make the magnetic beads move between different locations on a microfluidic chip. Here we need to control the wettability of different locations on the chip in order to isolate different fluid functions. The magnetic beads can then be used as transport vessels between different locations.

Progress
We have shown a new method for the actuation of agglomerates of magnetic beads in a microfluidic environment, using an external rotating eld. By careful design of magnetic structures just below the surface of a microfluidic chip, the local magnetic field will show a motion that can be used to move magnetic beads similar to a conveyer belt. Based on this principle, various methods to transport, mix and separate magnetic particles were proposed and demonstrated. In 2018, this project was concludes with a PhD defense.

Dissertations
-

Scientific Publications
1. Moving beads and drops in magnetic microfluidic chips, PhD thesis.
van Pelt, S., 25 Sep 2018, Eindhoven: Technische Universiteit Eindhoven. 123 p.



PROJECT AIM

The aim of this project is to create surfaces with topography controllable by external stimuli such as light or magnetic field, that can be used to control wettability and fluid motion, which leads towards self-cleaning applications.

PROGRESS

In previous years we demonstrated a biologically inspired method to transport droplets over surfaces by dynamically controlled surface deformation, a concept named "mechanowetting". This involves locally deforming a surface on which a droplet is present, which leads to a difference in effective contact angle between droplet edges so that a net force acting on the droplet drives the droplet to move. In 2018, we demonstrated that this effect can be generated by using magnetically actuated surfaces on which droplets can be transported in any direction.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. De Jong, E., Wang, Y., Toonder, J.M.J. den & Onck, P.R. (2018). Climbing droplets driven by mechanowetting on transverse waves. Science Advances, accepted.

PROJECT LEADERS

JMJ. den Toonder

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Ye Wang, Hongbo Yuan

COOPERATIONS

-

FUNDED BY

STW (100%)

FUNDED %

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

START OF THE PROJECT

2015

INFORMATION

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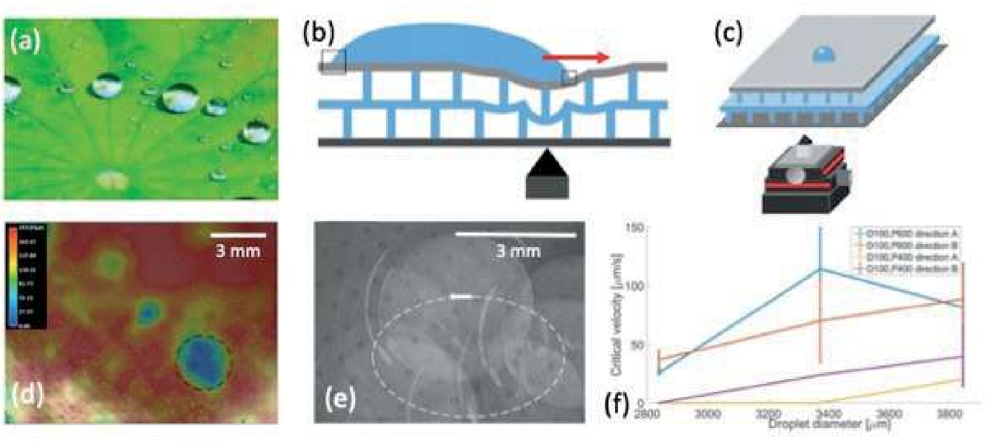

PROJECT LEADERS
JMJ den Toonder, R Luttge

RESEARCH THEME
Complex structures of fluids

PARTICIPANTS
Hossein Eslami Amirabadi

COOPERATIONS
-

FUNDED BY
STW 100%

FUNDED %

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

START OF THE PROJECT
2013

INFORMATION
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PROJECT AIM

The general goal of the project is to engineer tumor micro-environment in a controlled microfluidic system. In this work, our aim is to study the effect of physical properties of extracellular matrix (ECM) on the invasion of cancer cells. In order to realize a proper model for cancer cell invasion, we recreate the tumor-ECM interaction in 3D inside a microfluidic chip.

PROGRESS

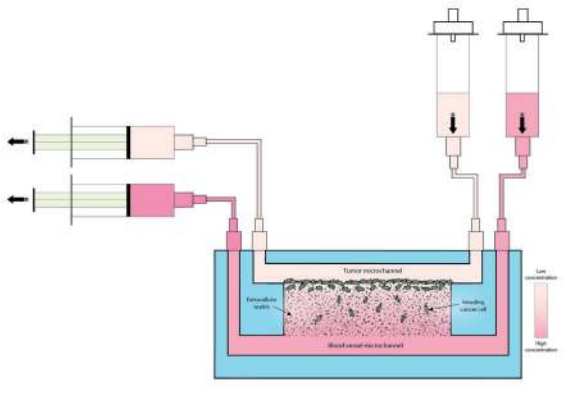
We have developed a new microfabrication method, called selective curing, to integrate ECM-mimicking layers between two microfluidic channels. This method enables us to study the effect of 3D matrices with controlled architecture, beyond the conventionally used hydrogels, on cancer invasion in a controlled environment. We used the chip to study the invasive behavior of various types of breast cancer cells, and found a good correlation between invasive behavior, E-cadherin status, and tumor aggressiveness observed in patients. In 2018 this project was concluded with a Phd thesis.

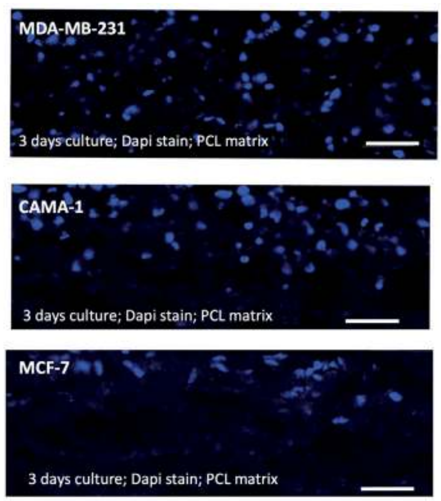
DISSERTATIONS

1. A novel microfluidic platform to study cancer cell invasion : self-standing matrices integrated in microfluidic chips, PhD thesis. Eslami Amirabadi, H., 11 Jun 2018, Eindhoven: Technische Universiteit Eindhoven. 116 p.

SCIENTIFIC PUBLICATIONS

1. Sleeboom, J.J.F., Eslami Amirabadi, H., Nair, P., Sahlgren, C.M., & Toonder, J.M.J. den (2018). Metastasis in context: Modeling the tumor microenvironment with cancer-on-a-chip approaches. Disease Models & Mechanisms 11. dmm033100. doi:10.1242/dmm.033100.





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 built a dedicated 3D printer that can print networks of carbohydrate filaments that form a template for creating a 3D model of the microvasculature in a chip. Branching networks could be printed, casted in elastomers (PDMS) as well as hydrogels, and were shown to be perfusable. This has resulted in a firs vasculature-on-a-chip model, that was used to do initial ultrasound imaging experiments.

Dissertations

-

Scientific Publications

1. A.M.A.O. Pollet, F.G.A. Homburg, M. Mischi and J.M.J. den Toonder, 3D printing of round microfluidic channels to mimic the microvasculature, Nanobiotech and IOOCs 2018 (poster).

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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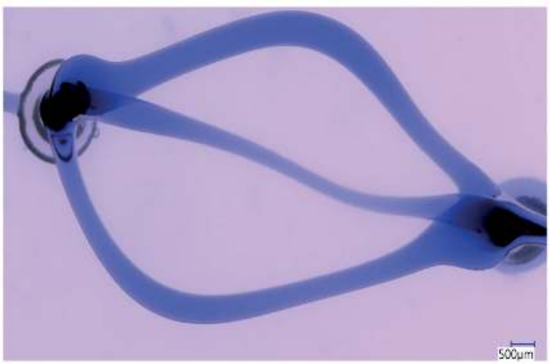

Project leaders
JMJ den Toonder
Research theme
Complex structures of fluids
Participants
Tanveer ul Islam
Cooperations
Prof. Yves Bellouard (EPFL)
Funded by
100 %
Funded %

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

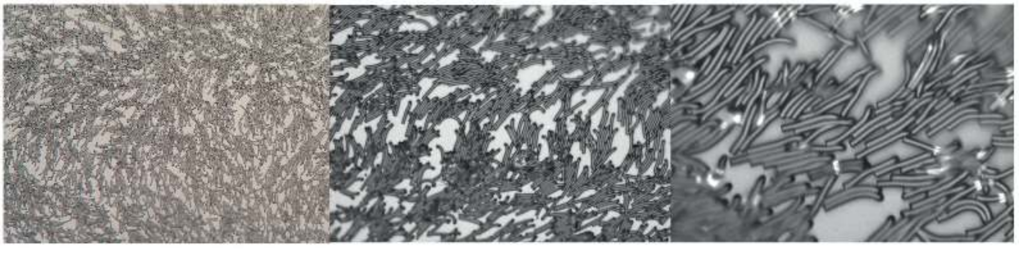
We developed a novel process to create artificial cilia that have similar dimensions as real cilia (length 20 microns). The cilia are made of specially developed elastomeric materials containing magnetic nanoparticles. The cilia are shaped using a casting process with a polymeric template that is sacrificed by etching after curing of the cilia within the template. The result is a surface covered with microscopic magnetic and flexible artificial cilia.

Dissertations

-

Scientific Publications

-



Multiphase reactors

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.

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

With the aim to resolve the multiscale phenomena occurring in mass transport and heat transport at gas-liquid interfaces, an octree based adaptive mesh refinement (AMR) technique is being implemented. A hybrid methodology has been developed which uses an adaptive framework only for the scalar field whereas the hydrodynamics will be solved using the in-house gas-liquid-solid solver. For convective flow over sphere, Nu numbers were reasonably accurate within 10% as compared to the RanzMarshall correlation. Further studies were also carried out with multiple particle systems. A sample simulation snapshot of flow over 3 cylinders for two different cylinder spacing and two different Pr number can be found in Figure 1

Dissertations

-

Scientific Publications

1. Das, S., Panda, A., Deen, N. G., Kuipers, J. A. M., “A sharp-interface Immersed Boundary Method to simulate convective and conjugate heat transfer through highly complex periodic porous structures”, Chemical Engineering Science, 2018 (191), 1-18.

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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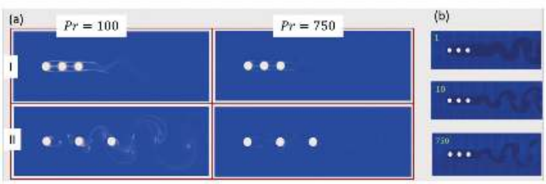
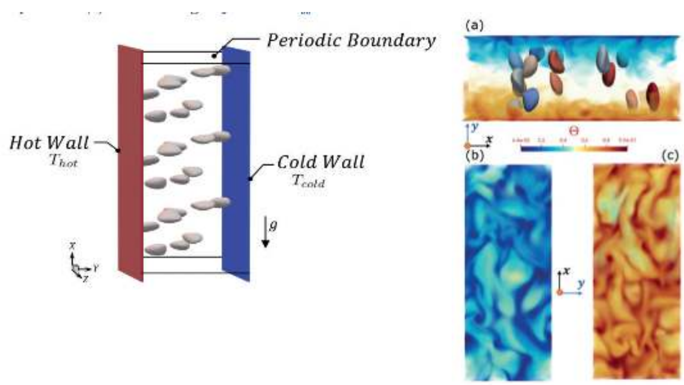


Flow over rigid surfaces (cylinders) for high Prandtl numbers (a) Contour plot of temperature (b) Associated grid for three different Pr numbers



(Left) Heat transfer in a periodic dense bubble swarm : Schematic case setup, (Right)(a) Temperature contours at the mid x-y plane (b) Temperature contour at the nearest x-z plane to the cold wall and (c) to the hot wall

PROJECT LEADERS
J.A.M. Kuipers
J.T. Padding
R.A. van Santen

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
A. Sengar
J.A.M. Kuipers
J.T. Padding
R.A. van Santen

COOPERATIONS
-

FUNDED BY
Netherlands Center Multiscale Catalytic 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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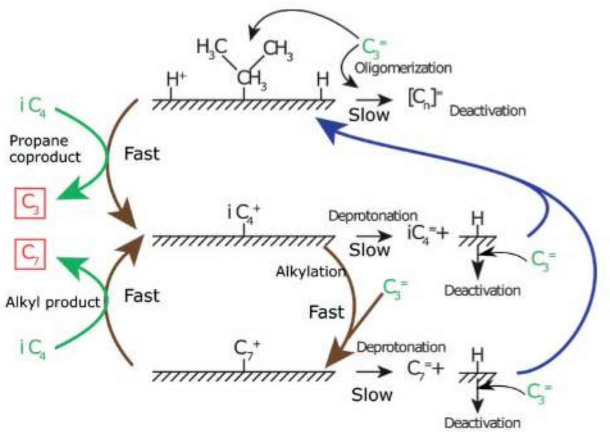
PROJECT AIM
In many catalytic reactors, a liquid flow is used to enhance the mass transfer to and from catalytic sites dotted on solid surfaces. Solid surfaces are usually corrugated on length scales of micrometers. In this project we will perform a fundamental investigation of the coupled convection-diffusion-reaction mechanisms in the boundary layer near corrugated walls. This will lead to correlations for sub-grid-scale corrections to the mass transfer rates. The project develops from implementing a simple reaction on a catalyst surface, generate dimensionless numbers for the same; with the aim to implement corrugations at a later time. Secondly, we study the deactivation kinetics of the alkylation reaction that produces high-octane fuel. The transition of such type of reactions from liquid-acid catalysts to solid-acid catalysts has motivated a theoretical understanding of the reaction.

PROGRESS
A multiscale heterogeneous catalytic reactor was modelled using SRD (stochastic rotation dynamics) [1]. Nonlinear catalytic reactions were coupled with convection and diffusion in the bulk to generate a mesoscale modeling technique that resolves the 3 scales of convection, diffusion and reaction. The nonlinear catalyst deactivation model of the alkylation reaction was studied [2]. The cause of non-exponential decay of this reaction under continuously stirred reactor conditions was found to occur when the surface catalyst sites comprise of 2 different types of active proton sites that interact with each other. Such effect was only observed to occur at differential condition. Under integral reactor conditions, the non-exponential decay might occur because of other reasons.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
1. Towards a particle based approach for multiscale modeling of heterogeneous catalytic reactors. A. Sengar, J. A. M. Kuipers, Rutger A. van Santen, and J. T. Padding. Chem. Eng. Sci 2018, 198, pp 184-197.
2. Deactivation Kinetics of Solid Acid Catalyst with Laterally Interacting Protons A. Sengar, Rutger A van Santen, E. Steur, J. A. M. Kuipers, J. T. Padding. ACS Catalysis 2018, 8(10), pp 9016-9033.



Example of a complex nonlinear catalyst deactivation scheme

Direct numerical simulation of boiling heat transfer in microchannels

Project Aim

To carry out meso-scale simulations of contactless and contactful boiling processes for controlled evaporation in microchannels. An inhouse 3D Front Tracking (FT) method will be extended to include phase transition. The resulting FT scheme will be modified to incorporate a film drainage model as a dynamic sub-grid model to properly account for micro-scale effects (for e.g. bubble coalescence). Simulations of the proposed test cases will be carried out and results will be validated against experimental data. Closure laws will be developed which will be utilized to set up engineering model for industrial partners.

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 flow boiling.

A comparison of simulation results with literature is shown in Figure 1. Initially, the bubble grows while retaining its spherical shape and moves downstream in the direction of flow. Then, the bubble starts to elongate in the direction of flow. Here the bubble has almost filled the channel cross-section and cannot expand any further in the y-z plane due to resistance from the wall.

Figure 2 shows the temperature and velocity field around the bubble. Formation of thermal boundary layer can be seen in the liquid near the wall. The bubble interface is accurately maintained at the saturation temperature even near the wall boundaries maintaining a sharp gradient in the temperature indicating high heat transfer across the liquid film (which is one of the main causes of increased heat transfer in microchannel flow boiling). The velocity vectors are much larger downstream of the bubble compared to the upstream indicating as the bubble grows the liquid is pushed towards outlet.

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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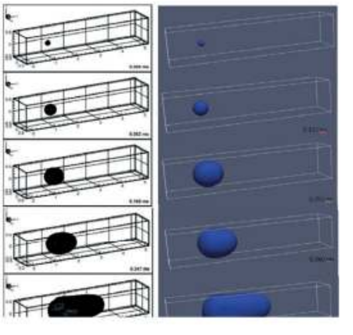
Dissertations

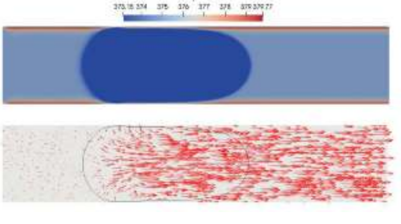
-

Scientific Publications

1. Rajkotwala, AH, Mirsandi H, Peters EAJF, Baltussen MW, Van der Geld CWM, Kuerten JGM and Kuipers JAM (2018), “Extension of Local Front Reconstruction Method with controlled coalescence/break up model”, Physics of Fluids 30, 022102.



Comparison of evolution of growth of vapour bubble with Mukherjee and Kandlikar, 2004.



Temperature and velocity field at the central vertical plane

Experimental study of transport and chemical reaction in three-phase flows

Project leaders
J.A.M. Kuipers
Research theme
Complex dynamics of fluids
Participants
G. Kong
K.A. Buist
E.A.J.F. Peters
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

The dynamics of rising bubbles are investigated experimentally with a high speed recording system. The purpose is to study the mechanism behind the hydrodynamics behavior.

Progress

The shape oscillation and rising velocity are studied to investigate the effect of rising motion on the shape oscillation. (Figure 1). The results are compared with DNS simulations. The interaction of side by side rising bubble pairs are studied in liquids with varying viscosity. Different rising interactions are identified. The lift and drag forces are calculated to characterize the interactions.

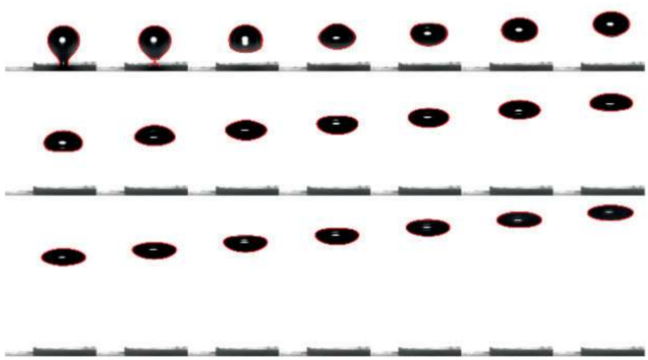
Dissertations

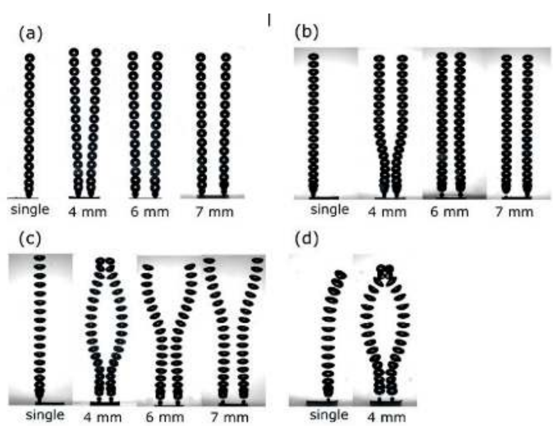
-

Scientific Publications

-

Bubble shape oscillation and rising dynamics.





Interaction between two side by side rising bubbles in liquids with varying viscosity.

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

-

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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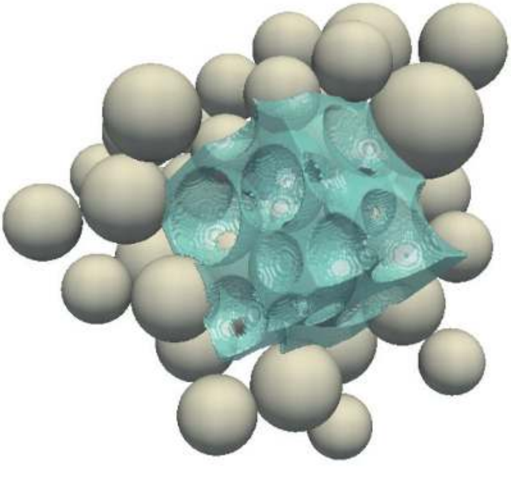
Simulated agglomerate in a poly-dispersed bed of particles for the characterization of transport coefficients and liquid cohesion.



PROJECT LEADERS
Prof. Dr Ir J.A.M. (Hans) Kuipers
Dr Ir E.A.J.F. (Frank) Peters

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

A numerical methodology is developed for simulating 3D multiphase flows through complex geometries on a non-body conformal Cartesian computational grid. Present coupled IBM-VOF solver can work with any arbitrarily shaped solid boundaries and is validated using a variety of benchmark test cases. Simulations of water flooding process through digitized porous rocks are performed based on typical pore-scale capillary and Reynolds numbers (Fig.1a). The effect of porosity on the mobility of oil-water flows through porous rocks is quantified.

Most challenging part of the VOF method is the accurate computation of the local interface curvature which is essential for finding the surface tension force at the interface. We have devised a machine learning approach to develop a model which predicts the local interface curvature from neighboring volume fractions. A novel data generation methodology is devised which generates a well-balanced randomized datasets comprising of spherical interfaces of different configurations/orientations. A two-layer feed-forward neural network with different network parameters (Fig.1b) is trained on this dataset and the developed models are tested on different shapes such as ellipsoid, 3D wave and Gaussian. The best model is selected based on specific criteria and compared with the conventional curvature computation methods (convolution and height function) to check the nature and grid convergence of the model.

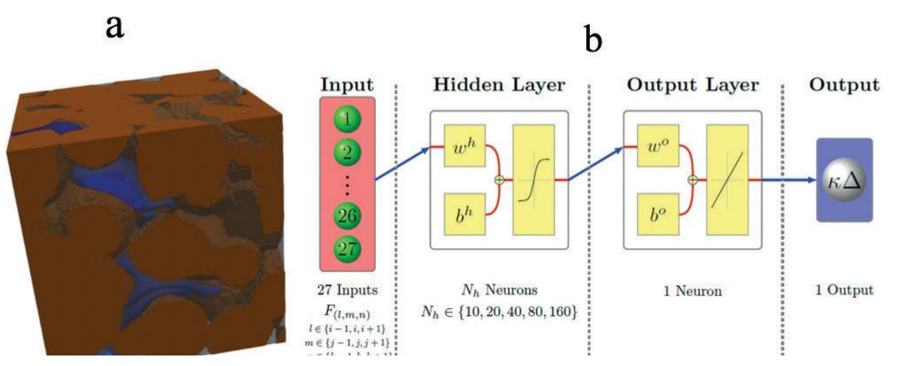
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. 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.

a) Viscous finger/s of water (in blue) displacing oil (in transparent grey) through digitized porous rock (in brown) b) Schematic diagram two-layer feed-forward neural network



PROJECT AIM

The main goal of the project is: to provide Tetra Pak with experimentally validated predictive computational tools that can be used to tailor spray drier operations. The first part of the project is based on the investigation of viscous effect on droplet interactions. Binary droplet collisions are analyzed numerically through DNS and experimentally trough droplet generator device. The obtained results are used to develop the theoretical model for the description of collision outcomes boundaries. The droplet collision model are used as closure for the Eulerian-Lagrangian spray model. The spray model is developed and compared with experiments using laser optical technique on a milk spray.

PROGRESS

The closures on collision outcomes boundaries are used in the spray drying Direct Simulation Monte Carlo (DSMC) model where an Eulerian-Lagrangian method is used to describe the dynamics of liquid droplets atomized in a high pressure spray nozzle. The gas phase is treated as a continuum and it is solved on a fixed Eulerian grid. The liquid is the dispersed phase treated with a Lagrangian method. The droplet collision rate is detected stochastically with a Direct Simulation Monte Carlo (DSMC) approach. Because the air is introduced in the spray at high velocities a self-induced turbulent gas flow is generated which needs to be solved with a turbulent method. A turbulent dispersion model has been included to account for the instantaneous fluid velocities along the particle trajectories. Accounting for the sub grid scale velocity fluctuations leads to an enhancement of the collision frequency.

DISSERTATIONS

1. Finotello, G., Padding, J. T., Buist, K. A., Jongsma, A., Innings, F., Kuipers, J. A. M., Droplet-droplet collisions in Spray Dryers, 13th International Conference on Computational Fluid Dynamics in the Minerals and Process Industries, December 2018, Melbourne, Australia. Awarded as best oral presentation.

SCIENTIFIC PUBLICATIONS

1. Finotello, G., Kooiman, R. F., Padding, J. T., Buist, K. A., Jongsma, A., Innings, F., Kuipers, J. A. M. (2018). The dynamics of milk droplet-droplet collisions. Experiments in Fluids, 59(1), 17.
2. Finotello, G., De, S., Vrouwenvelder J.C.R., Padding, J. T., Buist, K. A., Jongsma, A., Innings, F., Kuipers, J. A. M. (2018). Experimental investigation of Non-Newtonian droplet collisions: the role of extensional viscosity. Experiments in Fluids, 59 (7), 113.

PROJECT LEADERS

J.A.M Kuipers, J.T. Padding, K.A. Buist

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Giulia Finotello

COOPERATIONS

Tetra Pak

FUNDED BY

Tetra Pak

FUNDED %

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

START OF THE PROJECT

2014

INFORMATION

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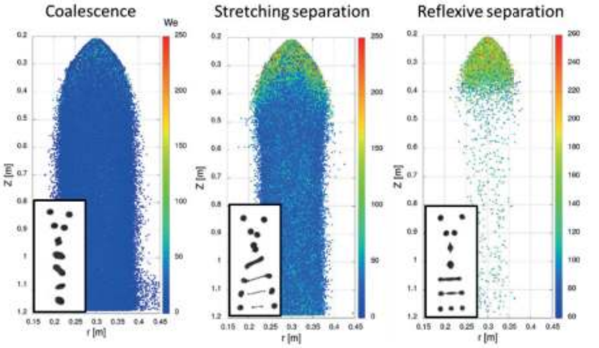

We numbers of the droplets in the entire spray system for whole milk 46% solids content droplet collisions.

Integrated and structured FCC reactor: G(L)S multi-scale modelling of a riser reactor with draft tube for intensified and uniform phase contacting

Project leaders
JAM Kuipers

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
L. Mu
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K.A. Buist
J.A.M. Kuipers

Cooperations
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P.C.A. Bruijnincx (UU)

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
2014

Information
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Project Aim

The aim of this work is to find out how heterogeneities affect the reactor performance. This includes heterogeneities in particle flow structures, particle size and liquid distribution. A CFD-DEM model employing state-of-the-art tools (LIGGGHTS/CFDEM/OpenFOAM) will be developed. Study the influence of each of the elements mentioned above systematically and validate the model experimentally for a cold-flow lab-scale setup.

Progress

As part of the project the OpenFoam Ligggths package was used to study hot-spot formation in a riser reactor under different superficial velocities. Furthermore the hydrodynamic effects of changing the inlet and outlet geometry have been studied. As a final step, because risers are quite large and a very large amount of particles, a coarse graining strategy is used to reduce the modeled number of particles. The effect of particle scaling on the solids holdup, solids flux and cluster characteristics is thoroughly checked.

Dissertations

-

Scientific Publications

-

PROJECT AIM

In fixed bed processes, reactions often take place at the surface active sites of catalyst particles. It is important to know how reactants are transported to these particles and how products move out with the fluid flow. Performance of catalysts is determined by reaction kinetics and transport. Most researchers focus on either reaction kinetics or transport, but in this project the flow of reactants and products around catalytic particles is modelled as well as the reactions that occur there. Using a massive computational model we aim at predicting the performance of a catalytic process by computer simulation. These simulations will give insight in the interplay of transport and reactivity.

PROGRESS

A direct numerical simulation (DNS) model which uses a ghost-cell based immersed boundary method is developed for modeling of realistic chemical reaction processes. Both variable reaction rates and significant heat effects are considered, which will reveal the insights in the interplay among chemical reactions, mass transport and heat liberation. For fluid-solid coupling, a second order quadratic interpolation scheme is implemented for handling the Robin boundary condition at the exact particle surface. For heat- mass coupling, particles are heated up by the liberated heat from chemical reactions and in turn influence the reaction rate by the Arrhenius equation.

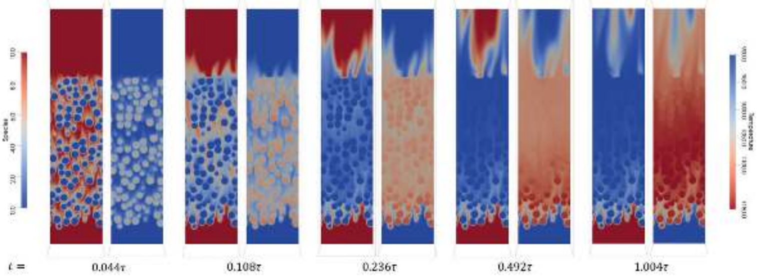
DISSERTATIONS

1. Lu, J. (2018). Direct numerical simulation of coupled heat and mass transfer in dense gas-solid flows with surface reactions. Eindhoven: Technische Universiteit Eindhoven.

SCIENTIFIC PUBLICATIONS

1. Lu, J., Peters, E. A. J. F., & Kuipers, J. A. M. (2018). Direct numerical simulation of fluid flow and mass transfer in particle clusters. Industrial and Engineering Chemistry Research, 57(13), 4664-4679. DOI: 10.1021/acs.iecr.8b00268.
2. Lu, J., Zhu, X., Peters, E. A. J. F., Verzicco, R., Lohse, D., & Kuipers, J. A. M. (2018). Moving from momentum transfer to heat transfer – A comparative study of an advanced Graetz-Nusselt problem using immersed boundary methods. Chemical Engineering Science. DOI: 10.1016/j.ces.2018.08.046.
3. Lu, J., Tan, M. D., Peters, E. A. J. F., & Kuipers, J. A. M. (2018). Direct numerical simulation of reactive fluid-particle systems using an immersed boundary method. Industrial and Engineering Chemistry Research, 57(45), 15565-15578. DOI: 10.1021/acs.iecr.8b03158.

Evolution of the concentration and temperature distribution inside a dense particle array ($Re_s = 80, Sc = 1, Pr = 0.8$)



PROJECT LEADERS
J.A.M. Kuipers

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
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E.A.J.F. Peters
J.A.M. Kuipers

COOPERATIONS
University of Twente

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
2014

INFORMATION

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Direct numerical simulation of mass & heat transfer in dense bubbly flows

Project leaders
J.A.M. Kuipers
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
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M.W. Baltussen
J.A.M. Kuipers
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

DNS and experiments are performed to study the contact line behavior during the bubble growth. Experiments show that for a hydrophobic surface (e.g. Teflon), the contact line recedes from the orifice, thus increasing the formation time and the volume of the bubble formed. It was also observed that once the bubble reaches its maximum spreading length, the contact line sticks on the surface for a relatively long period, while the contact angle increases from the receding angle to the advancing angle (Fig. 1). Inspired by this observation, we implemented a stick-slip model, in which the contact angle value is limited by the prescribed advancing and receding contact angle, to take into account the contact line dynamics. As can be seen in Figs. 1, the time evolution of the spreading length, bubble height, apparent contact angle, as well as bubble shape predicted by the present numerical model combined with stick-slip model agree relatively well with the experiments.

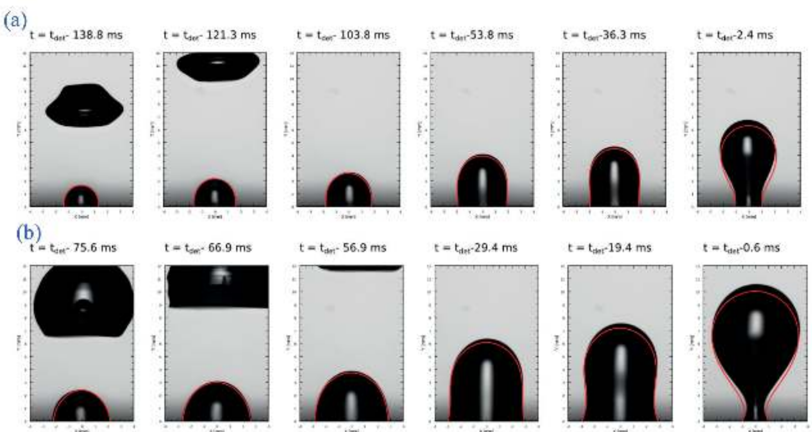
Dissertations

-

Scientific Publications

1. Mirsandi, H., Rajkotwala, A.H., Baltussen, M. W., Peters, E. A. J. F., Kuipers, J. A. M., "Numerical Simulation of Bubble Formation with a Moving Contact Line Using Local Front Reconstruction Method", Chemical Engineering Science, 187, 415-431.

Comparison of experimental and numerical (red line) bubble shapes: (a) σ = 47.8 mN/m, Q = 21.79 ml/min, and (b) σ = 72.5 mN/m, Q = 132.1 ml/min.



PROJECT AIM

In shale formations the gas-permeability is increased by injecting complex particle-filled liquids (fracking). The so-called proppant particles prevent the fractures from fully closing when the flow of liquid is stopped. In order to predict where the particles deposit in a network of fractures we need to know how proppant is transported in a network of fractures.

This research is aimed at modeling the particle transport on the relevant length scales. Three scales of coarse-grained computational multiphase fluid modeling will be used to analyse the sedimentation of particles. At all these scales, we will consider the behavior of sedimenting proppant particles at higher Reynolds number and/or in a visco-elastic medium. The creation of porous beds, also for polydisperse mixtures of grain-sizes, and the distribution of proppant in a network of fractures will be investigated.

PROGRESS

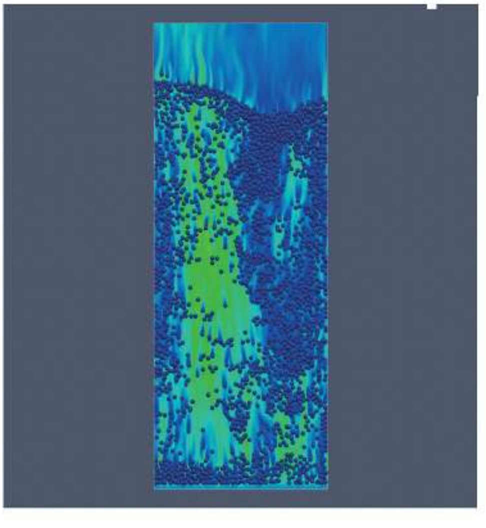
To understand the proppant transport at various flow conditions in rock fractures, 3D CFD model is developed. Sharp-interface ghost cell immersed boundary method (IBM) is implemented to account for the fluid-solid interaction. Moreover, there will be an interaction between solid-solid particles as well and this is accounted through the use of discrete element model (DEM) consisting of lubrication model and the collision model. The combined immersed boundary – discrete element model (IB-DEM) model is used for direct numerical simulation (DNS) of particle-laden flows and to improve the understanding of the transport phenomenon of proppants. The developed code is compared with experimental as well as numerical results for various Reynolds number. The sample simulation of fluidized bed is shown in the given figure.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Maitri, R. V., S. Das, J. A. M. Kuipers, J. T. Padding, and E. A. J. F. Peters. “An improved ghost-cell sharp interface immersed boundary method with direct forcing for particle laden flows.” Computers & Fluids 175 (2018): 111-128.



PROJECT LEADERS

J.A.M. Kuipers

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Dr. E.A.J.F Peters
Dr. J.T.Padding
Mr. Rohit Maitri, MSc

COOPERATIONS

Dr. Johan Romate- SHELL

FUNDED BY

FOM & Shell

FUNDED %

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

START OF THE PROJECT

2014

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
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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 slurry bubble columns using stochastic Euler-Lagrangian methods. Deterministic methods like 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. In addition, micron sized particles are being added to the system in the form of parcels to depict a slurry bubble column.

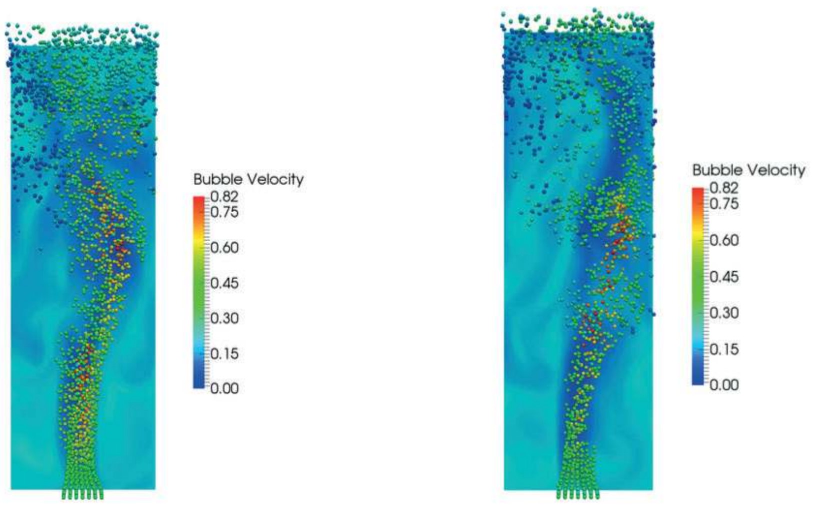
Dissertations

-

Scientific Publications

1. Kamath, S., Padding, J. T., Buist, K. A., & Kuipers, J. A. M. (2018). Stochastic DSMC method for dense bubbly flows: Methodology. Chemical Engineering Science, 176, 454-475.

Snapshot of a bubble plume from the DBM (left) and the DSMC (right), following the work of Deen 2001.



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

Apart from computationally inexpensive and accurate models the simulation of large scale system demands for a highly parallel and efficient numerical implementation. Thus, earlier designed and developed CFD framework was paralleled with MPI. The numerical code demonstrates linear scalability up to 3000 tested cores, see fig. 1. The developed numerical code is used to simulate large-scale system of approximately 1e6 bubbles (see fig.2) and to investigate influences of gas phase on heat transfer from solid walls (see fig.3).

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. M. Masterov, M.W. Baltussen, J.A.M. Kuipers, "Numerical simulation of a square bubble column using Detached Eddy Simulation and Euler–Lagrange approach", IJMF, volume 107, 275-288.

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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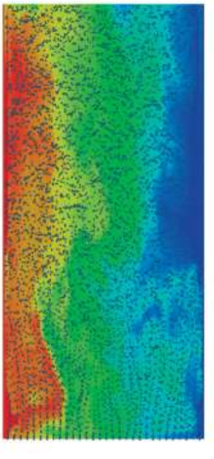
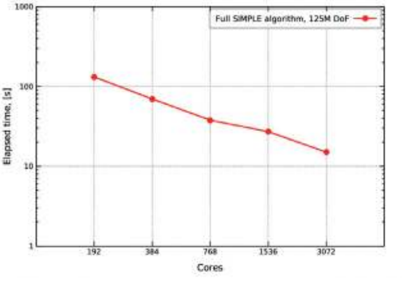
Visualization of O(1e6) bubbles rising in vertical bubble column (0.4x0.4x3.6m).



Temperature distribution in a pseudo-2D bubble column. Left wall is hot, right wall is cold.



Strong scaling of the developed CFD framework on example of Large Eddy Simulation of a flow in a square duct

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
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J.A.M. Kuipers
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
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. Newly designed metallic foam catalysts allow for higher surface area of reactivity, lower pressure drops, and better thermal stability and conductivity. In this project we will be studying coupled heat and mass transport through these catalysts using Direct Numerical Simulation techniques. A finite-volume based Immersed Boundary Method will be used to fully resolve transport phenomena at the pore-scale level.

Progress

The mass transport of reactants in porous media is a complex phenomenon where the reactant solutes are trapped in stagnant zones and are inhibited from reaching the active sites of the catalyst. Numerical simulations were performed to study the dispersion of inert solutes through open-cell solid foams using direct numerical simulation techniques. A second-order accurate Immersed Boundary Method is used to enforce the appropriate boundary condition at the interface of the porous solid object present within the computational domain. Volume averaging theory was used to measure hydrodynamic dispersion coefficients for varying flow-rates and porosities of an idealized structure of open-cell foams. Figure 1 pictorially represents the dispersion of a tracer solute in a unit cell of the open foam catalyst numerically simulated using the Immersed Boundary Method.

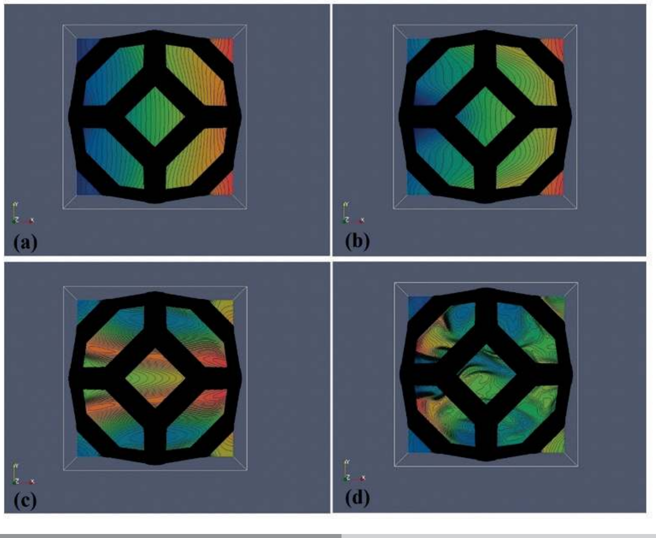
Dissertations

-

Scientific Publications

-

Hydrodynamic dispersion in open-cell foam of porosity 0.920. Contour plots showing the solute concentration across the XY plane for (a) $Pe = 2$ (b) $Pe = 10$ (c) $Pe = 50$ (d) $Pe = 200$



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. MRI experiments provided suitable 3-D datasets (Fig. 1) that can be applied for the validation of numerical codes used to model dispersion in packed beds.

Dissertations

-

Scientific Publications

1. Lovreglio, P., Das, S., Buist, K.A., Peters, E.A.J.F., Pel, L., Kuipers, J.A.M. (2018). Experimental and numerical investigation of structure and hydrodynamics in packed beds of spherical particles. AIChE Journal, 64(5), 1896-1907.

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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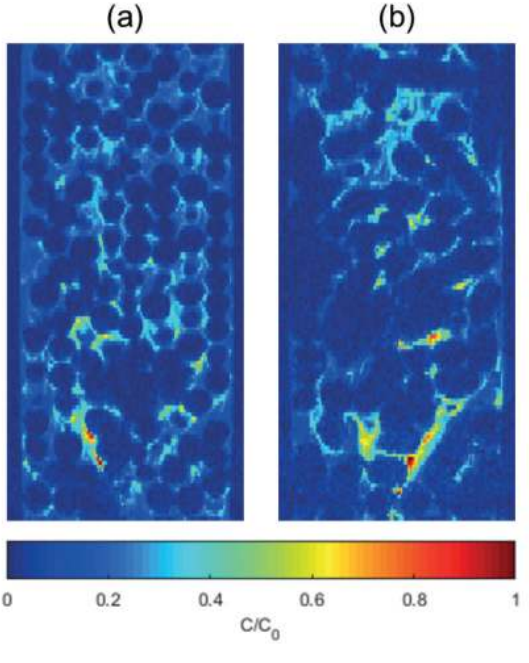

Experimental steady-state maps of tracer concentration along the main flow direction in packed beds of spheres (a) and spherocylinders (b) at Rep=50

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, the conceptual design of the model blast furnace was developed into a technical design, which is currently undergoing construction and assembly.

Dissertations

-

Scientific Publications

-

Prof.dr.ir. M van Sint Annaland

Chemical process intensification

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 simulation method for the analysis of the behavior of a fluidized bed with the presence of liquid. Even though this kind of system is widely used (i.e. bulk polyolefin production), many unknown aspects hamper the design optimization and safety management. For this purpose we develop multiple numerical 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 have set up a phenomenological model for the simulation of gas-phase 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. Moreover, a droplet percolation model has been obtained through simulations, which will be implemented in the DPM in a later stage.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir M. van Sint Annaland

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Dario M. Balice, Prof. N.G. Deen
Dr.ir. I. Roghair

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
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Prof.dr.ir. M. Van Sint Annaland
Dr.ir. Ivo Roghair
COOPERATIONS
-
FUNDED BY
European Union
FUNDED %

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

START OF THE PROJECT
2015
INFORMATION
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PROJECT AIM

This project is part of European project Intensified-by-Design (IbD®). IbD will create a holistic platform for facilitating process intensification design and optimization in processes in which solids are an intrinsic part. It will develop and upgrade methods for the handling of solids by intensification of currently existing processes, or through completely new approaches to the processing of solids. To support the design of intensified processes for solids handling, phenomenological models are developed making use of more fundamental simulations such as CFD and DEM models. The focus of this project lies on the development of predictive models for fluidized bed reactors.

PROGRESS

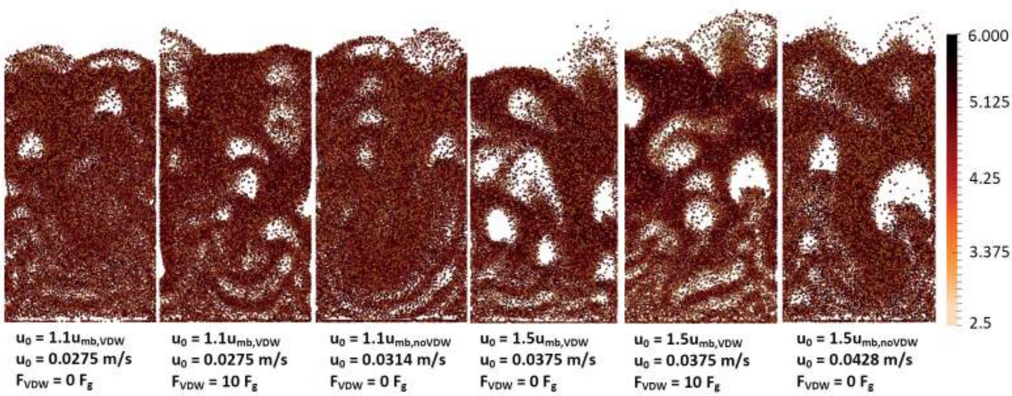
A DEM model is used to investigate the influence of inter-particle forces (van der Waals). Initial results showed the influence of the VdW forces to be higher for Geldart A then Geldart B, it was also found that due to this force particles could agglomerate. In addition, fluidization of Geldart B type particles is tested with different particles collision properties, since it was found in the literature that these properties are also changing with temperature.

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

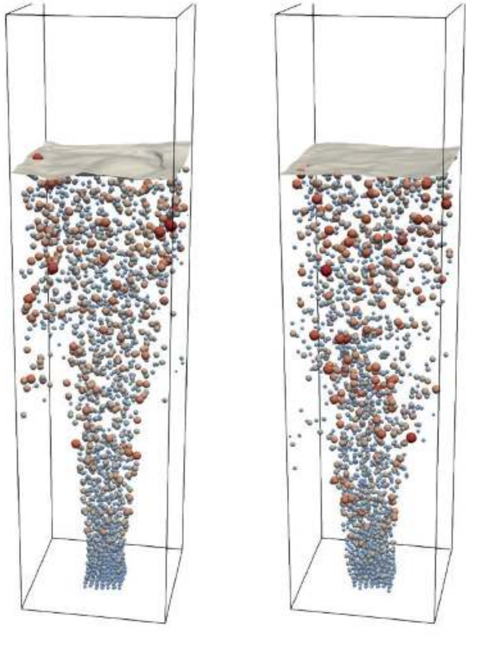
The DBM has been used to verify different collision/coalescence kernels for the TFM/PBM. A Front-Tracking free surface has been implemented in the DBM and validated to improve the top boundary condition. A bubble nucleation setup has been completed and first experiments have been performed. The DIA has also being adapted to perform the analysis of the experiments. In the meanwhile, the nucleation algorithm is being improved continuously (e.g. vertical surface etc.).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Battistella A., Aelen S.S.C., Roghair I., van Sint Annaland M., (2018) "Euler–Lagrange Modeling of Bubbles Formation in Supersaturated Water", ChemEngineering 2018, 2(3), 39.



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), DSM, Sabic, Shell, 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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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 solid surface under a convective gas flow is studied, both optically and by thermal imaging.

PROGRESS

Test sections for both experiments have been designed and commissioned. Experiments are currently ongoing.

A The growth of a vapor bubble in a microchannel is found to be influenced by the confinement provided by the channel walls (see Figure 1) in a way that is studied both with a simplified model and with a comparison with a CFD simulation by another PhD within the same project.

B Convective droplet evaporation leads high evaporation rates and inhomogeneous cooling of the droplet interface. The interface temperature of the droplet is measured simultaneously with drop shapes.

C Fouling that is common in industrial applications of once-through boilers with microchannels can be avoided by indirect heating with electromagnetic waves. Proof of principle has been delivered and currently a patent application is in consideration.

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

COOPERATIONS

TNO, Bronkhorst, ASM, PMI, Océ, TetraPak, Shell, AkzoNobel

FUNDED BY

STW and participants

FUNDED %

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

START OF THE PROJECT

2016

INFORMATION

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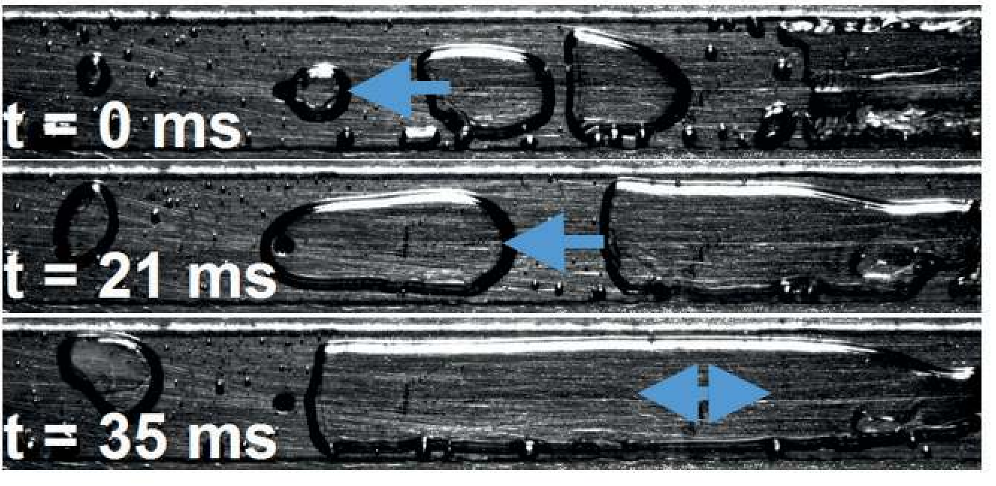
High speed recordings of a vapor bubble (see blue marker), rapidly expanding into a slug.



Prof.dr.ir. B Koren

Prof.dr. MA Peletier

Prof.dr. JJM Slot

Centre for analysis, scientific computing and applications (CASA)

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 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 developed a symmetry reduction based numerical framework to efficiently deal with model order reduction of transport/convection dominated phenomena. We proposed novel flux-redistribution approaches and primarily investigated the performance of the combined approach of symmetry reduction and reduced basis approximations in dealing with merging (discontinuous) wave-fronts via several numerical case studies, which included consideration of non-periodic boundary conditions. We also formulated the governing mathematical model (for drilling application) into a port-Hamiltonian form and started delving deep into structure preserving discretization and model reduction frameworks.

Dissertations

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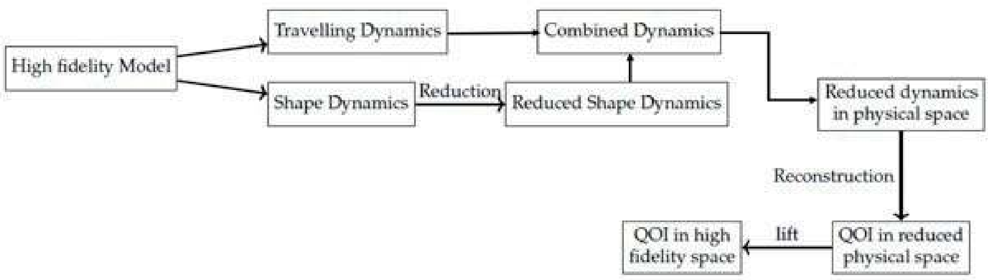
Scientific Publications

-

High-level flowchart of the proposed model order reduction methodology



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)
Stephan Rave (Germany)
Philipp Schulze (Germany)
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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EUROS Work Package 1.4: Wind-Farm-Wake Interactions

Project leaders
Prof. dr. ir. B. Koren

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
dr.ir. MJH Anthonissen (supervision)
MSc. R Beltman (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
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 this project is to start the development of a computational tool for the aerodynamic optimization under uncertainty of offshore wind farms. The variables to be optimized are: (i) wind-farm layout (plan form and turbine spacing), and (ii) yaw and pitch angles of individual turbines. Last five years, significant progress has been made in computational methods for: (i) offshore wind-farm-wake aerodynamics, (ii) shape optimization and (iii) uncertainty quantification. The time is perfectly right now to combine experts and algorithms, to start the development of an optimization algorithm for optimal wind-farm wakes under uncertainty.

Progress

Progress was made on physics-compatible discretization techniques for flow around objects immersed in a Cartesian mesh by use of the cut-cell approach. Discrete exact conservation statements were derived for the method.

An adaptive refinement algorithm was developed which was shown to be conservative.

Dissertations

-

Scientific Publications

1. R. Beltman, M.J.H. Anthonissen, B. Koren, Conservative polytopal mimetic discretization of the incompressible Navier-Stokes equations, Journal of Computational and Applied Mathematics 340, 443-473 (2018).
2. R. Beltman, M.J.H. Anthonissen, B. Koren, A locally refined cut-cell method with exact conservation for the incompressible Navier-Stokes equations, 6th European Conference on Computational Mechanics, 7th European Conference on Computational Fluid Dynamics (2018).

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

A two-dimensional extension to the numerical method was implemented. Furthermore, the method was improved upon by the use of a new limiter. Several test cases were numerically simulated to validate the method. Phase transition models were studied and compared and implementation of these was started.

Dissertations

-

Scientific Publications

1. R. de Böck, A.S. Tijsseling, and B. Koren. State-of-the-art finite-volume discretisation of Kapila's two-fluid flow model. 7th European Conference on Computational Fluid Dynamics (ECCM-ECFD 2018), Glasgow, 2018.

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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www.offshorewindenergy.org/EUROS/

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

In 2018 we worked on developing a two-phase approach for the uncertainty propagation, in which the uncertainty measures obtained in the first phase can be used to improve the sample selection of the second phase. In the future, this can also be used to discard unimportant input variables and reduce groups to one variable, such that the problem becomes lower-dimensional. Furthermore, we strengthened the theory behind our dependency analysis method.

Dissertations

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Scientific Publications

1. A. Eggels, D. Crommelin, and J. Witteveen, “Clustering-based collocation for uncertainty propagation with multivariate dependent inputs,” International Journal for Uncertainty Quantification, vol. 8, no. 1, pp. 43–59, 2018.
2. A. Eggels and D. Crommelin, “Uncertainty Quantification with dependent inputs: wind and waves,” in Proceedings of ECCM 6 and ECFD 7, 2018.

SLING

Project Aim

- Uncertainty Quantification
- Surrogate Modeling
- Machine Learning
- Fluid Mechanics
- Digital Twins

Progress

- Developed methods for uncertainty quantification in fluid dynamics.
- Developed reduced order methods for fluid dynamics
- Considered digital twinning in fluid mechanics

Dissertations

-

Scientific Publications

1. Y.van Halder, B. Sanderse, B. Koren, An adaptive minimum spanning tree multi-element method for uncertainty quantification of smooth and discontinuous responses, https://arxiv.org/abs/1803.06833.

Project leaders

Barry Koren
Benjamin Sanderse (CWI)

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

dr. ir. A.S. Tijsseling

Cooperations

CWI, GTT, MARIN, Shell

Funded by

NWO-TTW

Funded %

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

Start of the project

2017

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. S.M. Hassanizadeh (Utrecht)
Prof. Dr. Ing. R. Helmig (Stuttgart)
Prof. Dr. C. Rohde (Stuttgart)
Dr. K. Kumar (Bergen)

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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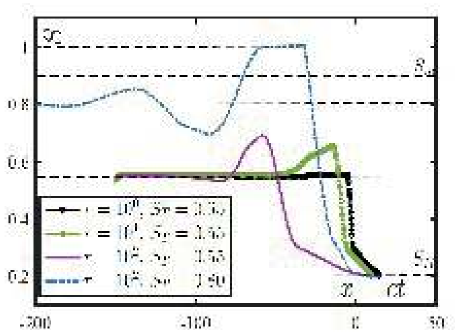
Project Aim
This project addresses issues related to the mathematical modelling, numerical simulation and upscaling of flow in porous media. The main focus is on heterogeneous and fractured systems and on non-equilibrium models where dynamic or hysteresis effects are included in the difference between the two phase pressures, and/or in the relative permeabilities.

Progress
In addition to the works that were submitted last year and were published this year, we have done: 1) Formulated a new linear iteration scheme for nonlinear parabolic equations rising from diffusion problems such as multiphase flow through porous media.; 2) Provided error estimates for a mixed finite element scheme that was proposed to solve two-phase porous transport equations with dynamic capillarity; 3) Completed the analysis on travelling waves incorporating both hysteresis and dynamic capillarity effects (see Figure 1); 4) Explained the development of viscous fingers using travelling waves.

Dissertations
-

Scientific Publications
1. van Duijn, C. J., Mitra, K. & Pop, I. S. (2018). Travelling wave solutions for the Richards equation incorporating non-equilibrium effects in the capillarity pressure. Nonlinear Analysis: Real World Applications, 41, 232-268.
2. Seus, D., Mitra, K., Pop, I. S., Radu, F. A. & Rohde, C. (2018). A linear domain decomposition method for partially saturated flow in porous media. Computer Methods in Applied Mechanics and Engineering, 333, 331-355.
3. van Duijn, C. J. & Mitra, K. (2018). Hysteresis and Horizontal Redistribution in Porous Media. Transport in Porous Media, 1-25.
4. Mitra, K. & Pop, I. S. (2018). A modified L-Scheme to solve nonlinear diffusion problems. Computers & Mathematics with Applications.
5. Cao, X. & Mitra, K. (2018). Error estimates for mixed finite element for two-phase porous media flow with dynamic capillarity. Journal of Computational and Applied Mathematics.



The profiles of saturation in a long vertical channel for different values of top saturation and dynamic capillarity parameter τ. Both hysteresis and dynamic capillarity are considered in the computations. They show that the profiles develop into travelling waves having overshoots that are close to those in experiments.

HYdraulics modeling for DRilling Automation (HYDRA)

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

An error bound and an error estimate after reduction of the system with the reduced basis method are derived. The error bound and estimate are also extended for a nonlinear partial differential equation under certain restrictions. In the single-phase flow, the reduced system is equipped with realistic features of the managed pressure drilling system such as area variation and a non-return valve at the bit. Finally, a similar procedure is being followed for reducing the dimension of a multi-phase flow. The validation of the high fidelity solver against the field data has been started.

Dissertations

-

Scientific Publications

1. S. Naderi Lordejani, B. Besselink, M.H. Abbasi, G.O. Kaasa, W.H.A. Schilders, N. van de Wouw, Model order reduction for managed pressure drilling systems based on a model with local nonlinearities, IFAC-PapersOnLine 51 (8) (2018) 50–55.

Project leaders

Nathan van de Wouw, Wil 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

European Union

Funded %

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

Start of the project

2016

Information

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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.

PROJECT AIM

The main objective of this research is to obtain fundamental knowledge on the impact of facade geometrical details on air flow and pollutant dispersion around buildings. This leads to the following sub-objectives:

(1) Investigate the performance of large eddy simulation (LES) and steady Reynolds-averaged Navier-Stokes (RANS) for wind flow and pollutant dispersion around buildings with balconies.

(2) Evaluate the impact of different types of building balconies on wind speed and surface pressure.

(3) Examine the impact of building balconies on pollutant dispersion in urban street canyons.

PROGRESS

Full-scale large eddy simulations (LES) were performed for high-rise buildings with and without balconies. In this case, 15 different balcony configurations were considered (three of them are shown in Fig. 1). In addition, simulations were performed to investigate the impact of building balconies on pollutant dispersion in a street canyon. The evaluation was based on wind-tunnel measurements of pollutant concentration for a generic urban street canyon.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Zheng, X., Montazeri, H. & Blocken, B. A numerical study of pressure coefficients distribution on high-rise buildings with balconies. XV Conference of the Italian association for wind engineering, 9-12 September 2018, Napoli, Italy.

PROJECT LEADERS

B Blocken

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

H Montazeri

COOPERATIONS

-

FUNDED BY

China Scholarship Council

FUNDED %

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

START OF THE PROJECT

2016

INFORMATION

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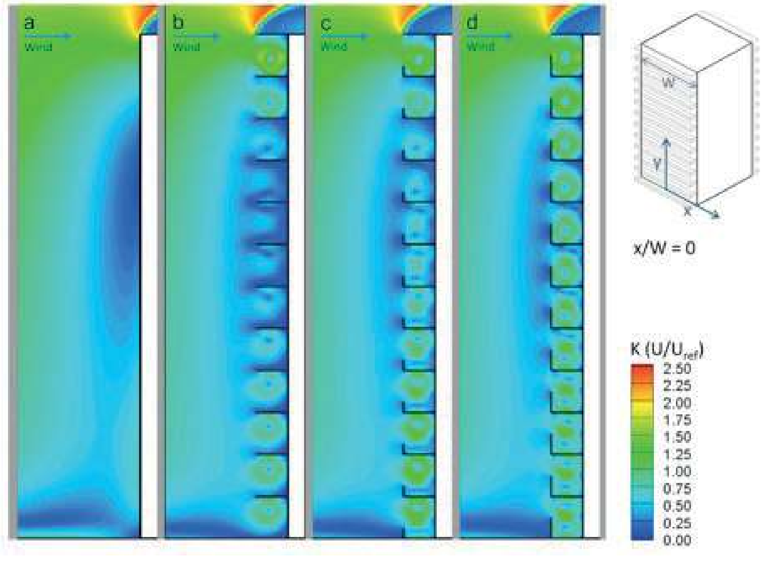
Impact of building façade details: (a) smooth façade, (b) 3 m balconies, (c) 3 m balconies with 1m parapet walls and (d) 3 m balconies with 2 m parapet walls.



PROJECT LEADERS
B. Blocken, H. Montazeri
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
-
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 in mitigating the heat stress in the outdoor environment. This research project will be executed based on the following sub-objectives:

1 - CFD validation for spray evaporation in turbulent flows.

2 - Investigate the impact of computational parameters on spray evaporation.

3 - Investigate the cooling potential of water spray systems under different meteorological conditions.

4 - Investigate the cooling potential of water spray systems for generic and real urban areas.

PROGRESS

In the first part of the research project, a CFD validation study was carried out for a spray system based on the measurements by Sommerfeld et al [1]. Two cases were considered: (1) single-phase flow and (2) two-phase flow. An overall good agreement was achieved between the CFD results and the experimental data. In addition, the impacts of the RANS turbulence model, the inlet turbulence intensity, the droplet parcel number, and the vaporization model on the simulation results were systematically investigated.

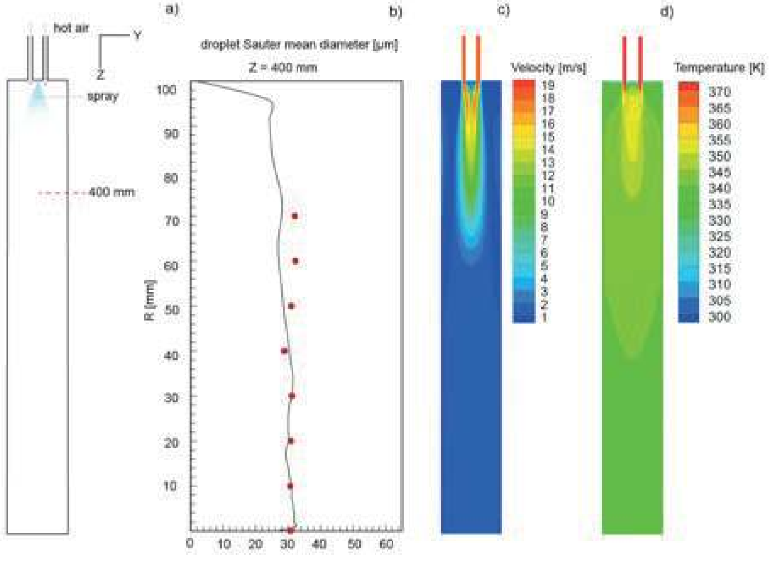
DISSERTATIONS

-

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

This research aims to combine Computational Fluid Dynamics (CFD) and Building Energy Simulations (BES) to study the urban heat island effect on the meteorological microscale and to conduct a numerical analysis of the implications of microclimate on building energy demand. The numerical analysis of urban microclimate can bring the possibility to evaluate urban adaptation measures (i.e. urban parks) which may be utilized to alter urban microclimatological conditions. With this numerical multiscale approach, urban microclimates can be designed for improved health and for buildings to operate in a more energy-efficient way.

PROGRESS

This research project initially focused on the development of a CFD modeling approach to simulate urban microclimatological occurrences with sufficient accuracy. In parallel, a literature review was conducted to investigate the research field of CFD urban microclimate analysis. Before 2018, this research had produced two papers published in international peer-reviewed journals. In 2018, two more papers have followed. A fifth paper is prepared and it is currently in revision. The research was finalized in 2018 by positioning each paper (five in total) as separate chapters in the thesis and the thesis was successfully defended on 25 April 2018.

DISSERTATIONS

1. Toparlar, Y. (2018) A multiscale analysis of the urban heat island effect: from city averaged temperatures to the energy demand of individual buildings. PhD Thesis – Eindhoven University of Technology, 220p. Thesis is supervised by Blocken, B., van Heijst, G.J.F, Maiheu, B.

SCIENTIFIC PUBLICATIONS

1. Toparlar Y, Blocken B, Maiheu B, van Heijst GJF. 2018. Impact of urban microclimate on summertime building cooling demand: A parametric analysis for Antwerp, Belgium. Applied Energy 228: 852-872.
2. Toparlar Y, Blocken B, Maiheu B, van Heijst GJF. 2018. The effect of an urban park on the microclimate in its vicinity: a case study for Antwerp, Belgium. International Journal of Climatology 38: e303-e322.

PROJECT LEADERS

B. Blocken, G.J.F. van Heijst, B. Maiheu (VITO)

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Y. Toparlar

COOPERATIONS

Eindhoven University of Technology (TU/e)
Flemish Institute for Technological Research (VITO)

FUNDED BY

TU/e and VITO

FUNDED %

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

START OF THE PROJECT

2013

INFORMATION

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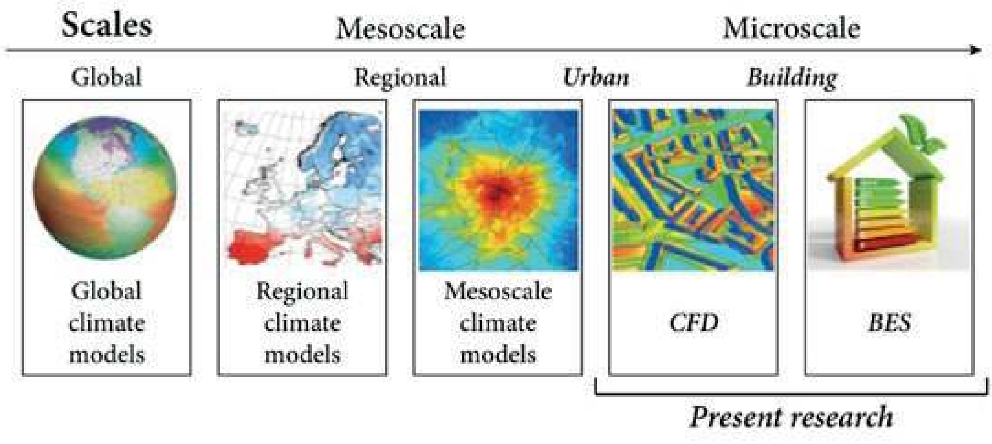

Cycling aerodynamics: optimization of individual and team time trial aerodynamics

Project leaders
B. Blocken
Research theme
Complex dynamics of fluids
Participants
Thijs van Druenen
Cooperations
Jumbo-Visma cycling team
Funded by
-
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 50 km/h the aerodynamic drag constitutes more than 90% of the cyclist's total resistance when riding on level terrain. 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 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 of fabrics and equipment on the aerodynamic drag is investigated.

Progress

General knowledge was obtained for the application of numerical (CFD) simulations to the field of cycling by grid-sensitivity analyses and validation by wind tunnel measurements. This led to insight in the aerodynamics in small (team time trial, 6 cyclists) and large (peloton, 121 cyclists) groups of cyclists. The drag of the cyclists in the mid rear of the peloton turned out to be only 5%-10% compared to a single cyclists riding alone, which was much lower than expected and documented in the literature. For an individual cyclist, 15 descent positions were investigated. Here, a difference of 27% in drag area was found between the fastest and slowest road race position.

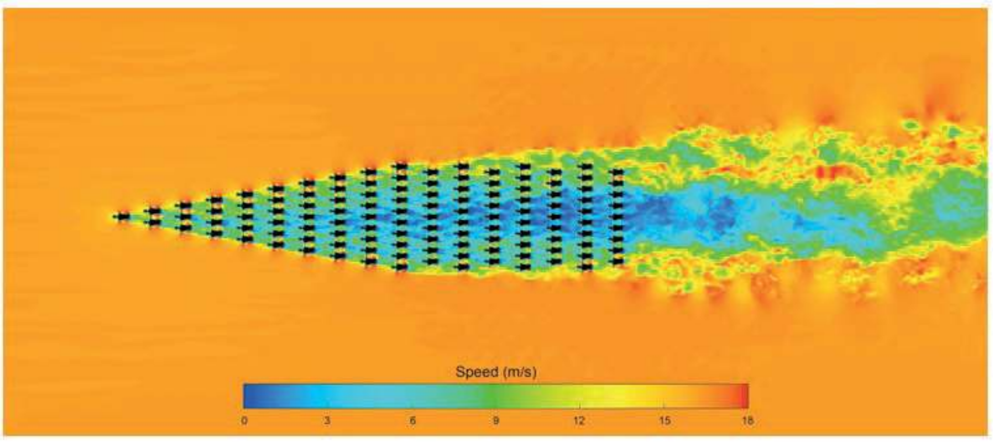
Dissertations

-

Scientific Publications

1. Blocken, B., van Druenen, T., Toparlar, Y., Malizia, F., Mannion, P., & Andrianne, T. et al. (2018a). Aerodynamic drag in cycling pelotons: New insights by CFD simulation and wind tunnel testing. Journal Of Wind Engineering And Industrial Aerodynamics, 179, 319-337.
2. Blocken, B., van Druenen, T., Toparlar, & Andrianne, T. (2018b). Aerodynamic analysis of different cyclist hill descent positions. Journal Of Wind Engineering And Industrial Aerodynamics, 181, 27-45.
3. Blocken, B., Toparlar, van Druenen, T., & Andrianne, T. (2018c). Aerodynamic drag in cycling team time trials. Journal Of Wind Engineering And Industrial Aerodynamics, 182, 128-145.

Contours of instantaneous wind speed at a horizontal plane in a cycling peloton containing 121 cyclists (Blocken et al., 2018a).



Project Aim

To investigate and quantify the aerodynamic forces associated with tandem Para-cycling and hand cycling.

To provide knowledge regarding the fundamental aerodynamic processes which may be useful for improving the aerodynamic performances of para-cycling athletes.

Progress

PhD candidate is in his fourth year of study, with his defense scheduled for the 19th February 2019. Seven international peer-reviewed journal papers have been published/accepted for publication, with an eighth paper under review.

The research has focused on tandem cycling and hand-cycling within the Para-cycling disciplines. The following approach has been used for both cycling disciplines: (1) CFD simulations for sensitivity studies on grid typology and turbulence modeling, (2) crosswinds research using both CFD simulations and wind-tunnel tests, (3) Evaluating different equipment and athlete posture/position variations.

Dissertations

-

Scientific Publications

1. Mannion, P., Toparlar, Y., Blocken, B., Hajdukiewicz, M., Andrianne, T., & Clifford, E. (2018). Improving CFD prediction of drag on Paralympic tandem athletes: Influence of grid resolution and turbulence model. Sports Engineering, 21(2) 123-135. https://doi.org/10.1007/s12283-017-0258-6.
2. Mannion, P., Toparlar, Y., Blocken, B., Clifford, E., Andrianne, T., & Hajdukiewicz, M. (2018). Aerodynamic drag in competitive tandem para-cycling: road race versus time-trial positions. Journal of Wind Engineering & Industrial Aerodynamics, 179, 92–101. https://doi.org/10.1016/j.jweia.2018.05.011.
3. Mannion, P., Toparlar, Y., Blocken, B., Clifford, E., Andrianne, T., & Hajdukiewicz, M. (2018). Analysis of crosswind aerodynamics for competitive hand-cycling. Journal of Wind Engineering and Industrial Aerodynamics. 180, 182–190. https://doi.org/10.1016/j.jweia.2018.08.002.

Project leaders
Bert Blocken, E Clifford (NUI Galway)

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
P. Mannion
Y. Toparlar
T. Andrianne (U Liège)
M. Hajdukiewicz (NUI Galway)

Cooperations
National University of Ireland, Galway
KU Leuven, Belgium
University of Liege, Belgium

Funded by
Research fellowship from the college of Engineering and Informatics, NUI Galway, Ireland

Funded %

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

Start of the project
2015

Information
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Aerodynamic optimization of particulate matter removal using electrostatic precipitator units

Project leaders
B. Blocken (TU/e, KU Leuven)
T. van Hooff (KU Leuven, TU/e)
R. Gijsbers (ENS Technology)

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
R. Vervoort

Cooperations
ENS technology
ANSYS CFD

Funded by
TU/e (45.8%)
4TU.Bouw (27.1%)
ENS Technology (27.1%)

Funded %

University	72,9 %
FOM	-
STW	-
NWO Other	-
Industry	27,1 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2016

Information
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Project Aim

Particulate matter (PM) is one of the most dangerous forms of air pollution; exposure is strongly related to human morbidity and mortality. Researchers have not been able to identify a threshold below which PM concentrations do not have a negative effect on human health. However, it is known that all-cause daily mortality and long-term risk of cardiopulmonary mortality increase when exposed to higher PM concentrations. Conversely, this implies that reduced exposure to PM can yield a reduced mortality risk. In this study, the indoor and outdoor PM concentration reduction potential, by local removal of PM by positive ionization units inside semi-enclosed environments, is assessed.

Progress

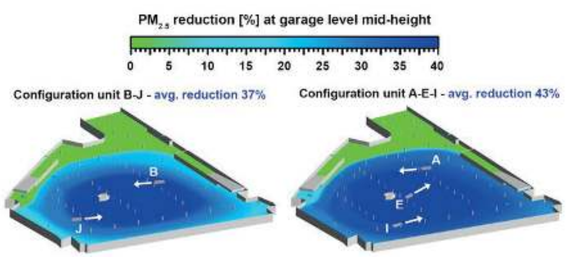
Computational fluid dynamics (CFD) analyses, using steady Reynolds-Averaged Navier-Stokes (RANS) in combination with the realizable k-ε turbulence model, are conducted on high-quality and high-resolution grids. Preliminary results show that application of positive ionization units can reduce PM2.5 concentrations with up to 43% in semi-enclosed parking garages and with up to 34% in a semi-enclosed building courtyard. Since air is continuously exchanged between the semi-enclosed buildings and their surroundings, this also means that ambient PM concentrations are reduced in the immediate vicinity of these buildings.

Dissertations

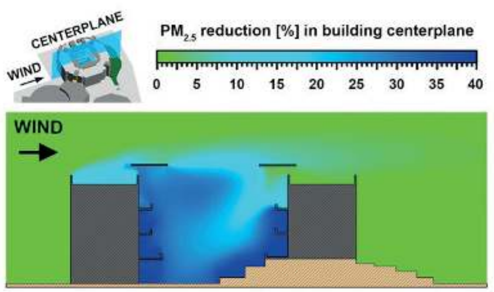
-

Scientific Publications

1. Vervoort R., van Hooff T., Blocken B. (2018). Reduction of particulate matter concentrations by local removal in a semi-enclosed parking garage. Proceedings of Roomvent&Ventilation, pp. 797-802.



PM2.5 concentration reduction at garage level mid-height in a semi-enclosed parking garage for a configuration with 2 and 3 ionization units.



PM2.5 concentration reduction at building center vertical cross-section (parallel to wind flow) in a semi-enclosed building courtyard for a configuration with 4 ionization units.

PROJECT AIM

The aim of this research is to characterize and improve the aerodynamic performance of urban-scale vertical axis wind turbines (VAWT) using computational fluid dynamics. The research has the following objectives:

- Development of guidelines to ensure the accuracy of CFD simulation of VAWTs;
- Characterization of the aerodynamic performance of VAWTs under the impact of various geometrical and operational parameters;
- Improving the aerodynamic performance of VAWTs using passive and active flow control devices.

PROGRESS

Generalized guidelines were developed to ensure the accuracy of CFD simulations of vertical axis wind turbines, where the minimum requirements for the computational settings for different tip speed ratios and solidities were identified. In addition, high-fidelity CFD simulations of VAWTs were performed to characterize the aerodynamic performance of VAWTs under the impact of various geometrical and operational parameters. The geometrical parameters investigated are the turbine solidity and number of blades and the operational parameters are the turbine tip speed ratio, Reynolds number, and turbulence intensity.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Rezaeiha A, Montazeri H, and Blocken B, "Towards optimal aerodynamic design of vertical axis wind turbines: Impact of solidity and number of blades," Energy 165 (B), pp. 1129-1148, 2018.
2. Rezaeiha A, Montazeri H, and Blocken B, "Characterization of aerodynamic performance of vertical axis wind turbines: impact of operational parameters," Energy Conversion and Management 169 (C), pp. 45-77, 2018.
3. Rezaeiha A, Montazeri H, and Blocken B, "Towards accurate CFD simulations of vertical axis wind turbines at different tip speed ratios and solidities: Guidelines for azimuthal increment, domain size and convergence," Energy Conversion and Management 156 (C), pp. 301-316, 2018.

PROJECT LEADERS

B Blocken

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

H. Montazeri

COOPERATIONS

European consortium in Horizon 2020 project

FUNDED BY

European Commission through Framework Program Horizon 2020, through the Marie Curie Innovative Training Network (ITN) AEOLUS4FUTURE – Efficient harvesting of the wind energy (H2020-MSCA-ITN-2014: Grant agreement no. 643167)

FUNDED %

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

START OF THE PROJECT

2015

INFORMATION

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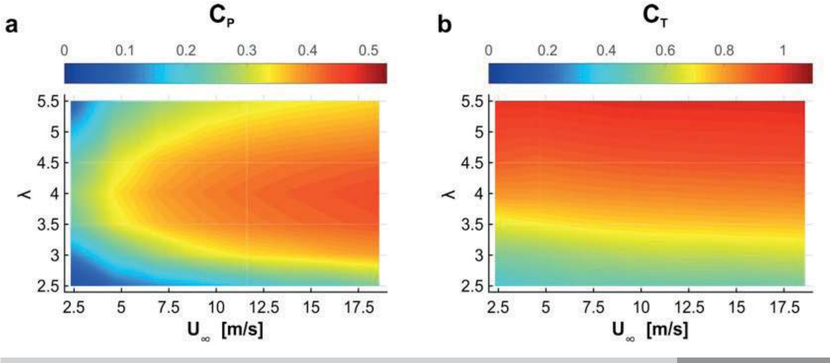
https://www.tue.nl/en/university/departments/built-environment/the-department-of-the-built-environment/staff/detail/ep/e/d/ep-uid/20154502/ep-tab/2/

Contour plots of turbine power and thrust coefficients versus freestream velocity for a 2-bladed VAWT with a low solidity of 0.12.



PROJECT LEADERS
B. Blocken, A. Ricci
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Peng Qin
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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PROJECT AIM

The dispersion of pollutants is of great relevance for people living in urban areas. Streets and squares are main zones where human activities take place but also where pollutants show a higher concentration compared to open areas. The present project aims at investigating the dispersion by different pollutant sources (e.g. moving and static vehicles) in idealized low-density and high-density urban areas under various atmospheric conditions by means of experimental (wind-tunnel tests) and numerical (Computational Fluid Dynamics, CFD) techniques.

PROGRESS

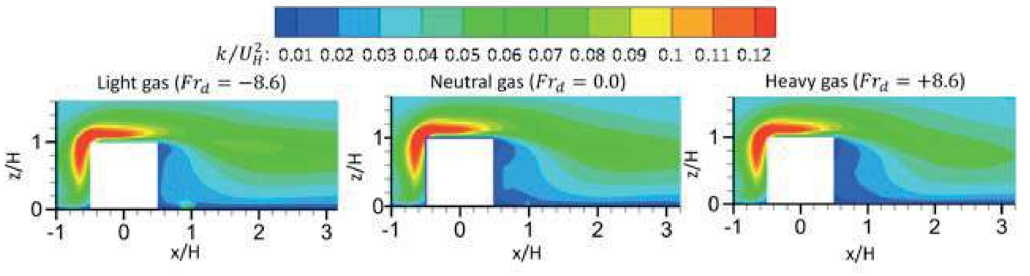
In a preliminary stage, CFD simulations have been performed on a well-validated case study present in the literature, i.e. an idealized building (a cube) with a pollutant source (e.g. C2H4 for neutral gas, C2H4 with He for light gas, and C2H4 with SF6 for heavy gas) located downstream, using steady-state RANS and different turbulence models: the standard k-ε model, the renormalization group k-ε model, the realizable k–ε model and the shear-stress transport k-ω model. The impact of the turbulent Schmidt number on the numerical results (in terms of concentration, velocity, turbulent kinetic energy, etc.) has also been analyzed.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Measures to improve the indoor environment and reduce the cooling demand of buildings in hot-humid climates

Project Aim

The research aims at developing and analyzing the potential of natural ventilation strategies to enhance the thermal quality of the indoor 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 roof ventilation concepts on the indoor environment as a strategy to optimize airflow and heat release in residential buildings in hot-humid climates will be investigated by numerical simulation using computational fluid dynamics (CFD) and building energy simulations (BES).

Progress

- Conducting a validation study using the wind tunnel experiment of Ohba et al. (2001) to assess the performance of the CFD approach. (WP 1).

Studying the impact of building height on indoor airflow in isothermal conditions based on the validation study (in progress). (WP 2.1)

- Studying the impact of wind direction on indoor airflow in isothermal conditions (in progress). (WP 2.2).

Dissertations

-

Scientific Publications

-

Project leaders

B. Blocken, T. van Hooff

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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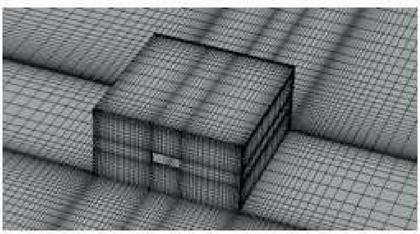

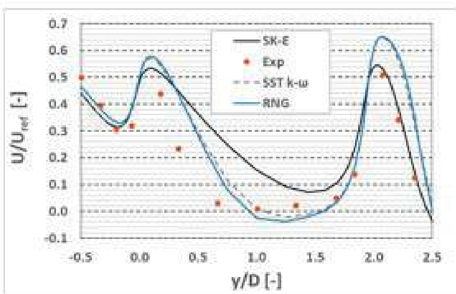

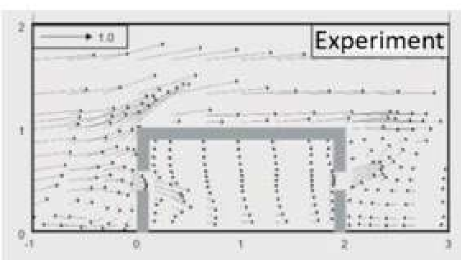

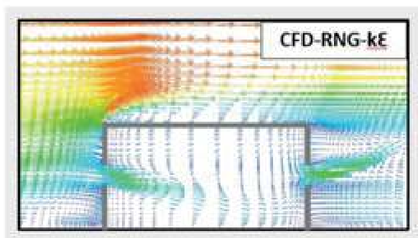

Analysis of wind effects on the performance of industrial ventilation systems

Project leaders
B. Blocken, A. Ricci, R. Guichard (INRS)

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

This project aims at investigating the wind effects on the performance of mechanical ventilation systems used for pollutant containment in asbestos removal worksites. Experimental (wind tunnel) and numerical (Computational Fluid Dynamics, CFD) techniques will be used to evaluate the internal and external wind pressure fields of an isolated building. The experimental and numerical results will be used to validate a network code (SYLVIA) developed by IRSN (French Institute of Radioprotection and Nuclear Safety) in order to predict steady and transient airflows inside industrial ventilation systems.

Progress

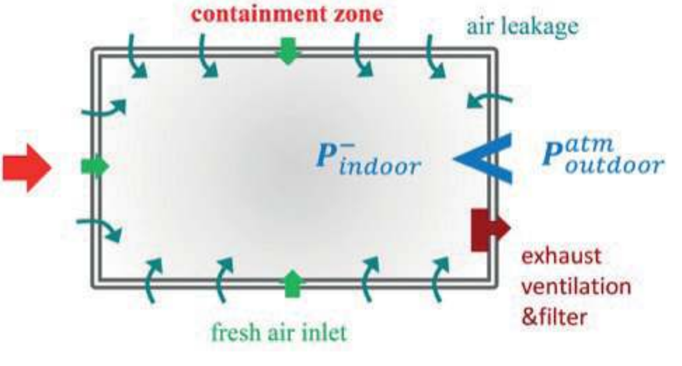
Literature review on the general topics of wind engineering and focusing on wind tunnel experiments, computational fluid dynamics, pressure load actuators and ventilation systems. Also working towards finalizing the research methodology.

Dissertations

-

Scientific Publications

-



Project Aim

The project aim is to obtain fundamental knowledge on the available wind energy potential in the urban environment and to explore possible ways to further enhance the wind energy potential. The objectives of this project are understanding the impact of (i) building arrangement and height; (ii) roof and façade corner shape (e.g. fillet corner); (iii) freestream turbulence and flow angle on the available wind power potential for high-rise buildings in generic dense urban areas.

Progress

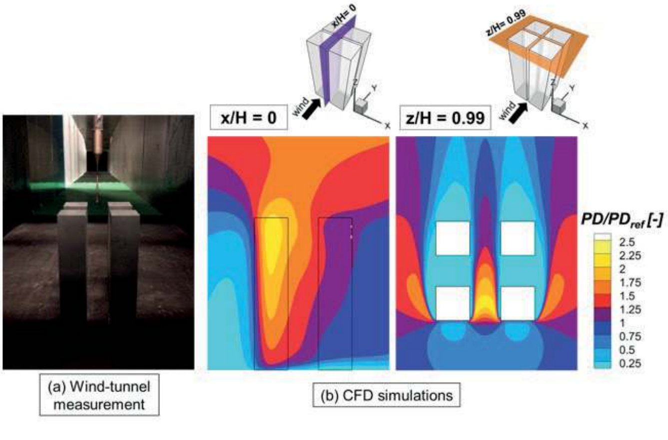
Wind energy potential for a 2×2 array of buildings with 90 m height is investigated. The impact of (i) the distance between the two upstream buildings (D1), (ii) the distance between the upstream and downstream buildings (D2), and (iii) height of upstream buildings (H) on the available wind power potential and the total turbulence intensity between the buildings as well as on their roof is studied using wind-tunnel measurements and steady Reynolds-averaged Navier-Stokes (RANS) simulations. The current results show that the power density between the downstream buildings and on their roof grows by increasing D1 and decreasing H while it remains insensitive to D2.

Dissertations

-

Scientific Publications

1. Juan, Y., Montazeri, H., Blocken, B., & Yang, A-S. (2018). Numerical analysis of urban wind power potential between high-rise buildings: impact of building orientations. 7th International Symposium on Computational Wind Engineering (CWE2018), Republic of Korea.
2. Juan, Y., Wen, C-Y., Yang, A-S., Montazeri, H., & Blocken, B. (2018). Potential wind power utilization in diverging passages between two high-rise buildings: using "Venturi effect" on the windward side. 34th edition of the International Conference on Passive Low Energy Architecture (PLEA2018), Hong Kong.



Project leaders

B. Blocken, H. Montazeri, A-S. Yang (Taipei Tech)

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Y-H. Juan, A. Rezaeiha

Cooperations

Department of Energy and Refrigerating Air-Conditioning Engineering, National Taipei University of Technology, Taipei, Taiwan

Funded by

Marie Skłodowska Curie Fellow on AEOLUS4FUTURE "Efficient Harvesting of the Wind Energy" project

Ministry of Science and Technology, Taiwan, ROC (Contract No. 107-2917-I-027-001

Funded %

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

Start of the project

2018

Information

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(a) Wind-tunnel measurements: a picture of the 2×2 array of building models. CFD simulations: contour plot of power density (PD) non-dimensionalized with PDref (corresponding to z/H = 1 at the inlet) on (b) the vertical streamwise plane between the buildings (x/H = 0) and (c) the roof-height horizontal plane (z/H = 0.99) .

Prediction of vortex-induced vibration on slender structures: the case study of the BARC

Project leaders
B. Blocken, A. Ricci
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Han Huang
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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Project Aim

The wind is one of the most destructive natural phenomena. Its actions can be crucial for the safety and cost of constructions. Slender structures, such as bridges and high-rise buildings, are well-known to be very sensitive to wind effects which may be the cause of dynamic and aero-elastic phenomena (e.g. galloping). In the present project the vortex induced vibration (VIV) for a generic bridge-deck geometry, so-called “BARC” (a Benchmark on the Aerodynamics of a Rectangular 5:1 Cylinder), will be investigated using the Computational Fluid Dynamics (CFD) technique. The results will be validated by means of wind-tunnel results available in literature.

Progress

In a first stage, CFD simulations have been performed on the static bridge-deck model for one angle of attack (i.e. 0°) using the steady-state RANS numerical approach and three different computational grids with different levels of refinement. Hence, a sensitivity-grid analysis has been performed and the results (in terms of drag, lift and pressure coefficient) of the best performing computational grid have been compared to CFD and wind-tunnel results present in the literature. A comparison between the results (in terms of pressure coefficient, Cp) of the current study and the ones presented by Patruno et al. (2016) are reported in Figure 1.

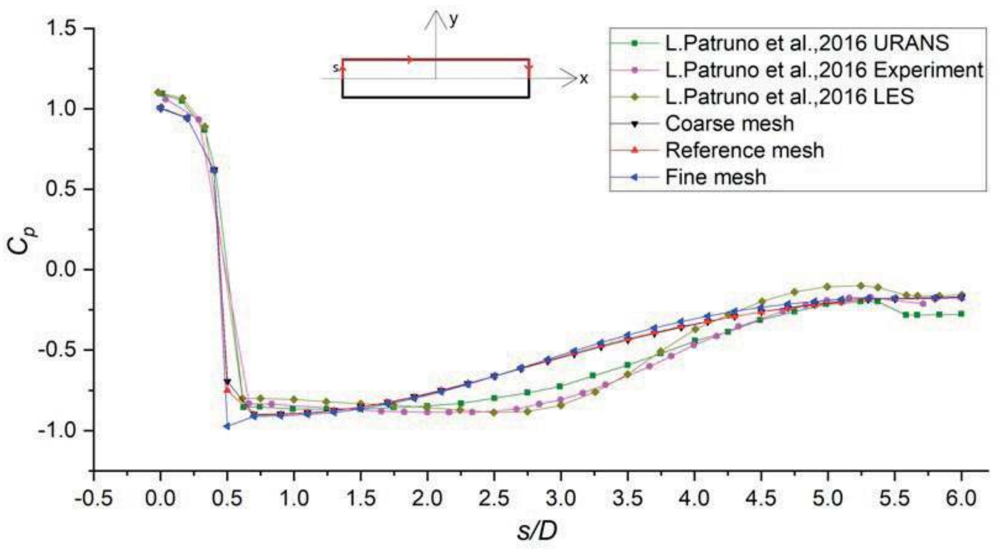
Dissertations

-

Scientific Publications

-

Time-averaged pressure coefficient (Cp) at central section for 0° attack angle.



The dynamics of turbulent impinging jets at high Reynolds numbers with applications to air curtains

Project Aim

In building applications, 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 an easy access of people, vehicles and material between the two environments. The present project strives to optimize the separation efficiency of air curtains by exploring the influence of jet excitation and environmental parameters on the jet and vortex behavior. For that purpose, computational fluid dynamics (CFD) simulations are conducted to analyze the fundamental flow behavior and systematically optimize the performance of an air curtain.

Progress

Quantitative predictions of the flow behavior in an air-curtain system, under different operational conditions, were performed by means of validated Reynolds-averaged Navier-Stokes and large eddy simulations. The jet behavior and vortex dynamics of the air-curtain system were parametrically evaluated and the separation efficiency of the system optimized based on the implementation of temporal and spatial jet excitation techniques. The excitation strategies that yielded the highest system performance were identified and a practical technological design solution was proposed, which is described in detail in the PDEng dissertation.

Dissertations

1. Optimization of air curtain technology through temporal or spatial jet excitation Alanis Ruiz, C.A., 5 Dec 2018, Eindhoven: Technische Universiteit Eindhoven. PDEng thesis.

Scientific Publications

1. CFD analysis of the effect of pressure gradients on the separation efficiency of a generic air curtain. Alanis Ruiz, C.A., van Hooff, T., Blocken, B.J.E. & van Heijst, G.J.F., 2 Jun 2018, Proceedings of Roomvent&Ventilation 2018, Helsinki: REHVA, p. 241-246 6p.

Project leaders

B. Blocken (TU/e, KU Leuven)
T. van Hooff (KU Leuven, TU/e)
G. van Heijst (TU/e)

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

C. Alanis Ruiz

Cooperations

Biddle B.V., ANSYS CFD

Funded by

Eindhoven University of Technology
Biddle B.V.

Funded %

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

Start of the project

2016

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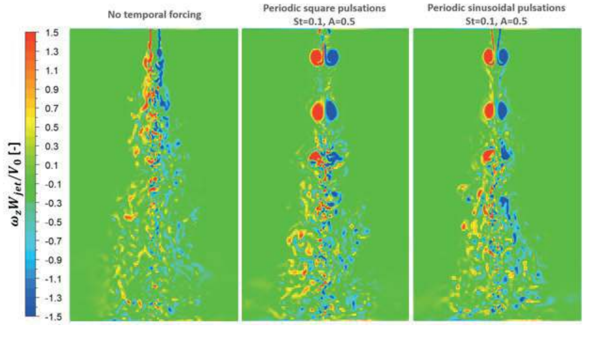
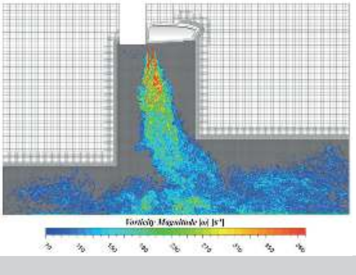


Formation of coherent vortical structures in a jet under temporal excitation (periodic sinusoidal and square pulsations) in comparison with a non-excited jet. Contours represent the normalized z-vorticity.



Representation of the computational grid (LES) and visualization of the turbulent flow structures generated in an air-curtain system by means of isosurfaces of Q-criterion colored by the vorticity magnitude. The air curtain is deflected under cross-jet density gradients.

Cardiovascular biomechanics

Prof.dr.ir. FN van de Vosse

The Cardiovascular Biomechanics group at the department of Biomedical Engineering aims to promote the use of experimentally validated predictive mathematical modeling, both in diagnosis and selection of therapy in clinical practice as well as in research and development in the medical device industry. The research in the group is divided in 4 areas of which the first is embedded in JMBC.

1. Hemodynamics

Hemodynamic factors such as like local pressure, velocity, wall shear stress and wall deformation are crucial for the proper functioning of the vascular system, the heart and its native valves. These factors play a key role in the genesis of vascular disease and, when measured properly, can also be predictive for the development of cardiovascular disease. Hemodynamics research in the group is focused on the development of mathematical models and the corresponding computational methods based on finite and spectral element approximations. These models are used to understand the functioning and response of the cardiovascular system. The models range from 0D lumped parameter and 1D wave propagation models of the entire cardiovascular system to 3D models of local fluid-structure interaction in specific arterial segments and heart valve dynamics. Both microscopic (blood as a suspension) as well as macroscopic (blood-wall interaction) scales are considered. In vitro laboratory experiments and measurement techniques are designed and used to validate the outcome of the computational simulations.

2. Mechanics and adaptation

Cardiovascular mechanics research is focused on the understanding of the mechanical response of vascular and cardiac tissue to mechanical loads, caused by the pulse wave propagation and cardiac contraction, as well as external forces caused by medical interventions.

3. Instrumentation and devices

Medical instrumentation and devices like ultrasound image modalities, pressure and flow sensors, particularly those used for advanced diagnostic measurements.

4. Clinical research

Through pilot or full clinical studies, in which patient data are gathered and used as input for patient specific modelling, evaluation of the predictive value of mathematical models to predict outcome of medical intervention can be performed.

REPORTS OF INDIVIDUAL RESEARCH GROUPS

UNIVERSITY OF TWENTE.

SCIENCE AND TECHNOLOGY (TNW)

Physics of Fluids (TNW-PoF)
Physics of Complex Fluids (TNW-PCF)

CHEMICAL ENGINEERING (CT)

Soft Matter, Fluidics and Interfaces (CT-SFI)

ENGINEERING TECHNOLOGY (CTW)

Engineering Fluid Dynamics (CTW-EFD)
Thermal Engineering (CTW-TE)
Multiscale Mechanics (CTW-TSMSM)
Water Engineering Management (CTW-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, Richard Stevens

Research theme
Complex dynamics of fluids

Participants
Chong Shen Ng, Steven Chong, Vamsi Arza, Xiaojue Zhu, Alexander Blass, Pieter Berghout, Martin Assen, Qi Wang, Farzan Sepahi

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R. Ostilla-Mónico (Houston)
Z. Wan (Hefei),
K.Q. Xia (Hong Kong)
B. Frohnapfel, P. Foroonghi (Karlsruhe)
Y. Wang (Peking)

Funded by
FOM, NWO,
Industry (MCEC), EU (DFG)

Funded %

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

Start of the project
2012

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Project Aim
The project aims at obtaining 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 concerns Taylor-Couette turbulence with rough walls, with either regular rib type roughness or more realistic sand grain type roughness. The second system concerns bubbles in Taylor-Couette turbulence and free convection. The third system is Couette flow with unstable, thermal, stratification. We focus on understanding the dominant mechanisms contributing to the drag and heat transport.

Progress
The Direct Numerical Simulations (DNS) of the respective systems have revealed key mechanisms and flow structures that contribute to drag and heat transport. In particular, it has been shown that rib roughness can lead to the ultimate regime of momentum transport in Taylor-Couette flow. Further, we found that the orientation of the large scale structure in Rayleigh–Bénard flow can be tweaked with ratchet surfaces. Other work focused on the development of more numerical tools to simulate highly turbulent, multiphase, flows.

Dissertations
1. Xiaojue Zhu-'Taylor-Couette and Rayleigh-Bénard turbulence: the role of the boundaries'(Feb 2018).

Scientific Publications
1. X. Zhu, R.A. Verschoof, D. Bakhuis, S.G. Huisman, R. Verzicco, C. Sun, and D. Lohse, Wall roughness induces asymptotic ultimate turbulence, Nature Phys. 14, 417–423 (2018)
2. V. Mathai, X. Zhu, C. Sun, and D. Lohse, Flutter to tumble transition of buoyant spheres triggered by rotational inertia changes, Nat. Commun. 9, 1792 (2018)
3. X. Zhu, V. Mathai, R.J.A.M. Stevens, R. Verzicco, and D. Lohse, Transition to the Ultimate Regime in Two-Dimensional Rayleigh-Bénard Convection, Phys. Rev. Lett. 120, 144502 (2018)
4. H. Jiang, X. Zhu, V. Mathai, R. Verzicco, D. Lohse, and C. Sun, Controlling Heat Transport and Flow Structures in Thermal Turbulence Using Ratchet Surfaces, Phys. Rev. Lett. 120, 044501 (2018)
5. V. Spandan, R. Verzicco, and D. Lohse, Physical mechanisms governing drag reduction in turbulent Taylor–Couette flow with finite-size deformable bubbles, J. Fluid Mech. 849, R3 (2018)
6. Y. Yang, R. Verzicco, and D. Lohse, Two-scalar turbulent Rayleigh–Bénard convection: numerical simulations and unifying theory, J. Fluid Mech. 848, 648–659 (2018)
7. D.J. Krug, X. Zhu, D. Chung, I. Marusic, R. Verzicco, and D. Lohse, Transition to ultimate Rayleigh–Bénard turbulence revealed through extended self-similarity scaling analysis of the temperature structure functions, J. Fluid Mech. 851, R1–R11 (2018)
8. C.S. Ng, A. Ooi, D. Lohse, and D. Chung, Bulk scaling in wall-bounded and homogeneous vertical natural convection, J. Fluid Mech. 841, 825–850 (2018)
9. D. Bakhuis, R. Ostilla-Mónico, E.P. van der Poel, R. Verzicco, and D. Lohse, Mixed insulating and conducting thermal boundary conditions in Rayleigh–Bénard convection, J. Fluid Mech. 835, 491–511 (2018)

10. R.J.A.M. Stevens, A. Blass, X. Zhu, R. Verzicco, and D. Lohse, Turbulent thermal superstructures in Rayleigh-Bénard convection, Phys. Rev. Fluids 3, 041501 (2018)
11. V. Spandan, D. Lohse, M. de Tullio, and R. Verzicco, A fast moving least squares approximation with adaptive Lagrangian mesh refinement for large scale immersed boundary simulations, J. Comput. Phys. 375, 228 – 239 (2018)
12. X. Zhu, E. Phillips, V. Spandan, J. Donners, G. Ruetsch, J. Romero, R. Ostilla-Mónico, Y. Yang, D. Lohse, R. Verzicco, M. Fatica, and R.J.A.M. Stevens, AFiD-GPU: A versatile Navier–Stokes solver for wall-bounded turbulent flows on GPU clusters, Comp. Phys. Comm. 229, 199–210 (2018)

PROJECT LEADERS
Detlef Lohse

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Y. Li, X. Zhu, R. A. Lopez de la Cruz, K. L. Chong, J. Encarnacion Escobar, X. Zhang, C. Diddens

COOPERATIONS
OCE, TUE

FUNDED BY
-

FUNDED %

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

START OF THE PROJECT
2014

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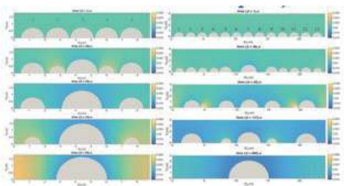

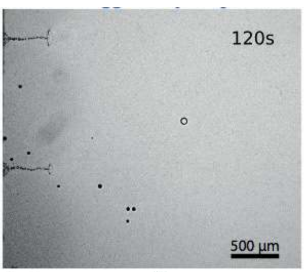

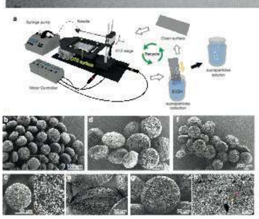

PROJECT AIM
Fill the gap between fluid dynamics and chemical engineering and colloidal & interfacial science by means of quantitatively understand the diffusive droplet dynamics and the fluid dynamics of liquid-liquid (micro)extraction processes. Therefore, to illuminate the fundamental fluid dynamics 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
In progress:

Top figure-Investigated the diffusive interaction of surface nanobubbles (which is closely related to surface nanodroplets).

Middle figure-Study of branch-like droplet formation in a 2D ouzo (water, ethanol, and oil) system triggered by evaporation as opposed to water diffusion as previously done.

Bottom figure-Evaporation-driven particle assembly for supraparticle fabrication. We use ouzo as suspension liquid and produce supraparticles by drying the colloidal ouzo drop on hydrophobic surfaces.

DISSERTATIONS
1. Tan, H. (2018). Evaporation and dissolution of droplets in ternary systems.

SCIENTIFIC PUBLICATIONS
1. Bao, L., Spandan, V., Yang, Y., Dyett, B., Verzicco, R., Lohse, D., & Zhang, X. (2018). Flow-induced dissolution of femtoliter surface droplet arrays. Lab on a Chip, 18(7), 1066-1074.
2. Dyett, B., Hao, H., Lohse, D., & Zhang, X. (2018). Coalescence driven self-organization of growing nanodroplets around a microcap. Soft matter, 14(14), 2628-2637.
3. Dyett, B., Kiyama, A., Rump, M., Tagawa, Y., Lohse, D., & Zhang, X. (2018). Growth dynamics of surface nanodroplets during solvent exchange at varying flow rates. Soft matter.
4. Li, Y., Lv, P., Diddens, C., Tan, H., Wijshoff, H., Versluis, M., & Lohse, D. (2018). Evaporation-triggered segregation of sessile binary droplets. Physical review letters, 120(22), 224501.
5. Peng, S., Spandan, V., Verzicco, R., Lohse, D., & Zhang, X. (2018). Growth dynamics of microbubbles on microcavity arrays by solvent exchange: Experiments and numerical simulations. Journal of colloid and interface science, 532, 103-111.
6. Zhu, X., Verzicco, R., Zhang, X., & Lohse, D. (2018). Diffusive interaction of multiple surface nanobubbles: shrinkage, growth, and coarsening. Soft matter, 14(11), 2006-2014.
7. Encarnación Escobar, J. M., Dietrich, E., Arscott, S., Zandvliet, H. J., Zhang, X., & Lohse, D. (2018). Zipping-Depinning: Dissolution of Droplets on Micropatterned Concentric Rings. Langmuir, 34(19), 5396-5402.

PROJECT AIM

Bubbles generated by exposing liquid-immersed plasmonic nanoparticles to resonant light play an important role in many plasmonic-enhanced processes for catalytic conversion, solar energy harvesting, micro/nanomanipulation, biomedical diagnosis and therapy. In this project we are studying the underlying physics of the phenomenon of bubbles nucleation and growth, by a combination of numerous experimental techniques (high-speed imaging, atomic force microscopy, Raman spectroscopy) and theoretical modeling, in order to optimize this process for various technologically relevant applications.

PROGRESS

The formation of microbubbles upon the irradiation of an array of plasmonic gold nanoparticles with a laser in n-alkanes (CnH2n+2, with n = 5-10) has been studied. Two different phases in the evolution of the bubbles can be distinguished. In the first phase, an explosive microbubble is formed. In the second phase, which sets in right after the collapse of the explosive microbubble, a new bubble forms and starts growing due to the vaporization of the surrounding liquid, which is highly gas rich. The final bubble size in this second phase strongly depends on the alkane chain length.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Y. Wang*, M. Zaytsev*, G. Lajoinie, H. Le The, J. C. T. Eijkel, M. Versluis, B. Weckhuysen, X. Zhang, H. J. W. Zandvliet, and D. Lohse Giant and Explosive Plasmonic Bubbles by Delayed Nucleation, Proc. Natl. Acad. Sci. U. S. A. 2018, 115, 7676-7681.
2. M. Zaytsev, G. Lajoinie, Y. Wang, D. Lohse, H. J. W. Zandvliet, and X. Zhang Plasmonic Bubbles in n-Alkanes, J. Phys. Chem. C, 2018, 122 (49), pp 28375-28381.

PROJECT LEADERS

Detlef Lohse, Harold Zandvliet

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Mikhail Zaytsev

COOPERATIONS

Yuliang Wang (Beihang University)
Xuehua Zhang (University of Alberta)
Thijs Verkaaik (Utrecht University)
Xiolai Li (Beihang University)

FUNDED BY

NWO, TNO, BASF, Albermarle

FUNDED %

University	-
FOM	-
STW	-
NWO Other	49,75 %
Industry	0,5 %
TNO	49,75 %
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2014

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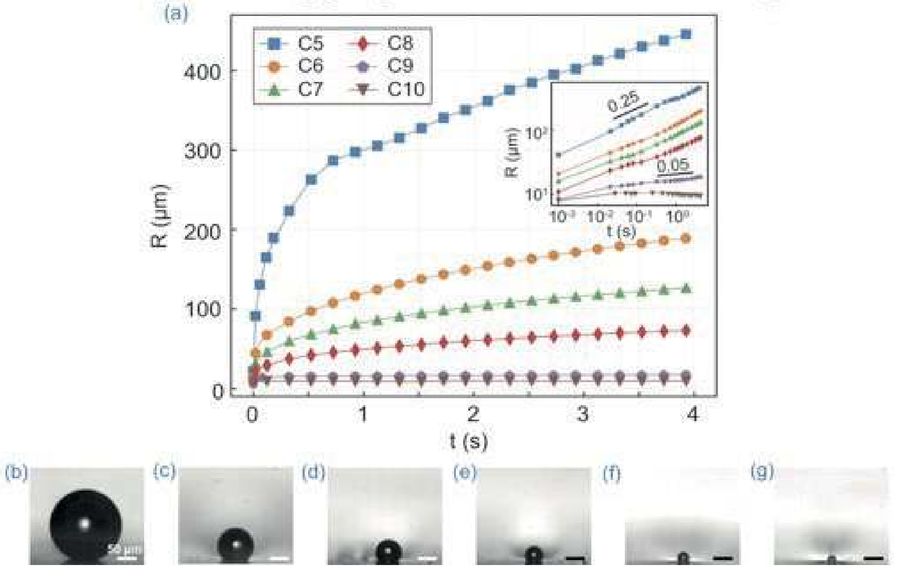

The kinematics of particles with varying forms of anisotropy in turbulent and quiescent fluids

Project leaders
Prof. Chao Sun & Prof. Detlef Lohse
Research theme
Complex dynamics of fluids
Participants
Jelle Will, Varghese Mathai, Dominik Krug, Sander Huisman
Cooperations
NWO-VIDI
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

Particles are present in most common flows found in nature and throughout many industrial applications. These particles are often assumed to be perfect, uniform, spheres; which in most applications is definitely not the case. The anisotropy of the particles can affect the particle dynamics and kinematics in surprising and sometimes useful ways. It is possible to create inhomogeneous particle distributions, create additional mixing, or try to affect turbulence at its core. In this project we aim to study these phenomena, and understand the underlying mechanisms that induce this interesting behavior.

Progress

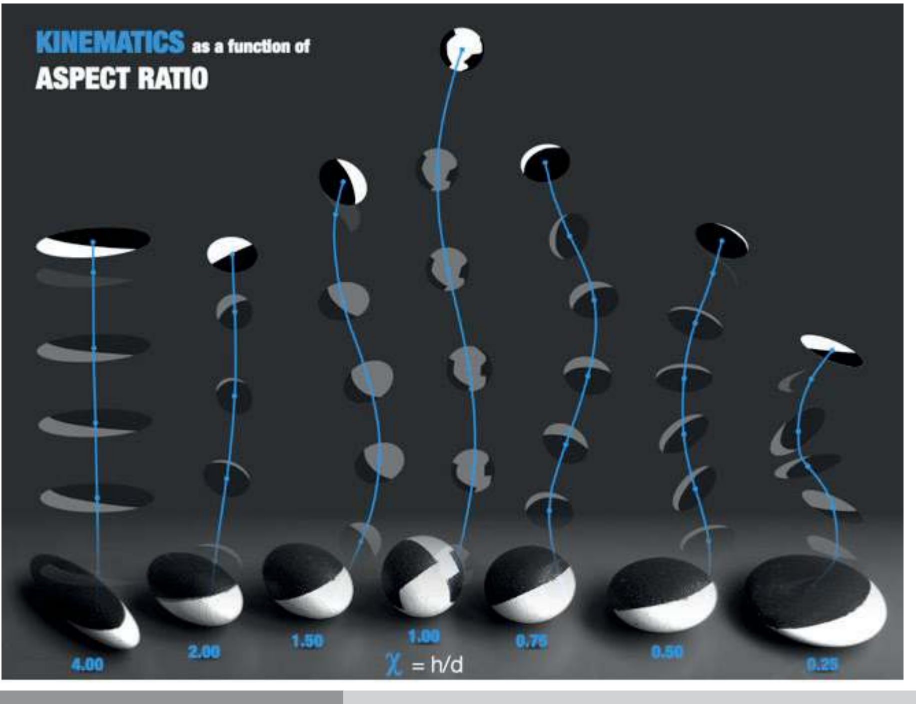
The effect of particle geometric anisotropy has been studied for buoyant ellipsoids freely-rising in a quiescent fluid. The rising mode was found to have a very strong dependence on the particle geometry, we managed to define different regimes and characterize them. Particle drag is also strongly affected, which can not simply be explained by the increase in cross sectional area. Further, work has started on Chiral particles, investigating their dynamics and kinematics but also their effect on the flow; inducing additional mixing. For these complex particles an algorithm has been developed to do full 3d tracking of both translation and rotation.

Dissertations

-

Scientific Publications

1. Mathai, V., Zhu, X., Sun, C., & Lohse, D. (2018). Flutter to tumble transition of buoyant spheres triggered by rotational inertia changes. Nat. Comm., 9(1), 1792.



Project Aim

Skin drag reduction in the naval transport, being the largest carrier of freight in the world, is of large environmental importance as this drastically reduces the fuel consumption. The practical concept is to create air lubrication alongside the hull of the ship, by injecting bubbles into the boundary layer. Several laboratory experiments easily result in drag reductions of 20% and above. However, application on real life ships barely results in 5%. A solid understanding of the bubble mechanism leading to drag reduction is still missing. To investigate the mechanism behind bubbly skin drag reduction, our group has designed two state-of-the-art turbulent two-phase Taylor-Couette setup. Two independently rotating cylinders, with a fluid in between the gap, comprise a closed and energy balanced system. At constant angular rotation rates and constant fluid temperature, one only has to measure the torque that the fluid exerts onto the cylinder's wall to get to the drag coefficient. We have the opportunity to study both global and local properties of the flow.

Progress

In 2018, we have successfully conducted the boiling experiments in the BTTC setup and the manuscript is currently under review. Using the T3C we performed measurements using mixtures of oil and water between 0 and 100% oil volume fraction. These measurements showed that drag reduction can occur for large non-deformable droplets and vanishes after phase inversion when these droplets are much smaller and non-deformable. In another project we varied the roughness pattern in the stream-wise direction. Changing the periodicity of these roughness bands, we are able to control the secondary flows. We studied the effect of a superhydrophobic membrane on the skin friction of the TC setup and found that two effects are competing. Air in the membrane allows for more slip and therefore decreases the drag, while for higher Reynolds numbers, the roughness of the membrane is of a similar size as the smallest flow structures and we see a drag increase.

Dissertations

1. Affecting drag in turbulent Taylor-Couette flow - by Ruben Verschoof, PhD thesis.

Scientific Publications

1. X. Zhu, R.A. Verschoof, D. Bakhuis, S.G. Huisman, R. Verzicco, C. Sun, and D. Lohse Nature Phys. 14, 417–423 (2018)
2. R.A. Verschoof, D. Bakhuis, P.A. Bullee, S.G. Huisman, C. Sun, and D. Lohse J. Fluid Mech. 851, 436–446 (2018)
3. D. Bakhuis, R.A. Verschoof, V. Mathai, S.G. Huisman, D. Lohse, and C. Sun J. Fluid Mech. 850, 246–261 (2018)
4. R.A. Verschoof, A.K. te Nijenhuis, S.G. Huisman, C. Sun, and D. Lohse J. Fluid Mech. 846, 834–845 (2018)
5. R.A. Verschoof, D. Bakhuis, P.A. Bullee, S.G. Huisman, C. Sun, and D. Lohse Int. J. Multiphase Flow 105, 264–273 (2018)
6. R.A. Verschoof, X. Zhu, D. Bakhuis, S.G. Huisman, R. Verzicco, C. Sun, and D. Lohse Eur. Phys. J. E Soft Matter 41, 125 (2018)
7. R. Ezeta, S.G. Huisman, C. Sun, and D. Lohse J. Fluid Mech. 836, 397–412 (2018)
8. D. Bakhuis, R. Ostilla Mónico, E.P. van der Poel, R. Verzicco, and D. Lohse J. Fluid Mech. 835, 491–511 (2018)

Project leaders
Chao Sun, D. Lohse, Sander G. Huisman

Research theme
Complex dynamics of fluids

Participants
Dennis Bakhuis, Ruben Verschoof, Rodrigo Ezeta, Pim Bullee

Cooperations
Damen Shipyards, Marin, Akzonobel, Shell,

Funded by
NWO, FOM, STW

Funded %

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

Start of the project
2011

Information
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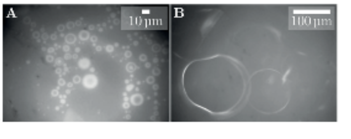
http://pof.tnw.utwente.nl/research/turbulencebubbles/bubbledragreduction

A) Oil droplets in water and B) water droplets in oil. Water droplets are much larger and therefore, more deformable. We expect this to be the key parameter for drag reduction



Transporting gas away from a catalyst surface

Project leaders
Detlef Lohse, Devaraj van der Meer
Research theme
Complex dynamics of fluids
Participants
Álvaro Moreno Soto, Pablo Peñas
Cooperations
-
Funded by
MCEC - NWO
Funded %

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

Start of the project
2015
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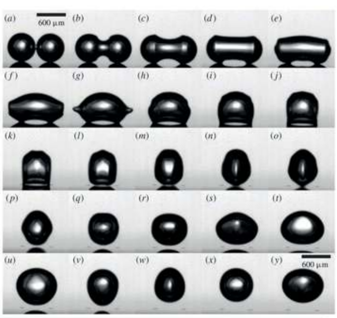

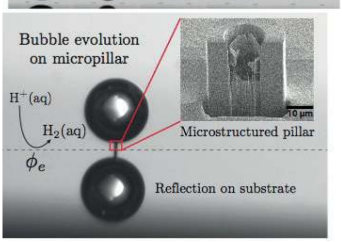

Project Aim

There is a substantial and increasingly important class of processes where a gaseous reaction product is produced on a catalyst surface in a liquid. In this project we want to study new ways of transporting gas away from the catalyst surface by (i) controlling the bubble size, (ii) enhancing bubble nucleation and growth and (iii) controlling the fluid flow using bubble detachment and buoyancy. We will study how isolated bubbles grow in confinement, how they detach, and how much fluid they are able to advect. Next, we will study how ultrasound affect bubble growth and detachment. Finally we will address how bubbles nucleate and grow on a photoelectrolytic surface.

Progress

Three new articles have been published in prestigious journals in the field. The first one deals with the coalescence process that bubbles which are close by may undergo. The analysis of the capillary waves which appear on the bubble surface is essential to understand an earlier potential detachment.

Secondly, two articles regarding bubbles in electrolytic processes have seen the light. One of them focuses on nanobubbles nucleating and blocking the reacting sites, whereas the second focus on the effect that microstructures have on the bubble evolution and final detachment. The outcome presents itself as a first milestone towards novel methods to improve the efficiency of chemical reactions.

Dissertations

-

Scientific Publications

1. Coalescence of diffusively growing gas bubbles, Á. Moreno Soto, T. Maddalena, A. Fraters, D. van der Meer and D. Lohse, J. Fluid Mech. 846, 143-165 (2018)
2. The nucleation rate of single O2 nanobubble at Pt nanoelectrodes, Á. Moreno Soto, S. R. German, H. Ren, D. van der Meer, D. Lohse, M. A. Edwards and H. S. White, Langmuir 34 (25), 7309-7318 (2018)
3. Gas evolution on microstructured silicon substrates, P. van der Linde, P. Peñas-López, Á. Moreno Soto, D. van der Meer, D. Lohse, H. Gardeniers and D. Fernández Rivas, Energy Environ. Sci. 11, 12, 3452-3462 (2018).

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 studied the use of vertical staggering in wind farms using large eddy simulations. We analyzed the effect of the turbine spacing, rotor diameter, and the hub height difference between consecutive downstream turbine rows on the power output. We find that vertical staggering significantly increases the power production in the entrance region of wind farms. Surprisingly, vertical staggering does not necessarily improve the power production in the fully developed wind farm region as the taller turbines capture most flow energy coming from above before it reaches the short turbines. More research on how to obtain the best vertical staggered wind farm designs is required.

Dissertations

-

Scientific Publications

1. L.J. Lukassen, R.J.A.M. Stevens, C. Meneveau, M. Wilczek, Modeling space-time correlations of velocity fluctuations in wind farms, Wind Energy 21, 474–487 (2018).
2. R.J.A.M. Stevens, L. Martinez-Tossas, C. Meneveau, Comparison of wind farm large eddy simulations using actuator disk and actuator line models with wind tunnel experiments, Renew. Energ. 116-A, 470–478 (2018).
3. M. Zhang and R.J.A.M. Stevens, Exploring a better turbine layout in vertically staggered wind farms, J. Phys. Conf. Ser. 1037, 072041 (2018).

Project leaders

Richard Stevens

Research theme

Complex dynamics of fluids

Participants

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Srinidhi Nagarada Gadde
Jessica Strickland
Anja Stieren

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Dennice F. Gayme (Johns Hopkins University, USA)
Michael Wilczek (Max Planck Gottingen, Germany)
Luis A. Martínez-Tossas (NREL, USA)

Funded by

FOM, STW

Funded %

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

Start of the project

2012

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 Cristian C Lalescu and Michael Wilczek, Max Planck Institute for Dynamics and Self-Organization, Gottingen)

Impacting experiments on slippery surfaces: Characterization of their stability

Project leaders
Detlef Lohse, Jacco Snoeijer
Research theme
Complex dynamics of fluids
Participants
Srinath Lakshman
Cooperations
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Beatriz Munoz (University of Seville)
Funded by
EU Marie Sklodowska-Curie
Funded %

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

Start of the project
2018
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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. Present experiments are performed to study the impact dynamics, visualize deformations of lubrication layer, measuring drop spreading and rebounding.

Progress

Figure 1 Impact scenarios. Impact experiments are performed for a water droplet (D = 2.2 mm and v = 0.44 – 2.52 m/s) impacting thin silicone oil films (η = 5 – 12500 cSt and h = 1.5 – 25 μm). For the range of parameters varied, three different impact scenarios are observed, a) Deposition, b) Partial rebound and c) complete rebound. Deposition and partial rebound scenarios are shown in the above figure.

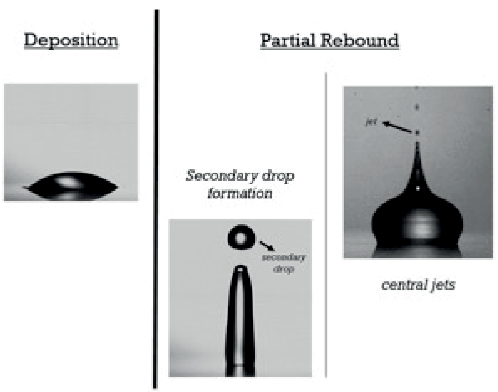
Figure 2 Lubrication deformation and relaxation. Impact experiments are performed for a water droplet (D = 1.25 mm and v = 0.63 – 0.83 m/s) impacting thin silicone oil films (η = 20 – 200 cSt and h = 5 – 15 μm). Drop rebound induces film deformations which is followed by its subsequent relaxation.
The relaxation dynamics is in accordance with the lubrication equation. Initial deformation profiles due to drop impact vary with film thickness and film viscosity; a strong characteristic of the air pressures between the drop and the film. Relaxation of thin film deformations is shown in the above figure..

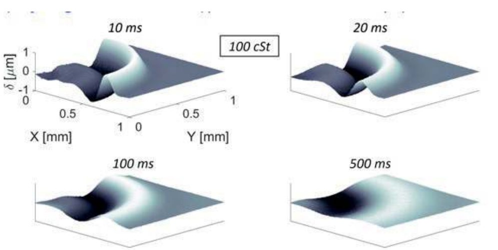
Dissertations

-

Scientific Publications

-





Project Aim

In this project we want to experimentally analyze and understand the properties and dynamics of surface nanobubbles and surface nanodroplets, using ultrafast imaging, AFM, and in-situ spectroscopic techniques. On the one hand, we aim to achieve at single nanobubble and single nanodroplet spectroscopy. On the other hand we want to understand collective effects of surface nanobubbles and surface nanodroplets, in particular the Ostwald ripening, which is related to their size distribution, surface coverage, and spatial arrangements.

Progress

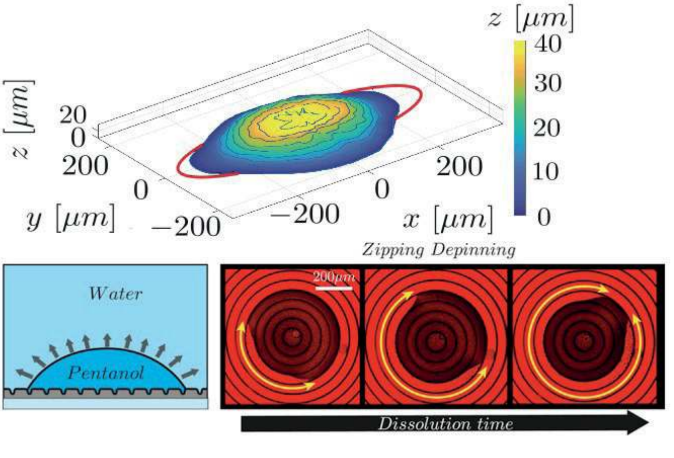
We study the dissolution and evaporation of sessile droplets on complex surfaces as well as the use of in situ optical measurement techniques to reconstruct the whole 3D shape of the droplets taken.

Dissertations

-

Scientific Publications

1. Zipping-Depinning: Dissolution of Droplets on Micropatterned Concentric Rings
José M. Encarnación Escobar, Erik Dietrich, Steve Arscott, Harold J. W. Zandvliet, Xuehua Zhang, and Detlef Lohse. Langmuir 2018 34 (19), 5396-5402 DOI: 10.1021/acs.langmuir.8b00256.
2. Morphology of Evaporating Sessile Microdroplets on Lyophilic Elliptical Patches José Manuel Encarnación Escobar, Diana Garcia-Gonzalez, Ivan Devic, Xuehua Zhang, and Detlef Lohse. Langmuir 2019, 35, 6, 2099-2105. DOI: 10.1021/acs.langmuir.8b03393.



Project leaders

Prof. Detlef Lohse

Research theme

Complex dynamics of fluids

Participants

José Manuel Encarnación Escobar

Cooperations

X. Zhang
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H. Zandvliet
E.S. Kooij
A. van Housselt
Soft Condensed Matter group
University of Utrecht
Physics of Interfaces and Nanomaterials, UT

Funded by

MCEC

Funded %

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

Start of the project

2016

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PROJECT LEADERS
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RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Shuai Li

COOPERATIONS
Shell

FUNDED BY
Shell

FUNDED %

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

START OF THE PROJECT
2018

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PROJECT AIM

A crucial method for marine geophysical survey employs airgun acoustic sources for acoustic wave generation. To extract the relevant information from these data, low frequencies in the 1 Hz regime are crucial, whereas high frequencies beyond 120 Hz are attenuated in the earth. The aim of this project is to optimize the sound emission in the low frequency range using boundary integral method, and to make suggestions on how to achieve this. The work will not be restricted to single bubbles, but we will also analyse bubble clusters and their collective sound emission.

PROGRESS

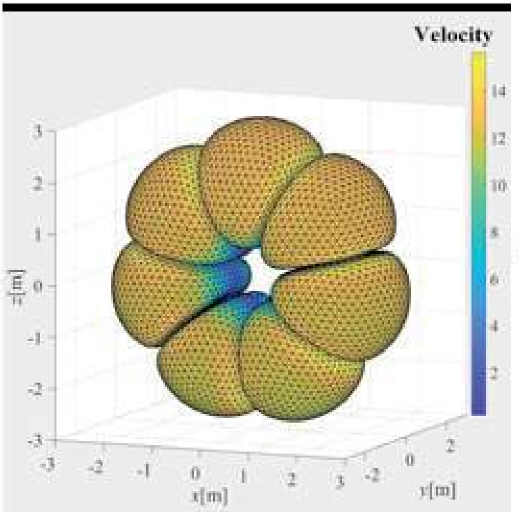
In this project, the boundary integral method is adopted to simulate the airgun bubble motion and sound wave emission, which allows highly non-spherical deformations of the bubble interface. An improved model is proposed to consider the process of air release from the airgun port, which is found to be the most crucial factor to estimate the initial peak of the sound wave. The numerical simulations show good agreement with experiments, in terms of non-spherical bubble shapes and sound waves. Thereafter, the effects of the port opening time Topen, water depth, heat transfer and gravity are numerically investigated.

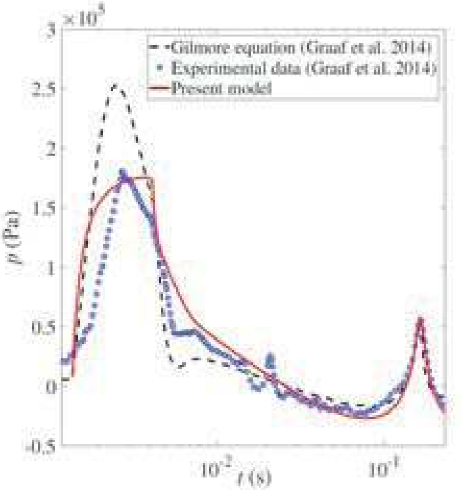
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-





PROJECT AIM

The main scientific goal of the program is to create insight into unresolved issues in the current inkjet process and to improve and extend the functionality of the inkjet printing process 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 over droplet evaporation and absorption processes.

PROGRESS

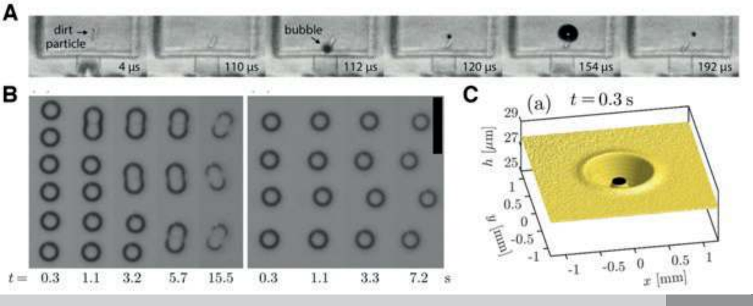
Meanwhile, almost all FIP positions are filled and a lot of related side projects are involved. It has been revealed that particles in the ink induce nozzle failure through bubble nucleation, see Fig. A. Furthermore, the interaction between droplets printed on a thin film were shown to be nonmonotonic due to the droplet-induced wave-like deformation of the thin film, see Fig. B and C. The evaporation dynamics of surfactant laden droplets from hydrophobic surfaces was shown to be governed by substrate wettability modification though surfactant adsorption. Finally, we studied phase segregation in multicomponent droplets during evaporation.

DISSERTATIONS

1. Arjan Fraters, "Inkjet printing: bubble entrainment and satellite formation", University of Twente, Dec 21, 2018.

SCIENTIFIC PUBLICATIONS

1. M. Hack, M. Costalonga, T. Segers, S. Karpitschka, H. Wijshoff & J.H. Snoeijer, Printing wet-on-wet: Attraction and repulsion of drops on a viscous film, Appl. Phys. Lett. 113, 183701 (2018)
2. Y. Li, P. Lv, C. Diddens, H. Tan, H. Wijshoff, M. Versluis & D. Lohse, Evaporation triggered segregation of sessile binary droplets, Phys. Rev. Lett. 120(22):224501, (2018)
3. Q. Xie and J. Harting. From dot to ring: the role of friction on the deposition pattern of a drying colloidal suspension droplet. Langmuir 34, 5303-5311 (2018)
4. O. Aouane, Q. Xie, A. Scagliarini, J. Harting. Mesoscale simulations of Janus particles and deformable capsules in flow, in High Performance Computing in Science and Engineering '17, ed. W. Nagel, D. Kröner, M. Resch, Springer, 369-385 (2018) .



(A) Bubble nucleation on a dirt particle inside a MEMS based piezo-acoustic printhead. (B) The interaction between droplets printed on a thin film nonmonotonic and it is induced by the droplet-induced wave-like deformation of the thin film (C).

PROJECT LEADERS

Detlef Lohse

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Detlef Lohse
Michel Versluis
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Harald van Brummelen
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Tim Segers
Christian Diddens
Arjan Fraters
Michiel Hack
Maaike Rump
Wojtek Kwiecinski
Yaxing Li
Yogesh Jethani

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

START OF THE PROJECT

2017

INFORMATION

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Project leaders
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Research theme
Complex dynamics of fluids
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Cooperations
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Bracco (Geneva)
Nanomi BV (Oldenzaal)
Erasmus MC (Rotterdam)
Oxford University (UK)
Universite de Grenoble (France)
Funded by
Techmed center for personalized medicine
Funded %

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

Start of the project
2015
Information
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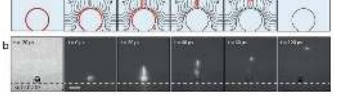
a. Schematics of the release process of a drug payload (red) along the streamlines (solid black lines). b. Experimental recording of the release of the fluorescent material from a microbubble. Scale bar indicates 10 µm



Project Aim
This project aims at developing novel agents as well as novel approaches in order to improve medical imaging and therapy based on ultrasound techniques.

Progress
Major progress has been made on the physical description of the interaction between ultrasound and microbubbles. In particular, we have recently achieved a finer understanding of the bubble coating behavior and of the non-linearities it induces in the bubble response. It has been proposed the base for a novel imaging strategy. In the area of drug delivery, we have explained the mechanisms underlying the controlled delivery of a drug payload with microbubbles, which has been a long-standing puzzle. The potential application of these findings for mixing, enhanced transport as well as their translation to complex, 3D tissue structures are being investigated

Dissertations
-

Scientific Publications
1. Laser-activated microparticles for multimodal imaging: ultrasound and photoacoustics,Visscher, M., Lajoinie, G., Blazejewski, E., Veldhuis, G. & Versluis, M., 29 Jan 2019, In : Physics in medicine and biology.64, 3, 14 p., 034001.
2. Cleaning lateral morphological features of the root canal: The role of streaming and cavitation, Robinson, J. P., Macedo, R. G., Verhaagen, B., Versluis, M., Cooper, P. R., van der Sluis, L. W. M. & Walmsley, A. D., Jan 2018, In : International endodontic journal. 51, S1, p. e55–e64
3. High-precision acoustic measurements of the nonlinear dilatational elasticity of phospholipid coated monodisperse microbubbles, Segers, T., Gaud, E., Versluis, M. & Frinking, P., 1 Jan 2018, In : Soft matter. 14, 47, p. 9550-9561 12 p.
4. Layered acoustofluidic resonators for the simultaneous optical and acoustic characterisation of cavitation dynamics, microstreaming, and biological effects, Pereno, V., Aron, M., Vince, O., Mannaris, C., Seth, A., De Saint Victor, M., Lajoinie, G., Versluis, M., Coussios, C. C., Carugo, D. & Stride, E., 1 May 2018, In : Biomicrofluidics. 12, 3, 034109.
5. Monodisperse Versus Polydisperse Ultrasound Contrast Agents: Non-Linear Response, Sensitivity, and Deep Tissue Imaging Potential, Segers, T., Kruizinga, P., Kok, M. P., Lajoinie, G., de Jong, N. & Versluis, M., Jul 2018, In : Ultrasound in medicine and biology. 44, 7, p. 1482-1492
6. Non-spherical oscillations drive the ultrasound-mediated release from targeted microbubbles, Lajoinie, G., Luan, Y., Gelderblom, E., Dollet, B., Mastik, F., Dewitte, H., Lentacker, I., de Jong, N. & Versluis, M., 31 May 2018, In : Communications Physics. 1, 9 p., 22.
7. Optical verification and in-vitro characterization of two commercially available acoustic bubble counters for cardiopulmonary bypass systems, Segers, T., Stehouwer, M. C., de Somer, F. M. J. J., de Mol, B. A. & Versluis, M., 1 Jan 2018, In : Perfusion. 33, 1, p. 16-24 9 p.

Multiphase flows: the mixing of a scalar field and the kinematics of anisotropic particles with/without incident turbulent flow

Project Aim

Particles are present in most common flows found in nature and throughout many industrial applications. These particles are often assumed to be perfect, uniform, spheres; which in most applications is definitely not the case. The anisotropy of the particles can affect the particle dynamics and kinematics in surprising and sometimes useful ways. Apart from solid particles, bubbles can be also be considered as deformable particles. It is possible to create inhomogeneous particle distributions, create additional mixing of a scalar field (e.g. temperature and concentration field), or try to affect turbulence at its core. In this project we aim to study these phenomena, and understand the underlying mechanisms that induce this interesting behavior.

Progress

The effect of particle geometric anisotropy has been studied for buoyant ellipsoids freely-rising in a quiescent fluid. The rising mode was found to have a very strong dependence on the particle geometry, we managed to define different regimes and characterize them. Particle drag is also strongly affected, which cannot simply be explained by the increase in cross sectional area. Further, work has started on Chiral particles, investigating their dynamics and kinematics but also their effect on the flow; inducing additional mixing. For these complex particles an algorithm has been developed to do full 3d tracking of both translation and rotation. For the particles being bubbles rising with high particle Reynolds number, it was found out that the dimensionless global heat transport was enhanced with the gas volume fraction in vertical convections. For inhomogeneous bubbly flow, for low void fraction, heat transport was enhanced compared to homogeneous bubbly flow because of the mixing enhanced by large-scale recirculation of bubbles; but for high void fraction, heat transport enhancement was reduced due to the mixing competitions with shear-induced turbulence at the shear layer between bubbly column and quiescent liquid region.

Dissertations

-

Scientific Publications

1. Mathai, V., Zhu, X., Sun, C., & Lohse, D. (2018). Flutter to tumble transition of buoyant spheres triggered by rotational inertia changes. Nat. Comm., 9(1), 1792.
2. Mathai, V., Huisman, S.G., Sun, C., Lohse, D. & Bourgoin, M. (2018). Dispersion of Air Bubbles in Isotropic Turbulence. Phy. Rev. Lett. 121, 054501.
3. Gvozdić, B., Alméras, E., Mathai, V., Zhu, X., van Gils, D.P.M., Verzicco, R., Huisman, S.G., Sun, C. & Lohse, D. (2018). Experimental investigation of heat transport in homogeneous bubbly flow. J. Fluid Mech. 845, 226-244.
4. Gvozdić, B., Dung, O.-Y., Alméras, E., van Gils, D.P.M., Lohse, D., Huisman, S.G. & Sun, C. (2019). Experimental investigation of heat transport in inhomogeneous bubbly flow. Chem. Eng. Sci., 198, 260-267.
5. Gvozdić, B. (2018). Bubbly turbulence with heat transfer. PhD thesis. University of Twente.

Project leaders
Prof. Chao Sun & Prof. Detlef Lohse

Research theme
Complex dynamics of fluids

Participants
Jelle Will, On-Yu Dung, Biljana Gvozdić, Varghese Mathai, Dominik Krug, Sander Huisman

Cooperations
-

Funded by
-

Funded %

University	-
FOM	-
STW	-
NWO Other	66 %
Industry	33 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017

Information
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Left: Kinematics of ellipsoidal particles as a function of aspect ratios. Right: inhomogeneous bubbly column in the vertical convection cell (left wall would be heated and right wall would be cooled when heat transport measurements were performed).

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
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Cooperations
Rijnstate hospital Arnhem
Erasmus medical center
Funded by
University, Industry, NWO
Funded %

University	20 %
FOM	-
STW	30 %
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2013
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Project Aim

A large number of clinical studies report about the performance of endovascular stent placement. However, they don't take into account the 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 enhance planning of 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 relevant for clinical planning and surveillance.

Progress

After proving feasibility in healthy volunteers (Figure 1) two clinical trials have been initiated. The main goal is to investigate the feasibility of our echoPIV technique in a real world patient population. The second goal is to study if the echoPIV tool can be used to reveal the link between blood flow perturbations and stent failure and/or disease progression. Furthermore, projects were initiated to validate the echoPIV technique with gold standard laser PIV measurements. Laser PIV measurements were used to capture the hemodynamics in flow dividers, used for popliteal aneurysm treatment. The purpose was to investigate the effect of 1 vs. 2 stents.

Dissertations

-

Scientific Publications

1. Engelhard S, Voorneveld J, Vos HJ, Westenberg JJ, Gijsen FJ, Taimr P, et al. High-frame-rate contrast-enhanced US particle image velocimetry in the abdominal aorta: first human results. Radiology. 2018;289(1):119-25.
2. Holewijn S, van der Velde L, van Helvert M, Urgert T, Buitenhuis G, Jebbink EG, et al. Validation of synthesized central pressure waveform in Patients with an infrarenal aortic aneurysm before and after endovascular repair. Artery Research. 2018;24:82-3.
3. Hoving AM, Voorneveld J, De Vries EE, Jebbink EG, Versluis M, Bosch JG, et al., editors. In vitro high-frame-rate contrast-enhanced ultrasound particle image velocimetry in a carotid artery stent. Medical Imaging 2018: Ultrasonic Imaging and Tomography; 2018: International Society for Optics and Photonics.
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5. Taeymans K, Jebbink EG, Holewijn S, Martens JM, Versluis M, Goverde PC, et al. Three-year outcome of the covered endovascular reconstruction of the aortic bifurcation technique for aortoiliac occlusive disease. Journal of vascular surgery. 2018;67(5):1438-47.
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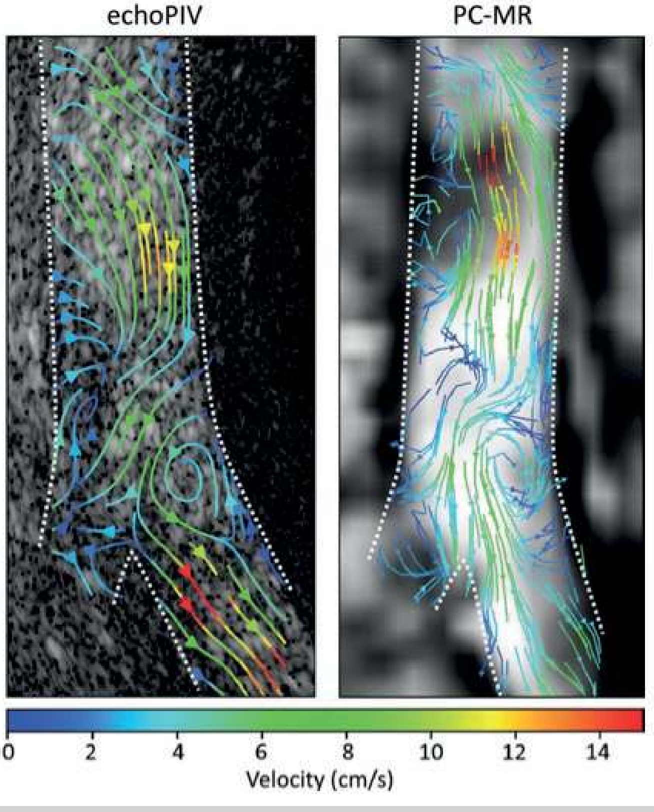
9. Voorneveld J, Engelhard S, Vos HJ, Reijnen MM, Gijsen F, Versluis M, et al. High-Frame-Rate Contrast-Enhanced Ultrasound for Velocimetry in the Human Abdominal Aorta. IEEE transactions on ultrasonics, ferroelectrics, and frequency control. 2018;65(12):2245-54.

Streamline representation of blood flow velocities during early diastole in participant 7. Similar flow patterns can be observed in both data sets, including a slow (counterclockwise) recirculation zone near the origin of the left common iliac artery. This recirculation zone occurred during a longer time period in the phase-contrast MRI (PC-MR) data (five of 30 phases) than in the US particle image velocimetry (echoPIV) data (10–15 msec). Dashed lines show estimated delineation of the vessel wall.1



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
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Project Aim

To understand the role of free surface instabilities in sloshing of liquids close to their boiling temperature.

Progress

We started by simplifying the scenario to that of having a disk impact on water and attempt to understand what happens immediately defore the disk hits on the water surface. We have used mainly experimental, but also analytical and numerical approaches to tackle this problem. Salient achievements are listed below:

1. Development of a new technique “TIR-D” (total internal reflection - deflectometry) to visualise small free surface deformations at the water-air interface

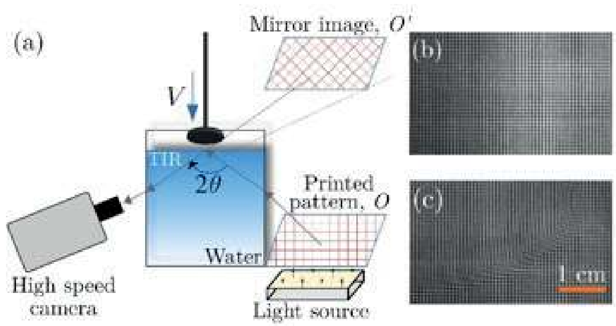
2. New understanding on the air-cushioning effect that occurs immediately prior to the moment of water impact by a solid object. We performed experiments to measure the free-surface deformations caused by rapidly escaping air in the air-cushioning layer. We show that there occurs a Kelvin-Helmholtz instability at the water-air interface, whose features can be analytically estimated. Additional effects are identified and are explained to be a result of Bernoulli suction and interfacial stress distributions known to occur in shear flows over bumpy flexible surfaces.

Dissertations

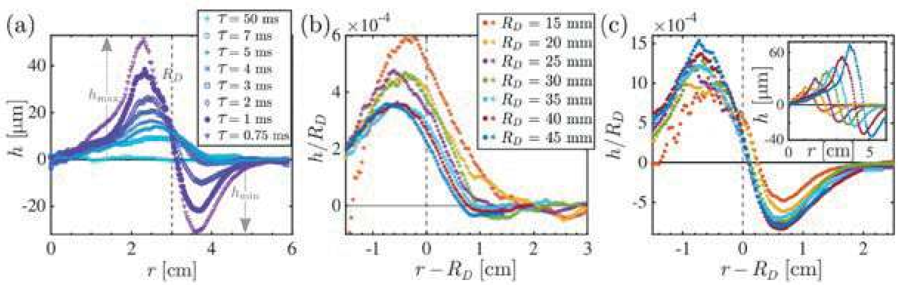
-

Scientific Publications

-



Visualisation method using total internal reflection at the water interface



Radially averaged free surface profiles of water before impact obtained using (a) 60 mm wide disk and (b, c) with a range of disc sizes as shown in the legend

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.

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 found that the wettability of brine droplets can be strongly influenced by small amounts of divalent cations, and carbonate ions, at temperatures above 40°C, with fatty acids in the oil phase. The droplet spread initially, and then retract to contact angles up to 160° over the course of 20 minutes. We investigated the substrate around the droplet after this 'autophobing' process by AFM imaging, and found that organic multilayers of several nm's thickness had been deposited by the moving contact line. We speculate from the observed structures that the layers consist of alternating fatty acids bilayers bound together by CaCO3.

Dissertations

-

Scientific Publications

1. Salinity-dependent contact angle alteration in oil/brine/silicate systems: The effect of temperature; M E.J.Haagh, N Schilderink, M H.G.Duits, I Siretanua, F Mugel, I R Collins; Journal of Petroleum Science and Engineering.

Project leaders

Frieder Mugele

Research theme

Complex dynamics of fluids

Participants

M Haagh, I. Siretanu, MHG Duits, F.Mugele

Cooperations

-

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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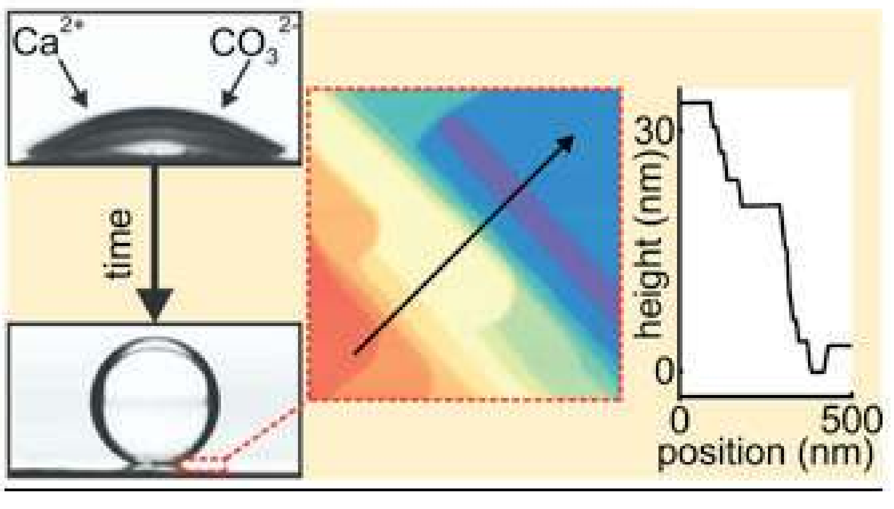

MicroGrease: understanding the relation between the microstructure of lubricating grease and its oil-separation properties

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 correction is implemented to quantify the oil extracted from the grease into the filter paper. It corrects the overestimation of the previous boundary-tracing method (see Fig.1.)

The wetting affinity increases after de-saturation, suggesting that the oil retention increases in the real life where the grease matrix collapses during bleeding (see Fig.2).

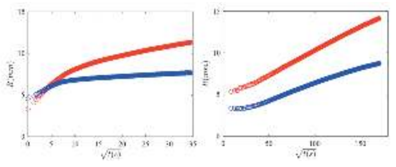
Preliminary experiments were performed to explored the spreading of oil from grease on a flat surface using optical thin film interferometry and preliminary x-ray scattering from the greases (see Fig.3).

Dissertations

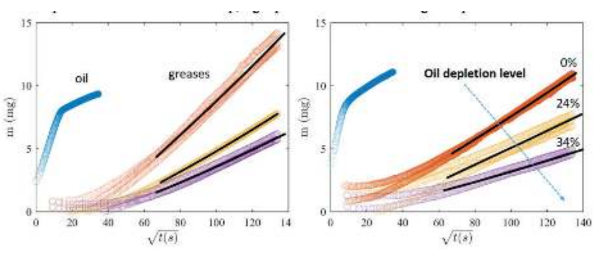
-

Scientific Publications

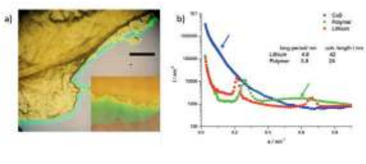
-



Effective radius estimated by boundary-tracing (red) vs. by intensity conversion (blue). Left panel: imbibition of an oil drop; right panel: imbibition from a grease patch.



Spreading of an oil drop vs. grease bleeding. The time scale of grease bleeding is in general much larger than that of oil spreading; grease with more oil depletion bleeds more slowly as compared to the fresh grease.



Optical microscopy image of the edge of a grease patch (yellowish) on a flat silicon wafer with a 300nm silica coating. Greenish halos show an oil layer of nanometric (<100nm) thickness. Main image: after 1week; inset: after 4 weeks of spreading. Note the widened greenish halo. Grease in bearings releases oil for years. Scale bar: approx. 200µm. b) Small angle x-ray scattering data from 3 different types of greases. Peaks in green and red data point to the presence of lamella in both Li- and poly-urea greases with a d-spacing of 4.8 and 3.8nm, respectively and up to ten repeat units. For CaS, WAXS shows the presence of calcite.

Combined microfluidics and Raman platform to study enhanced oil recovery

Project Aim

Understanding the microscopic mechanisms causing the release of oil from rock (as in EOR) presents challenges. Exposure of the rock to the flooding water causes a wettability alteration, but the role of specific chemical species herein, and the ensuing changes in the 3D distribution of water and oil remain elusive. We aim to develop a platform combining a microfluidic device (i.e. a model rock pore) with confocal Raman microscopy, to provide such chemical and spatial resolution, and use it to screen various waterflooding parameters that influence oil recovery.

Progress

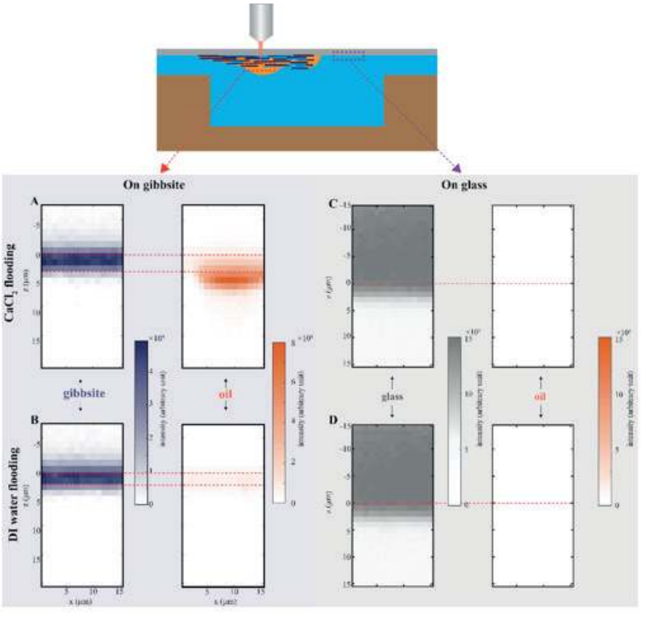
The combined microfluidics and Raman platform has been built. The applicability is verified in a model system. In our results (Fig. 1), we found that oil (mineral oil) containing a fatty acid (1 mM stearic acid), preferentially adsorbs on the gibbsite, as opposed to the absence of oil on glass. This indicates that the presence of clay is important for low salinity EOR. Furthermore, we found that removal of the divalent cations by subsequent flooding with deionized water leads to release of the oil droplet on gibbsite. This finding is consistent with the Multi-Ion-Exchange mechanism. These results were recently summarized and submitted to a journal for publication.

Dissertations

-

Scientific Publications

1. Jun Gao, Sachin Nair, Michel H. G. Duits, Cees Otto, Frieder Mugele Confocal Raman imaging for the development of a rock-on-a-chip, poster presented at Physics@Veldhoven 2018.



Project leaders

Frieder Mugele, Michel H. G. Duits, Cees Otto

Research theme

Complex dynamics of fluids

Participants

Jun Gao, Sachin Nair

Cooperations

-

Funded by

BP and NWO

Funded %

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

Start of the project

2017

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PROJECT LEADERS
Frieder Mugele

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Prof. dr. Frieder Mugele, B Ilhan

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 major mechanism behind the discontinuous shear thickening behavior (ie., liquid to solid transition) of colloidal systems. Crucial prospect of this project is to observe the effect of roughness on flow behavior of colloids. Systems 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.

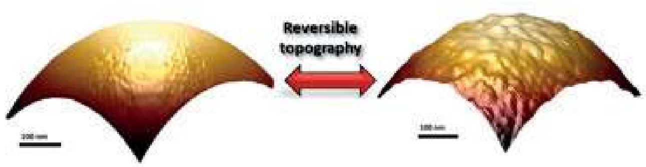
PROGRESS
We have developed a novel method to induce and control nano-scale and reversible roughness on polymer latex colloids Roughness amplitude can be tuned via temperature and repetition of the treatment (Fig.1 and 2).

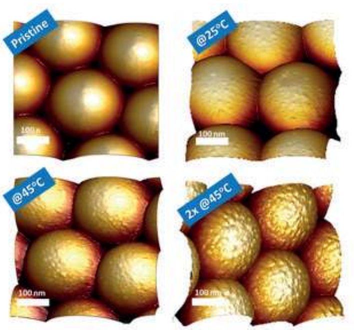
On another line of work, we have produced raspberry-like SiO2 particles(Fig 3 a & b)by making use of hetero-aggregation via electrostatic interactions. Roughness amplitude can be tuned and relatively higher yield of material can be attained compared to existing methodologies. Such particles will be further studied for particle dynamics experiments.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-

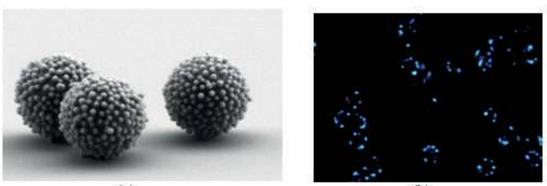
Reversible control over roughness on polymer colloids demonstrated by AFM scans





Control over induced roughness on colloids by different experimental conditions (AFM micrographs of 200 nm sized colloidal particles treated at different conditions)

a) SiO2 raspberry particles. b) Raspberry particles imaged by CSLM



(a) (b)

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

-

PROJECT LEADERS
F Mugele

RESEARCH THEME
Complex structures of fluids

PARTICIPANTS
Simone van Lin

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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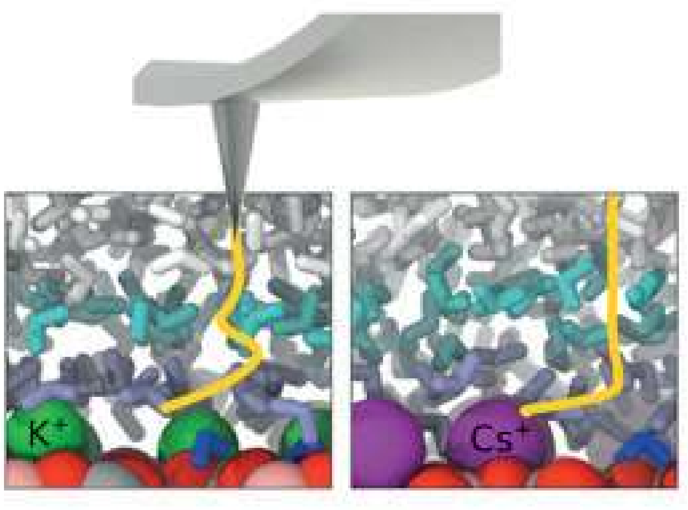

Distribution of inorganic and organic matter at solid-electrolyte interfaces studied by confocal Raman microscopy

Project leaders
Prof. Dr. Frieder Mugele
Prof. Dr. Cees Otto

Research theme
Complex dynamics of fluids

Participants
Sachin Nair

Cooperations
-

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 Aim

Goal of this project is to provide lateral maps of the chemical composition of the samples using confocal Raman microscopy to determine a) the distribution of clays, minerals and organic components on heterogeneous natural rock samples, b) the distribution of organic components sticking on/precipitating onto homogeneous and heterogeneous surfaces, and c) distribution of oil in decomposing unstable thin oil films.

Progress

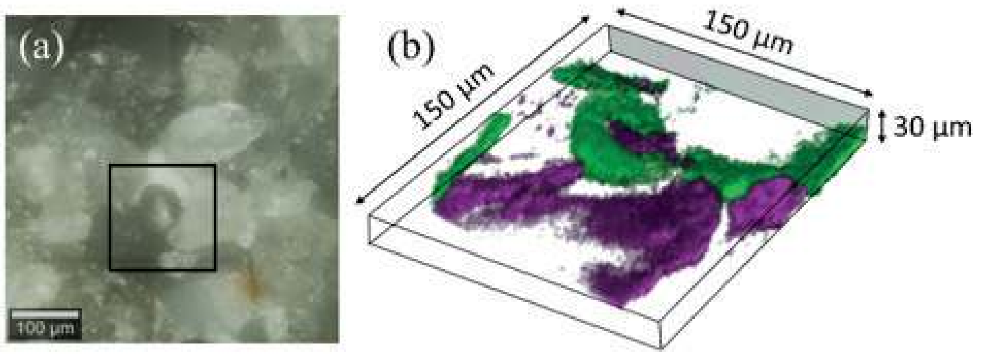
A protocol for increasing the signal-to-noise ratio (SNR) for Raman mapping of 2D materials was developed. The protocol involves using an Electron-multiplying charge coupled device (EMCCD) to collect Raman data, in combination with an efficient denoising technique based on Principal Component Analysis (PCA), to enhance the SNR. An increase in SNR directly translates to faster 3D mapping and thin material detection and mapping, which is important to attain the goals for this project. Rock samples (a – optical and b-3D Raman) and 2D nanosheets were successfully scanned by this method.

Dissertations

-

Scientific Publications

-



PROJECT AIM

Investigate the charge trapping phenomenon in fluoropolymers induced by electrowetting. Explore the possibility of energy harvesting by utilizing the trapping charge in fluoropolymers.

PROGRESS

The formation of trapped charge triggered by an applied voltage at the interface of a screen printed fluoropolymer film and a water droplet was detected and confirmed by Kelvin Probe Force Microscopy measurement. Trapping charges are found highly related with the charging voltage and charging time. An initial trial of energy harvesting shows an promising results.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

Frieder Mugele

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Hao Wu, Frieder Mugele,
Igor Siretanu, Dirk H.T.M Van Den Ende

COOPERATIONS

Guofu Zhou, Lingling Shui

FUNDED BY

South China Normal University

FUNDED %

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

START OF THE PROJECT

2017

INFORMATION

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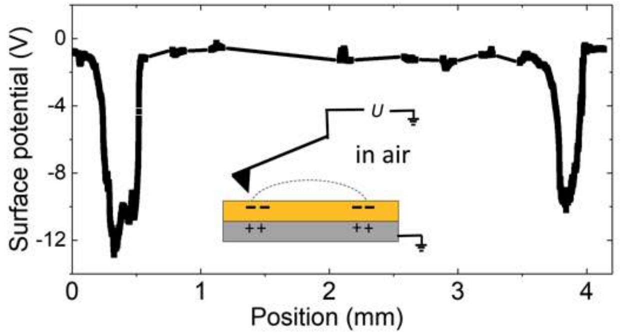
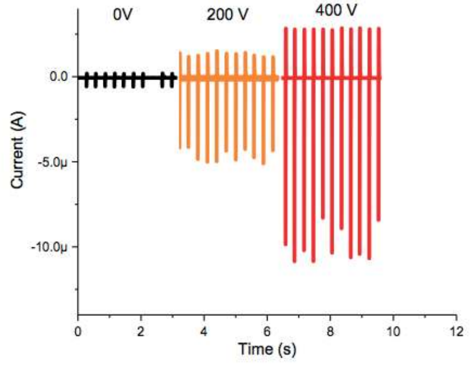
Surface potential measured by Kelvin probe force microscopy of a sample with 0.8 μm thick Teflon film charged by 90V for 5 min.





Initial trial of energy harvesting from water droplet. Current generated from 0.6M NaCl water droplet with 0V, 200V and 400 V charged Teflon sample. (Volume of water droplet is 17 uL)

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 will be investigated. The challenge is to permeate the dispersed phase (oil droplets) instead of the continuous phase (water). Therefore, oil droplets should come in contact with the membrane. To achieve this goal, an external field, such as electric and acoustic, will be applied. Correspondingly, electrophoretic and acoustophoretic movement of oil droplets will be investigated in details and further application of cross flow electro (or acousto) filtration will be studied.

Progress

We investigated the capability of SLIMs for gravity-assisted permeation of oil from an O/W emulsion. The movement of oil droplets towards the membrane surface was accomplished only by gravity. Our results revealed that by setting the pressure between the entry pressure of oil and that of the surfactant solution, oil can be selectively permeated. At high surfactant concentration water also permeated. The amount of water permeated through SLIM is lower than that through non-infused membranes. This is mainly because of liquid-lining which leads to an additional interface with the oil giving rise to an increase in the overall interfacial energy with the surfactant solution [1].

Dissertations

-

Scientific Publications

1. Bazyar, H., Lv, P., Wood, J. A., Porada, S., Lohse, D., & Lammertink, R. G. H. (2018). Soft Matter. Soft Matter, 14, 1780–1788.

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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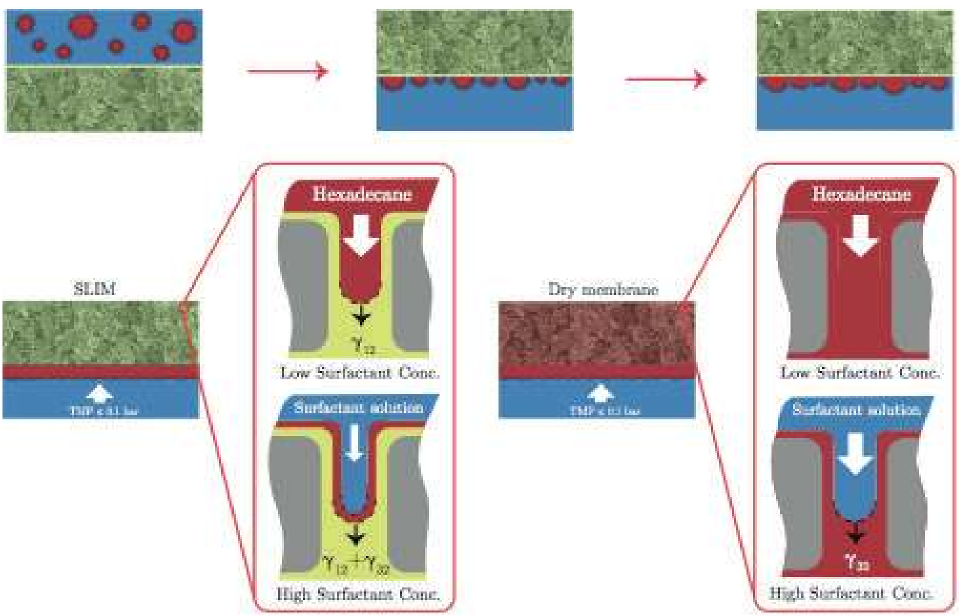

PROJECT LEADERS
Prof.dr.ir. R.G.H. Lammertink
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Abimbola Ashaju
COOPERATIONS
-
FUNDED BY
NWO
FUNDED %

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

START OF THE PROJECT
2017
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PROJECT AIM

Boundary layer is a common feature within Solid/Liquid interface that is central to many engineering efforts involving process intensification, chemical conversions and separations, and it acts to limit mass transport affecting negatively production output, time and energy. This project aims at exploring surface reaction driven flow that affect mass transport.

PROGRESS

The catalytic current arising from an electrochemical reaction at different metas (peroxide at Au and Pt) was measured experimentally and analyzed with TAFEL curves (fig a). The ionic flux stemming from the production and consumption of protons at the electrode surfaced has been profiled using fluorescence lifetime imaging (fig b) and showed significant agreement with numerical simulations. The surface induced convective fluid flow has been visualized using tracer particles towards studying the flow directionality and magnitude. Zeta potential for individual metals were measured and incorporated into existing numerical models to complete the actuation of the electrokinetic process (fig c).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

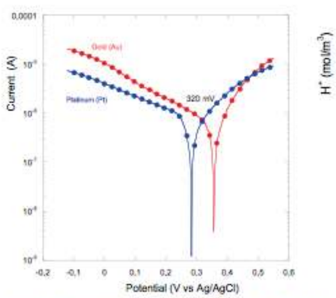

Fig (a) Tafel curves for Pt and Au electrodes in 4% H_2O_2

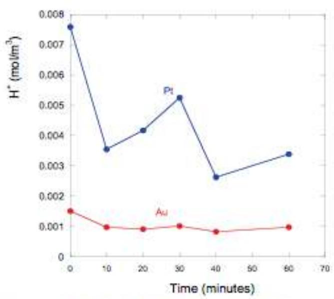

Fig (b) Proton concentration profile

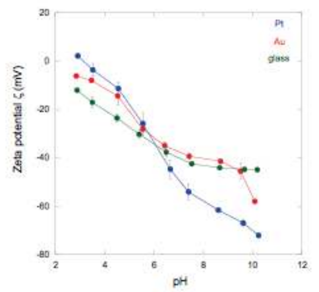

Fig (c) Measured zeta potential for platinum, gold and glass

Project Aim

Diffusio-osmosis flow is a 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. We numerically study a wide variety of parameters, indicating the impact of diffusio-osmosis. On experimental basis is the goal to show if and when the diffusio-osmosis enhances product conversion for different parameters and to show the velocity gradients microscopically by combining TIRF with microPIV and FLIM.

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. At first, the influence of the external stimulus is studied, which is still ongoing. Experimental parameters are used as input for a numerical study for broader knowledge about the system.

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

Information

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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
Information
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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 economical 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 at Reynolds numbers between 0.5 and 1.8 million showed enhanced bubbly drag reduction (DR) over a superhydrophobic surface compared to bubbly DR over a hydrophyllic surface. For this effect, a minimum amount of air bubbles in the flow is required. Above a certain limit, a further increase of the amount of air does not lead to more DR. The micrometer lengthscale roughness of the superhydrophobic coating significantly increases the drag when no bubble injection is used. Further studies on the influence of patched roughness on bubbly DR showed bubbles migrating to the location where their effect is highest: at the high shear regions above the roughness.

Dissertations

-

Scientific Publications

-

PROJECT AIM

This research seeks to provide a novel water treatment method, based on 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 elucidated 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

Dead-end filtration and catalysis experiments are in progress to refine the 1D transport model. Different concentrations of methylene blue solution are filtrated through alumina membranes, with a porous titanium dioxide layer under constant UV light irradiation and varying the flows.

The combination of membrane filtration and catalytic oxidation showed a remarkable reduction of the concentration polarization. In the following graph, the experimental data obtain with one membrane are represented with the model predictions for normalize permeate concentration. The model contains the membrane function (rejection, α) and the photocatalytic degradation (reaction, Da) including light distribution.

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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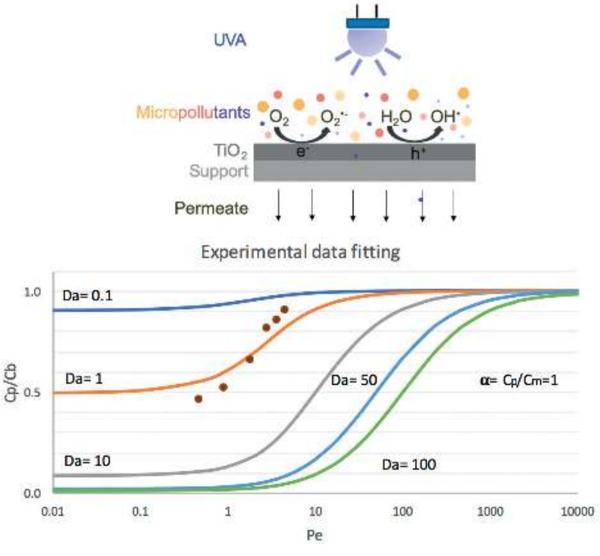
Fig. 1. Graphical abstract (top). Filtration rate vs. concentration under continues UV light irradiation. Model predictions for permeate concentration with experimental data fitting (bottom).
When using lower flows, there is more time for the photocatalytic oxidation to take place and therefore the outlet 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 (NWO-I)
Funded %

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

Start of the project
2016
Information
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Project Aim

Graphene is a single-atom thick sheet of carbon atoms. Being thin and hydrophobic in nature it exerts minimum resistance to the incoming fluid. Theory predicts that graphene has good potential to be used as a membrane material for desalination. In our project, we aim to come up with a novel technique to produce multi-porous graphene membrane which takes care of the intrinsic defects in graphene and also can be used for mass transport. Then we want to explore its filtration property and transport phenomena in details.

Progress

We study the ion transport through a perforated graphene membrane. The membrane is cation selective. When the membrane is placed between two reservoirs containing a high concentration solution in one side and a low concentration solution at the other side, the selectivity varies with the variation of salt concentrations in both the reservoirs. We measure the potential generated due to the cation selectivity of the membrane. When the salt concentration is low the membrane is highly selective to cations and we obtain a high value of membrane potential. With the increase in salt concentrations the membrane potential goes down and the selectivity decreases. This is explained by Teorell, Meyer and Sievers (TMS) theory. The theory describes the membrane potential as a combination of Donnan and diffusion potential. At a very low concentration the potential is high due to the Donnan exclusion of ions and at very low concentration the diffusion potential dominates arising from difference in diffusivities of cation and anions inside the membrane. This study shows how the selectivity of graphene membrane can be tuned with the concentration of the working solution and can be used as an ion exchange membrane for desalination purposes.

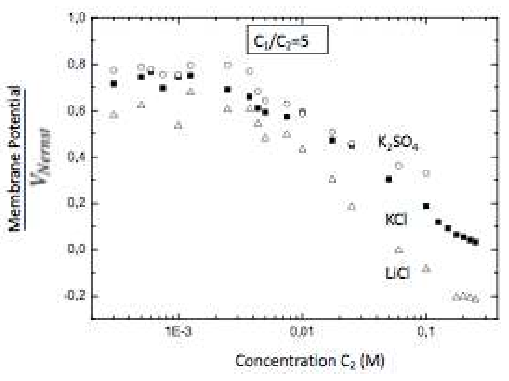
Dissertations

-

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

Membrane Potential vs Concentration



Project Aim

The aim of the project is to study the transport phenomena near heterogeneous interfaces using electro-diffusio-osmotic effects. The surface charge near a solid-fluid interface, e.g. photocatalysts like TiO2, will be explored in relation to reaction induced gradients that drive fluid flow. This would eventually enhance the tranport of different species within the boudary layer, thereby improving the performance, in a fundamentally different manner.

Progress

A steady experimental set up has been built in order to measure the change in surface charge of photocatalytic surfaces during operation. A microfluidic chip was fabricated wherein the microchannels were sputtered with TiO2. Experiments are ongoing to quantify the generation and depletion of charged species by the surface using different electrolytes and organic species. A suitable reaction mechanism will be proposed based on the results.

Dissertations

1. Master thesis: UV irradiation induced transport phenomena near titanium dioxide surface.

Scientific Publications

-

Project leaders

Rob Lammertink

Research theme

Complex dynamics of fluids

Participants

Arputha Paul

Cooperations

-

Funded by

NWO

Funded %

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

Start of the project

2017

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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) is under development. ENFLOW has been extended such that the first and second derivatives of the velocities and temperature can be extracted from the flow solution as well as boundary layer information. The attachment line of the wing is found and integration lines are determined along which the stability code will be used to determine the transition locations. Furthermore, a method for the detection of the maximum laminar extend before laminar separation was selected such that full laminar boundary layer data can be obtained.

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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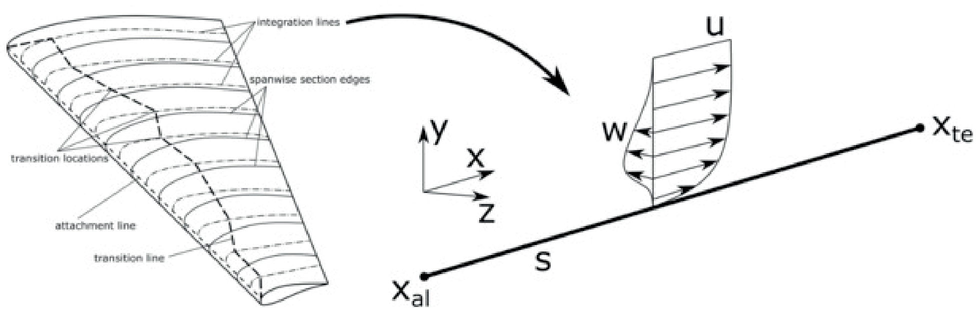
The integration lines on the wing surface and in the COSALX reference frame.



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 incompressible solver of SU2 has been extended to a pressure based solver, which is better suited for the flow around wind turbines than an artificial compressibility density based solver. The solver is currently in the testing phase, showing the expected results.

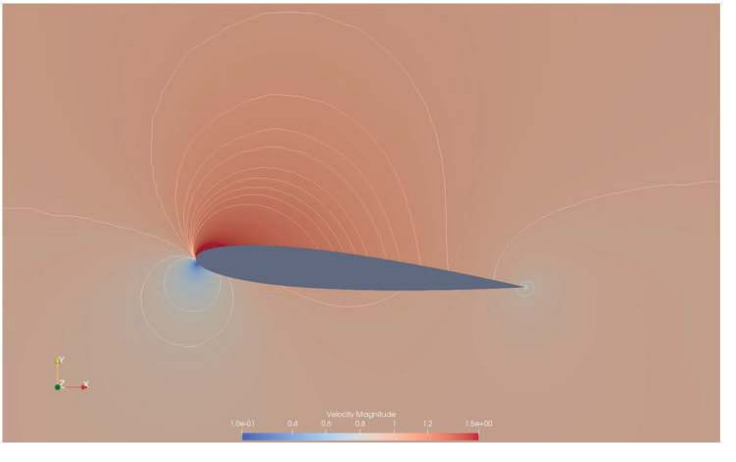
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

The velocity distribution of the inviscid, incompressible flow over a NACA-0012 at 5 degrees angle of attack in a channel with dimensions 20c (length) x 12c (height), where c is the chord length.



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

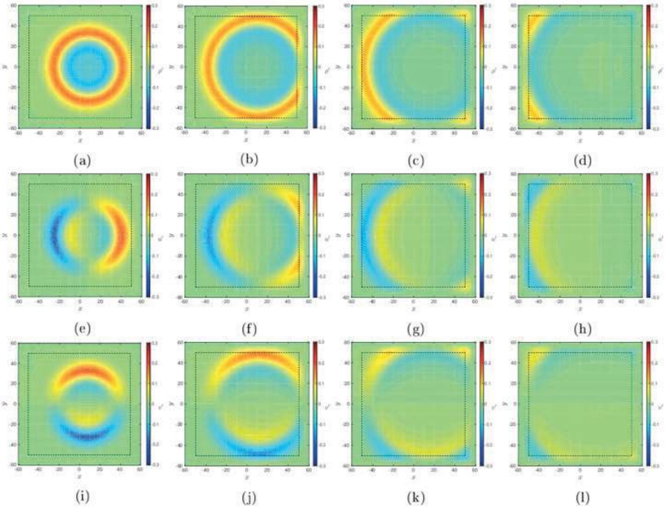
An initial study has been carried out to investigate the working of the Perfectly Matched Layer (PML) approach as a possibility to apply non-reflecting boundary conditions. In this study the dimensionality of the problem has been reduced to 2 and the governing equations simplified to the linearized Euler equations. The spatial discretizations used are a finite difference method and a discontinuous galerkin method, both of high accuracy (up to 6th order). The initial conditions are composed of acoustic, vorticity and entropy waves. The PML method shows promising results for the test cases and will be investigated further for the Navier-Stokes equations.

Dissertations

-

Scientific Publications

-



Propagation of the waves from the physical domain (dotted lines) into the PML layer. 6th order discontinuous galerkin in combination with a 4th order Runge-Kutta time integration scheme.

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	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
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.

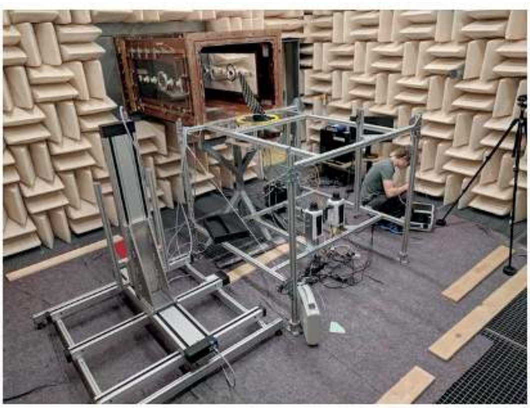
Dissertations

-

Scientific Publications

1. Groot Koerkamp, L.H., 2018, PIV Measurements in the wake of a robotic bird. MSc Thesis, University of Twente, ET, Engineering Fluid Dynamics EFD-287.
2. Gijsman, F., and Hoeijmakers, H.W.M., 2018, Experimental study of flow in wake robotic bird. AIAA 2018 applied aerodynamics conference, Aviation Forum, 2018-3175. https://doi.org/10.2514/6.2018-3175.

Setup of flexible robird flapping wing in windtunnel for PIV measurements



Project Aim

The project aims at designing a device that can be applied to the inner side of the cavity of a passenger car tyre in order to reduce the interior noise of a passenger car.

Progress

Several new concepts to reduce cavity noise have been proposed, analyzed and investigated. The most promising concepts have been experimentally validated. These concepts have been finalized and made ready for production at Apollo Tyres. One of the concepts has been patented and is currently further developed at Apollo Tyres. Project completed in 2018.

Dissertations

1. Goosens, M. 2018, Reduction of Cavity Noise from Passenger Car Tyres. Thesis PDENG.

Scientific Publications

-

Project leaders

Dr. Ir. Y.H. Wijnant, Prof. C.H. Venner

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Ir. Martin Goossens

Cooperations

Apollo Tyres

Funded by

Apollo Tyres

Funded %

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

Start of the project

2016

Information

Dr.ir. YH Wijnant
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(a) SoundComfort technology

(b) Noise Shield technology

(c) Pirelli Noise Cancelling System

(d) ContiSilent

(e) Acoustic Technology

(f) Silent Core

(g) Sound Absorber

Digital MEMS microphones for characterization unsteady wall pressure and noise prediction

Project leaders
L. de Santana, C.H. Venner
Research theme
Complex dynamics of fluids
Participants
M. Sanders
Cooperations
TUDelft
Funded by
University of Twente
Funded %

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

Start of the project
2016
Information
Leandro de Santana
053 489 25 87
leandro.desantana@utwente.nl

Project Aim

The physics of turbulent flow reaching the airfoil trailing edge is fundamental to the understanding of the Turbulent Boundary Layer (TBL) noise production mechanism. The experimental validation of semi-empirical and computational models requires novel experimental techniques to accurately determine the turbulent structures. To experimentally determine the unsteady wall pressure, this research investigates use of digital MEMS microphones embedded in an airfoil. The experimental technique is challenging as sensors and components must be miniaturized to maximize the sensor's spatial resolution.

Progress

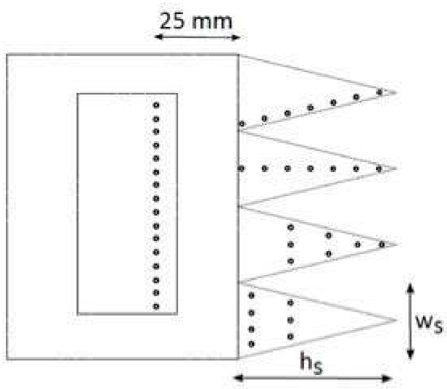
Digital MEMS microphones have been employed in combination with 3D printing techniques for the measurement of unsteady surface pressure fluctuations on a NACA0012 airfoil with 200,000<Re<700,000. Measurements showed that useful information related to the boundary layer characteristics was obtained in despite of the relatively low acoustic overload point of the sensor (120 dB). For higher Reynolds number flow, digital MEMS microphones with an acoustic overload above 130 dB should be used to avoid data clipping. However, some spatial resolution might be lost, making the sensor unsuitable for some applications.

Dissertations

-

Scientific Publications

1. Martinus P.J. Sanders, Leandro Dantas de Santana and Cornelis H. Venner, Unsteady Surface Pressure Measurements on Trailing Edge Serrations Based on Digital MEMS Microphones, 24th AIAA/CEAS Aeroacoustics Workshop, Atlanta/USA, 2018.



Dimensions of the printed circuit boards.


Installed printed circuit boards.

Layout of location of MEMS microphones on airfoil surface and trailing edge serrations (left) and actual serrations with embedded MEMS.

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

-

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

Start of the project

2016

Information

C.H. Venner
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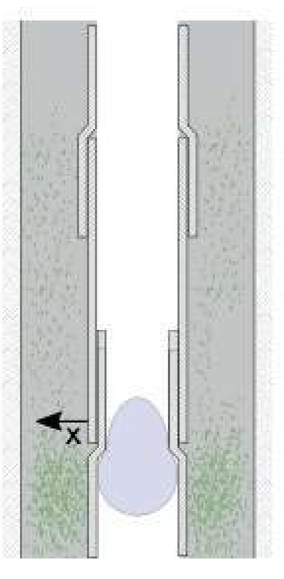
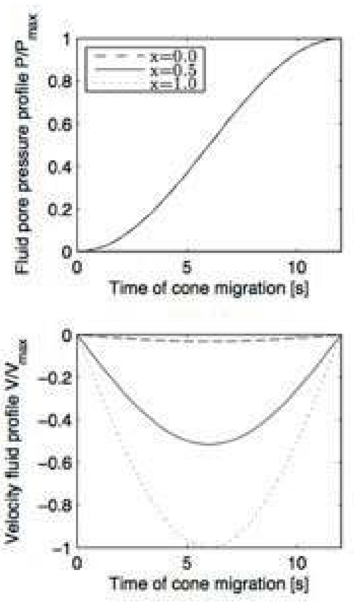
For upward cone migration the cement- and fluid in between the cement along the pipe is compressed. As a result the fluid is displaced towards the interface of cement and oil-pipe, potentially separating the pipeline with its foundation.





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.
FUNDED BY
UT/SKF
FUNDED %

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

START OF THE PROJECT
2007
INFORMATION
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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. Continuation of research on fundamental aspects and friction prediction.

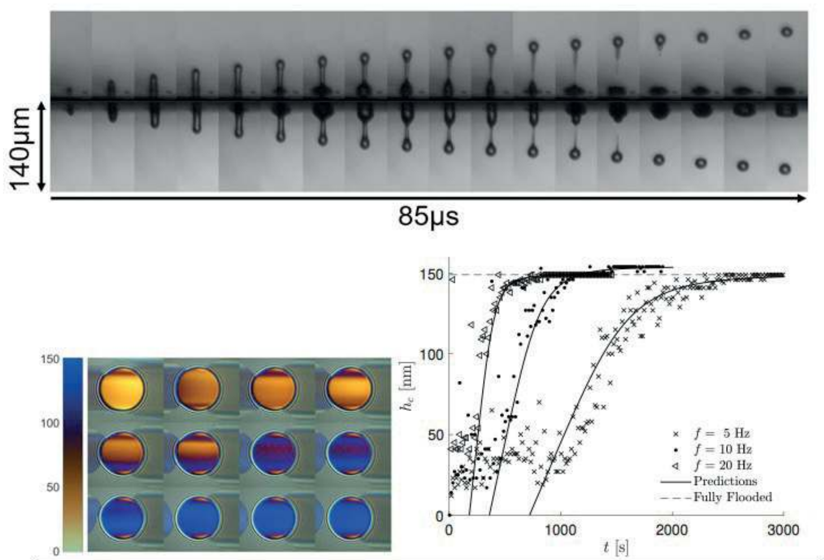
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Lubrecht, A.A., Biboulet, N., Venner, C.H., (2018), Boundary layers: Unifying the impact and rolling EHL point contacts, Tribology International, V. 126, pp. 186-192. doi.org/10.1016/j.triboint.2018.05.019.

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.



Inverse design multilevel panel method for wind turbine rotor flow simulations

Project Aim

Development of a 3D inverse design mode fast multilevel panel method for wind turbine rotor aerodynamics simulations.

Progress

Development of a 3D inverse design method for wind turbine rotor aerodynamics simulations based on a multilevel panel method. A 2D pilot code showed the advantage of using hyper-dual numbers in an analysis-mode boundary element method. With limited modifications the gradients needed in the minimization of the integrated pressure difference objective function could be determined. The method was shown to able to reconstruct an airfoil and its pressure distribution at a selected angle of attack from an arbitrary starting geometry, as well as from a 'laminar flow' target pressure distribution find the geometry that resulted in the smallest difference in pressure distribution.

Dissertations

-

Scientific Publications

1. T.T. Çakir, Dual and Hyper-dual Numbers in Non-Linear Wind Turbine Aerodynamics Simulation Methods, MSc thesis, University of Twente, 2018.

Project leaders

C.H.Venner, A van Garrel

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Dr.ir. A. van Garrel, Prof.dr.ir. C.H. Venner, T.T. Çakir.

Cooperations

-

Funded by

-

Funded %

University	10 0%
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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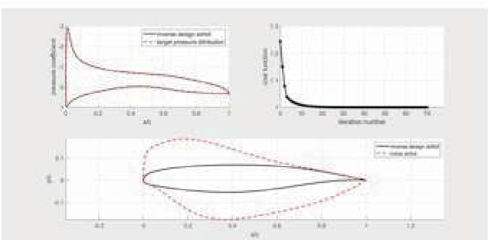
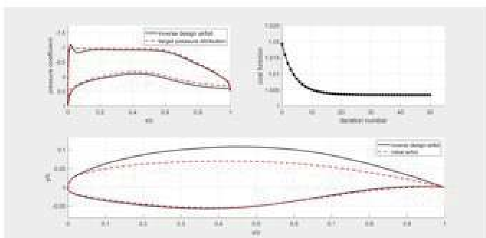
Optimization results of airfoil





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	-
FOM	-
STW	-
NWO Other	-
Industry	10 %
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 2018, the multigrid algorithm used to solve 3D stress field in anisotropic material was further developed so that it can be used to calculate the stress field of anisotropic material with large anisotropy ratio. The next innovative step has been to include the Elastohydrodynamic Lubrication problem as a surface condition. The resulting algorithm is unique in its capabilities. Actual implementation in fatigue life calculations for industrial relevance are realized and yielding results. Publications are in press and preparation.

DISSERTATIONS

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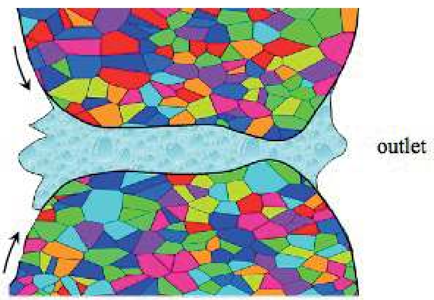
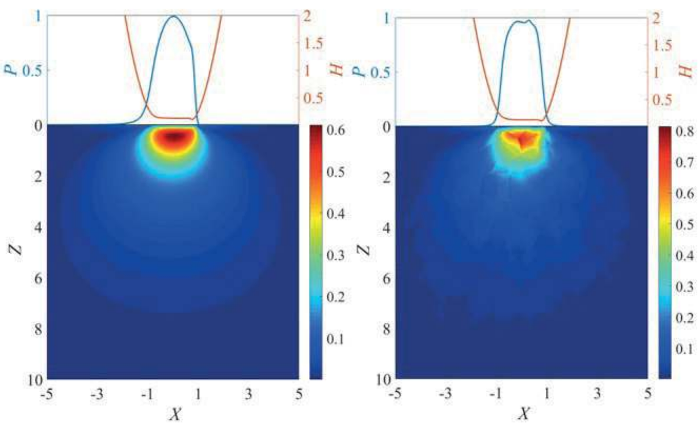
SCIENTIFIC PUBLICATIONS

-



Schematic graph of an EHL lubricated conjunction with anisotropic material



The influence of isotropy and polycrystalline anisotropy material on EHL pressure, film thickness and subsurface Von Mises stress distribution (Newtonian fluid, L=10, M=50)

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.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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

C.H.Venner, HWM Hoeijmakers

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

E.T.A. van der Weide, H.N.J. Dekker, K. Boulognje, S. de Maag

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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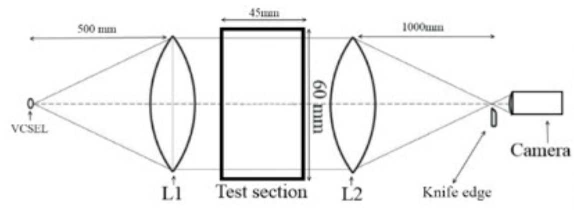

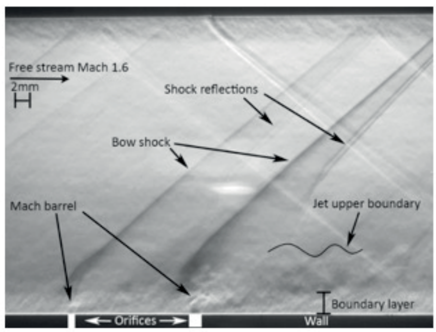

PROJECT LEADERS
Dr. Ir. Y.H. Wijnant
Prof. C.H. Venner

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Ir. Martin Goossens

COOPERATIONS
Apollo Tyres

FUNDED BY
Apollo Tyres

FUNDED %

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

START OF THE PROJECT
2017

INFORMATION
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PROJECT AIM

The project aims to provide a prediction tool for tread pattern induced tyre noise. The focus lies in the prediction in the early stages of the design process and includes the effects of tread pattern and the transmission path to the acoustic domain and the propagation to the far field.

PROGRESS

The models have been implemented. The project is in the validation stage, validating the results of the model with tread pattern noise measurements preformed on the Leuven's LMS/Siemens drum facility.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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

Under liquid laser ablation is a material removal technique in which a focused laser beam passes through a liquid layer on top of the sample to be processed. The efficiency can be optimized by varying the liquid layer height, which is often realized by pouring a pre-defined amount of liquid on the sample surface. We propose experimental set-up which circumvents existing accuracy issues of a curved free surface.A 7 picosecond pulsed laser source ($M^2 \leq 1.3$) at a wavelength of 515nm was used to study the efficiency of laser ablation of stainless steel for a range of liquid layer heights. A detailed quantification of crater depth as a function of liquid layer height is shown.

Dissertations

-

Scientific Publications

1. Picosecond pulsed laser ablation of liquid covered stainless steel: effect of liquid layer thickness on ablation efficiency, Sietse VAN DER LINDEN, Rob HAGMEIJER and Gert-willem RÖMER, Proceedings of LPM2018 - the 19th International Symposium on Laser Precision Microfabrication.

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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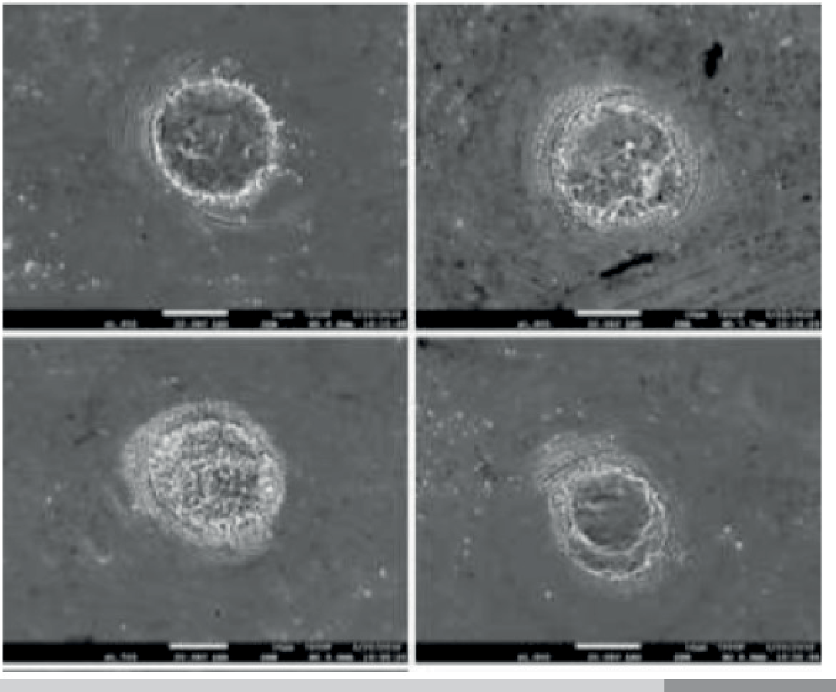

Towards a clinical decision support system in high-flow ventilation therapy: integrated respiration monitoring

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).

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
2018

Information
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Project Aim

High flow nasal cannula (HFNC) therapy is widely used in hospitals to treat critically ill patients with acute, severe respiratory disorders. However, there is a persistent lack of criteria to support clinical decisions with respect to (a) initiation of HFNC therapy, (b) titration of HFNC therapy, and (c) control of airway pressure. We propose a revolutionary approach to use the HFNC-device itself as the monitoring device, supported by an optimized and validated theoretical lung model in the background.

Progress

During preliminary research, we have discovered in-vitro that upper airway pressure can accurately be measured within the HFNC device itself. This opens the route towards continuous monitoring of individual infants, and we propose to investigate this approach on three complementary levels. We have discovered in-vitro that upper airway pressure can accurately be measured within the HFNC device itself. This opens the route towards continuous monitoring of individual infants, and we propose to investigate this approach on three complementary levels.

Dissertations

-

Scientific Publications

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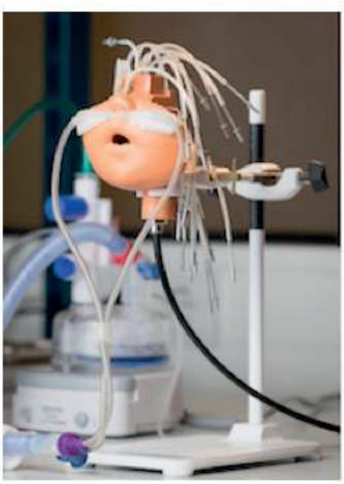

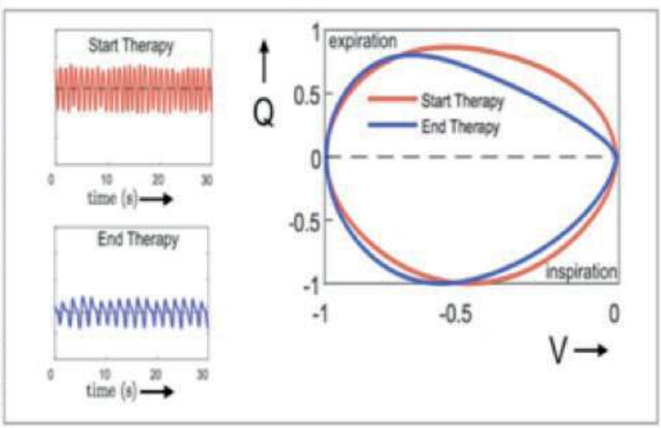

Development of a flat spectrum filter for 3D printed custom-made hearing protection

Project Aim

This PDEng project aims to develop a flat spectrum hearing protection device. Normally, sound attenuation in hearing protection devices increases for higher frequencies. A so-called flat spectrum filter, i.e. a protection device that attenuates sound equally for all frequencies, would be beneficial as e.g. music would not distort.

Progress

A mathematical model to simulate sound propagation through the hearing protection device has been implemented and associated hardware has been manufactured.

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. Hamed Faghanpourganji

Cooperations

Comfoor

Funded by

Comfoor
EFRO PDEng Cluster Smart Industries Oost Nederland

Funded %

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

Start of the project

2018

Information

Dr. Ir. Y.H. Wijnant
053 489 3635
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Project leaders
F.H.C. de Jongh, CH Venner
Research theme
Complex dynamics of fluids
Participants
Frans de Jongh
Cooperations
AMC (UVA) Amsterdam
MST Enschede
Funded by
UVA/UT
Funded %

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

Start of the project
2001
Information
Frans de Jongh
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In the calibration and validation phase of the smart-shirt project, a healthy volunteer wears a face mask which continuously can measure respiration. In this way we can compare respiration measured at the mouth with the signals measured by the smart shirt (picture: Techmed Centre Utwente)

Project Aim

From early diagnosis till treatment of respiratory diseases from premature neonate till elderly patients.

Progress

Ongoing research, now focussed on eletronic nose technology to “smell” (pulmonary) diseases and electromyography to measure activity of the main respiratory muscle (the diaphragm) and related that to the respiration/ventilation of the patient, and to wearable sensors (smart shirt) to measure the respiratory system (e.g. dynamic) hyperinflation in patients with chronic obstruction pulmonary diseases.

Dissertations

1. Transcutaneous electromyogrpahy of the diaphragm. C.G. de Waal (F. De Jongh co-promotor) 12-10-2018.

Scientific Publications

1. Retrospective validation of a new volumetric capnography parameter for the exclusion of pulmonary embolism at the emergency department. Fabius TM, Eijsvogel MMM, Brusse-Keizer MGJ, Sanchez OM, Verschuren F, de Jongh FHC. ERJ Open Res. 2018 Dec 21;4(4).
2. Multi-centre prospective study on diagnosing subtypes of lung cancer by exhaled-breath analysis. Kort S, Tiggeloven MM, Brusse-Keizer M, Gerritsen JW, Schouwink JH, Citgez E, de Jongh FHC, Samii S, van der Maten J, van den Bogart M, van der Palen J. Lung Cancer. 2018 Nov;125:223-229.
3. ERS technical standard on bronchial challenge testing: pathophysiology and methodology of indirect airway challenge testing. Hallstrand TS, Leuppi JD, Joos G, Hall GL, Carlsen KH, Kaminsky DA, Coates AL, Cockcroft DW, Culver BH, Diamant Z, Gauvreau GM, Horvath I, de Jongh FHC, Laube BL, Sterk PJ, Wanger J; American Thoracic Society (ATS)/European Respiratory Society (ERS) Bronchoprovocation Testing Task Force. Eur Respir J. 2018 Nov 15;52(5.
4. Patient-ventilator asynchrony in preterm infants on nasal intermittent positive pressure ventilation. de Waal CG, van Leuteren RW, de Jongh FH, van Kaam AH, Hutten GJ. Arch Dis Child Fetal Neonatal Ed. 2018 Jul 21. pii: fetalneonatal-2018-315102.
5. A humidifier in the invasive mode during noninvasive respiratory support could increase condensation and thereby impair airway patency. Flink RC, van Kaam AH, de Jongh FH. Acta Paediatr. 2018 Nov;107(11):1888-1892.

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 2018 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

1. Detert Oude Weme, D.G.J. & van der Schoot, M.S. & Kruyt, N.P. & van der Zijden, E.J.J. (2018). Prediction of the effect of impeller trimming on the hydraulic performance of low specific-speed centrifugal pumps. Journal of Fluids Engineering (Transactions of the ASME) 140, 081202.

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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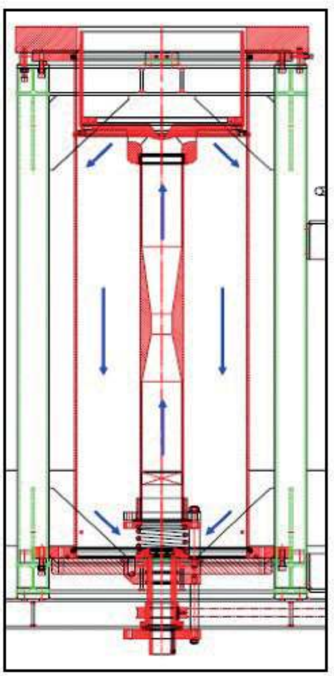

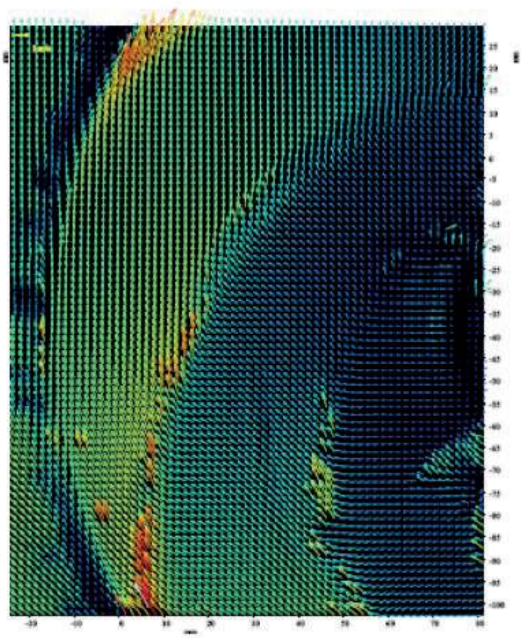

PROJECT LEADERS
Dr. Ir. Y.H. Wijnant
Prof. C.H. Venner

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Msc. Jagruti 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.

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. Zhao, C.F. & Kruyt, N.P. & Millet, O. (2018). Capillary bridge force between non-perfectly wettable spherical particles: an analytical theory for the pendular regime. Powder Technology 339, 827–837.

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
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PROJECT AIM

Development of 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. N. Consten, de Jong, Wijnant. APPLICATION OF THE LOCAL PLANE WAVE METHOD TO MEASURE IN-SITU SOUND ABSORPTION USING A SPHERICAL MICROPHONE ARRAY. Conference Proceedings 24th ICSV, London.
2. 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

Dr. Ir. Y.H. Wijnant
Prof. 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

Dr. Ir. Y.H. Wijnant
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ADVANCING AIRCRAFT SILENT DESIGN BY WIND TUNNEL TEST UNCERTAINTY REDUCTION: MEASUREMENT UNCERTAINTIES IN AEROACOUSTIC WIND TUNNELS

PROJECT LEADERS
L.D. de Santana, C.H. Venner
RESEARCH THEME
Complex structures of fluids
PARTICIPANTS
J.Biesheuvel (PhD), M. Tuinstra
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
Leandro de Santana
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PROJECT AIM

Investigation and reduction of the uncertainties in aeroacoustic phased array measurements in wind tunnel experiments allowing aircraft OEM to reduce their wind tunnel testing costs and decrease design lead times. In this project emphasis is on understanding and development of a correction method for coherence loss occurring when the acoustic wavelength is comparable to the turbulence length scales.

PROGRESS

Acoustic measurements have been performed to assess the current state-of-the-art microphone coherence loss models. Furthermore these models have been applied to predict the loss of SPL in beamforming results on an industrial scale, which are to be published in the AIAA Aeroacoustic conference 2019.

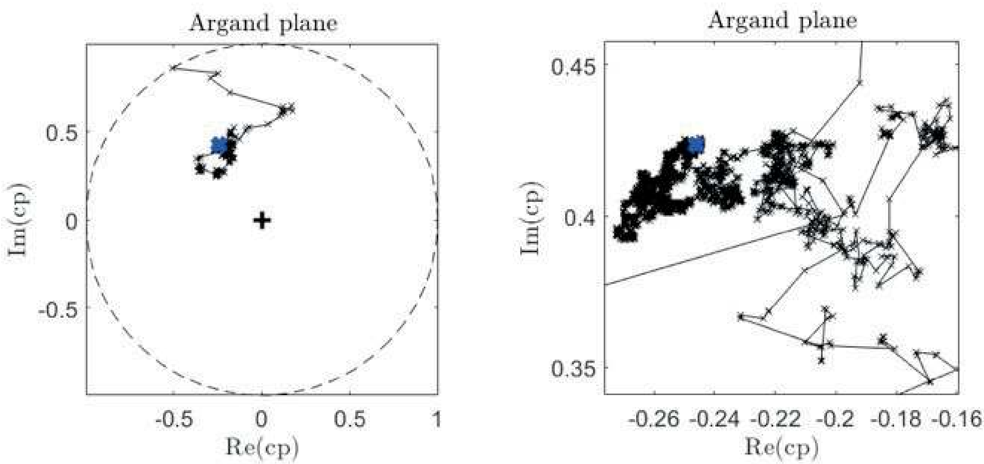
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Figure: Convergence of a coherence matrix cross-power (cp) obtained by averaging samples. Each sample has (per definition) a coherence of unity. Because the samples have lost part of their coherence the mean coherence is no longer equal to unity.



PROJECT AIM

Air traffic noise is a major societal problem causing discomfort and stress related health issues to the population near airports. High bypass ratio engines have significantly reduced engine noise and currently the non-propulsive part of the airplane, aka airframe, is the predominant source. In Silent Approach the University of Twente, the aeronautical institutes NLR and DNW, and the aircraft OEM EMBRAER generate fundamental knowledge and reliable methodologies to minimize the noise of the wing slats and flaps. This project will perform wind tunnel tests in scaled models which will contribute to the optimization of the acoustics performance of future aircrafts.

PROGRESS

Slat noise production encompasses a broadband and a tonal phenomenon. The tonal noise production is originated at the slat cusp. At that location the boundary layer separates producing a shear layer flow. The shear layer reattaches near the trailing edge of the slat mixing with the boundary layer of the top side. The high turbulence intensity in the shear layer makes the slat trailing edge a very effective noise scattering source. The shape of the slat, and the slat cove, effectively amplify the noise. The recirculation bubble in the slat cavity emits low frequency sound.. A feedback mechanisms may occur producing powerful pressure waves emitted by the trailing edge of the slat which propagate upstream and excite associated turbulent eddy structures at the slat cusp.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Choudhari, M., and Khorrami, M., “Slat Cove Unsteadiness: Effect of 3D Flow Structures,” 44th AIAA Aerospace Sciences Meeting and Exhibit, Aerospace Sciences Meetings, American Institute of Aeronautics and Astronautics, 2006.

PROJECT LEADERS

L. de Santana, C.H. Venner

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Marijn Sanders (PhD)
Embraer, NLR and DNW

COOPERATIONS

Embraer, NLR and DNW
Aerounautical Depatment USP/Brazil

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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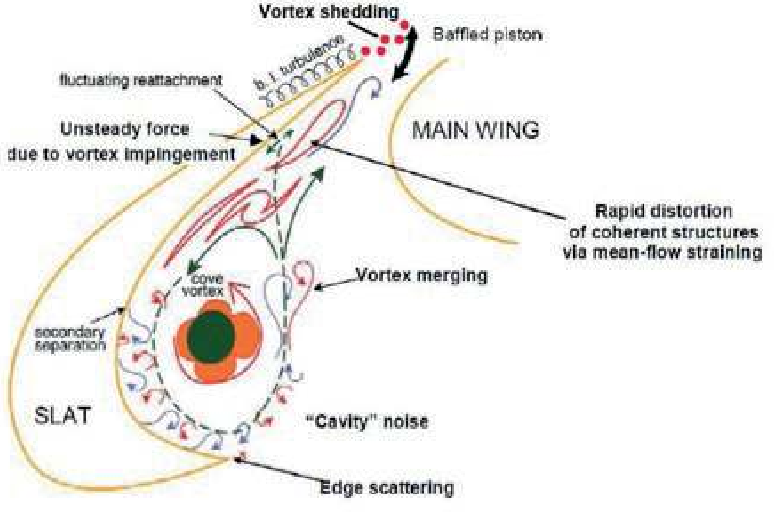

Viscoelastic layer modeling for contact mechanics with heterogeneous materials and (mixed) lubrication layer islands interface

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
CSC/SKF

Funded %

University	-
FOM	-
STW	-
NWO Other	-
Industry	10 %
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 effcient Multigrid/Multilevel computational methods which allow simulate full 3D heterogeneous, granular, and anisotropic material behavior yielding a novel and effcient way to analyze and optimize lubricated contacts as transitional interfaces.

Progress

In 2018, experiments were carried out using PCS EHD instrument with HVI 60 oil under different loads. Some experiments also carried out with different polyalphaolefin (PAO) oils. The further experiment work will focus on using several kinds of polymer layers to validate the developed model under different temperature and load conditions. Besides, the develop model will also be optimized to predict the behavior of full 3D heterogeneous, granular, and anisotropic material and to optimize lubricated contacts as transitional interfaces.

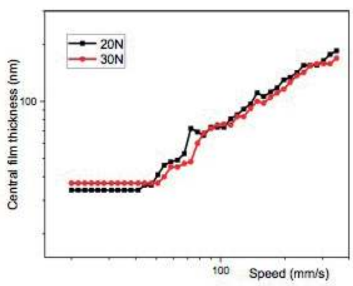
Dissertations

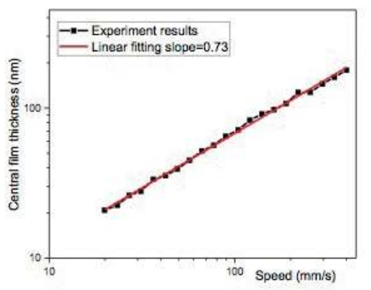
-

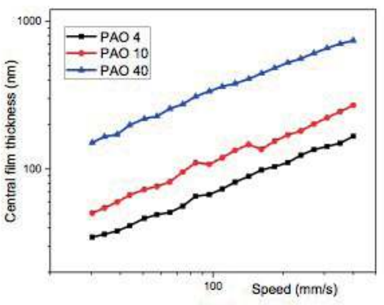
Scientific Publications

-

Experiment results with HVI 60 oil under different loads using 3D mapper measurement method (on the left) in room temperature HVI 60 oil with spectrometer measurement method with load 20N (on the right) in room temperature







Experiment results with three kinds of PAO oils using spectrometer measurement method with load 20N in room temperature

PROJECT AIM

Recent studies have indicated that non-invasive ultrasonic transit time flow measurements (TTFM) on human arteries exhibit unexpected flow rate error behavior. Vendors claim that the Acoustic Coupling Index (ACI) is a proper indicator for the performance of the flow measurement, however, experiments at MST have demonstrated non-consistent behavior (see figure below). Detailed numerical simulations of the ultrasonic wave propagation through the blood and artery wall will shed light on the potential sources of the mismeasurement. An experimental setup that allows for pulsatile flow will be developed to verify the TTFM measurement under realistic conditions.

PROGRESS

A FEM model has been built to simulate the 2D wave propagation through the blood and artery wall. The calculation module in the TTFM device has been rebuilt in a Python script. Initial preparations have been made to develop a pulsatile flow calibration setup that can be used to validate the TTFM measurement for the conditions experienced during by-pass operations.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

R. Hagmeijer

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

D.S. van Putten

COOPERATIONS

Medical Spectrum Twente, Thorax Centrum Twente.

FUNDED BY

Heart Foundation Twente, DNV GL

FUNDED %

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

START OF THE PROJECT

2018

INFORMATION

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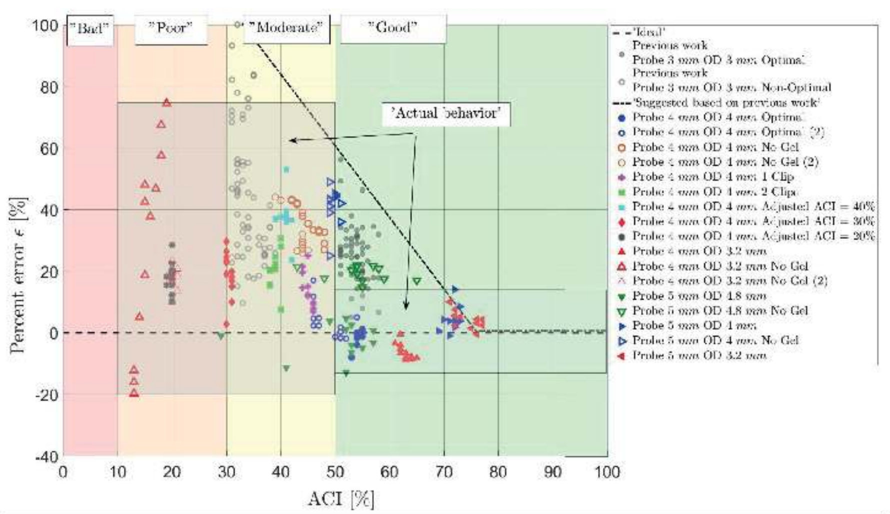

Nasal high-flow therapy to treat COPD exacerbations: a matter of monitoring and controlling settings?

Project leaders
R. Hagmeijer, C.H. Venner
Research theme
Complex structures of fluids
Participants
R. Hagmeijer (UT), H.C. Venner (UT, M. Duiverman (UMCG), P.Wijkstra (UMCG), R. Hebbink (UT)
Cooperations
Universitair Medisch Centrum Groningen
Funded by
TKI Longfonds
Funded %

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

Start of the project
2018
Information
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Project Aim

Chronic Obstructive Pulmonary Disease (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). Options to treat exacerbations effectively are limited, many patients have persistent loss of vital functioning and suffer from frequent re-hospitalisations. The aim of the present study is to prove efficacy of nHFT (Nasal High Flow Therapy) in enhancing recovery from COPD exacerbations. We aim to improve the effectiveness of nHFT by developing new technologies to control and monitor the effect of nHFT and by providing background for optimal settings of nHFT.

Progress

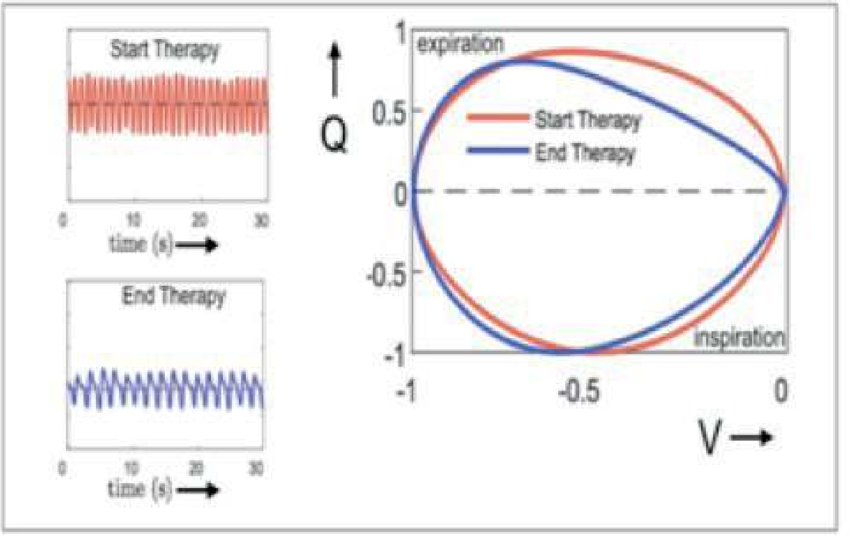
Initial measurements in-vitro and in-vivo have been done, analysis is in progress.

Dissertations

-

Scientific Publications

-



Project Aim

As part of our new research theme and section on fluid mechanics of functional materials and in-air microfluidics, the main goal of this project is to enable the production of controlled monodisperse air shells and other capsules of medicine of advanced materials and encapsulates on industrial scale.

Progress

Initiation, realization of a laboratory and installation of equipment including safety protocoals, and logistics. Setup for specific project realized which is now fully operational. First liquid combinations tested which resulted in successful partial encapsulation.

Dissertations

-

Scientific Publications

-

Project leaders
C.H. Venner, C.W. Visser
Research theme
Complex structures of fluids
Participants
Dr. Jieke Jiang, Gary Shea (MSc student)
Cooperations
With Bether Encapsulates and IamFluidics
Funded by
EFRO
Funded %

University	60 %
FOM	-
STW	-
NWO Other	-
Industry	40 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2018
Information
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Microscopy image of encapsulated particles composed with liquid cores and biodegradable solid shells that are efficiently produced by in-air microfluidics”

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.

Combustion Modeling of Complex 3D Heat Exchanger Geometries and Systematic Design Optimization

Project Aim

This project aims to develop a model that can be used to estimate emission values (CO, NOx) in complex 3D heat exchanger. This model will be implemented to improve the current pin-fin heat exchanger in a domestic boiler by a systematic optimization 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

A 2D model of a pin-fin heat exchanger has been optimized using the discrete adjoint method in ANSYS Fluent 18. The final shapes (see picture below) give better performance and results are presented in a conference (see publication list below). Furthermore, 3D cases are developed for 3D optimization of the heat exchanger. A single cylinder in a confined flow and an array of cylinders are modeled. The results show that there are different cross sectional shapes along the spanwise length of the cylinders. Low Reynolds number and constant temperature were used for these models.

Dissertations

-

Scientific Publications

1. Multi-objective Optimization of a Heat Exchanger Using the Discrete Adjoint Method, Proceedings of 16th IHTC (2018) 5577-5584, doi: 10.1615/IHTC16.hte.023615.

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

Information

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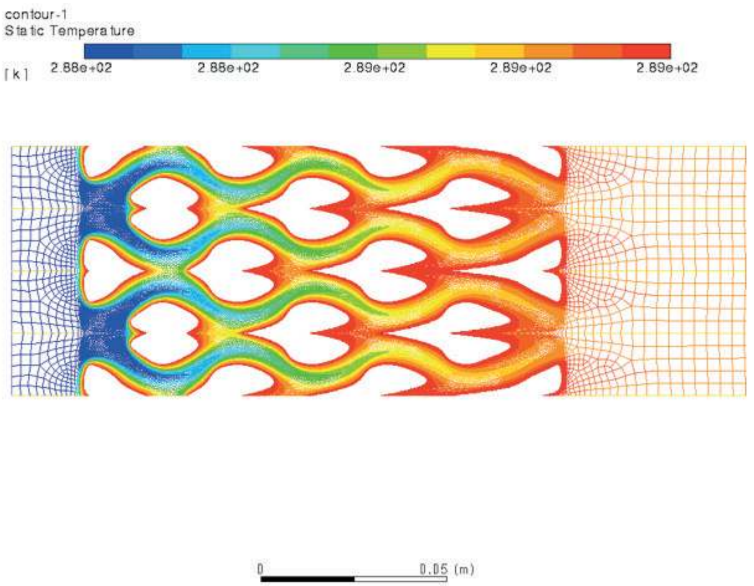

A novel thermosiphon-like cooling system based on magnetocaloric nanofluids

Project leaders
Dr. Mina Shahi
Prof. dr. ir. H.J.M. ter Brake (Marcel)
Research theme
Complex structures 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

The following entities were shortlisted to be used for nanofluid preparation:

o Magneto-caloric material: (i) Gadolinium, (ii) Brück material - MnFe(P,Si,B), and (iii) Calorivac H - LaFeSiH. o Base liquid for colloid preparation: (i) Galinstan, and (ii) (Olive) oil. Using a simplified setup, the possibility of pumping a magnetic fluid by varying magnetic fields was verified experimentally. A mechanical setup to quantify magnetic pumping of a magnetic liquid from a lower to a higher reservoir is built.

Dissertations

1. E.C.J. Karaliolios, Numerical Exploration of Ferrofluid Magnetic Refrigeration based on Convection Principles, Master Thesis Research 2018, University of Twente.

Scientific Publications

1. Karaliolios, E. C. J. , De la cuesta de cal, D., Shahi,M., (2018) Numerical Exploration of Ferrofluid Magnetic Refrigeration based on Convection Principles. In: Thermag VIII International conference on caloric cooling, 16-20 September, 2018, Darmstadt, Germany.

The smart way of cooling in meat industry (CrestCool)

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

CFD simulations using electrostatic paint sprays, as a benchmark, were performed in Ansys Fluent with application of UDFs. The results were validated with the available experimental data showing good match. The model was then extended to evaporating sprays, in order to take into account the effect of heat transfer between droplets, air and meat. In the next step, a sensitivity analysis will be perform to identify the parameters which significantly affect the meat cooling process.

Dissertations

-

Scientific Publications

-

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, Kors, 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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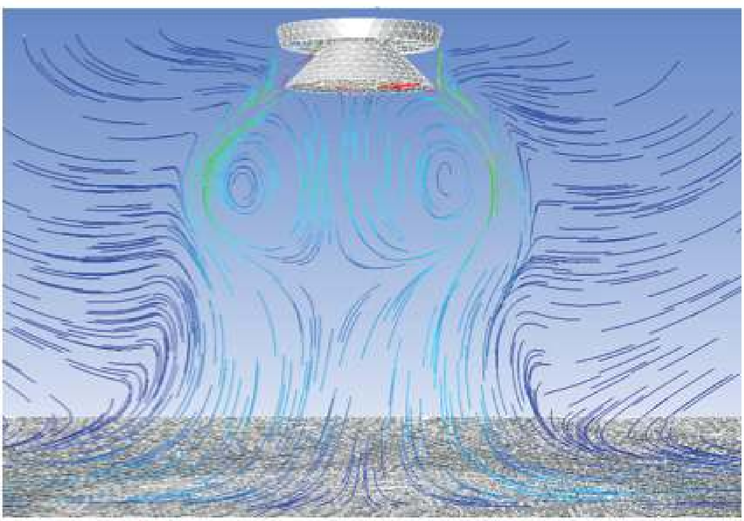
Gas flow pattern under e-field



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
2017

Information
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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.

Progress

Hiring all 15 ESRs at their respective research institute. Holding the first workshop and the first summer school of the ITN. CFD design of an appropriate Airblast swirl atomizer as the basis of future experiments. Starting data acquisition from experimental setups at various research institutes and examining proper machine learning techniques in order to predict combustion instabilities. CFD investigations of the combustion process and the flame transfer function using various software packages.

Dissertations

-

Scientific Publications

1. L. Marocco, F. Garita, Large Eddy Simulation of liquid metal turbulent mixed convection in a vertical concentric annulus. Journal of Heat Transfer, 140 (7), (2018). doi: 10.1115/1.4038858.

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 simulation in Open FOAM using diesel as a reference fuel has been performed and validated with the available experimental data. This results present a qualitatively good agreement with the experiment. Furthermore, a model containing phenol, water and char as a surrogate of pyrolysis oil was developed and investigated at full and partial load conditions. The preliminary results show the importance of the char content and droplet size on the combustion process and fuel residence time.

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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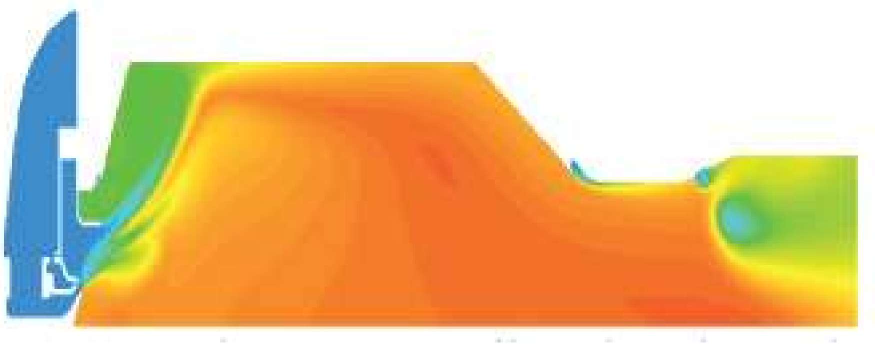
An example temperature profile inside combustion chamber



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 will be validated and applied to design an optimized industrial scale digester.

PROGRESS

Validation of CFD code was done with dimensionless numbers of mixing impellers and with experimental velocity data obtained from PIV measurements, see Fig.1. Several turbulence models and MRF and sliding mesh approach were used for the computations. The selected model was then applied to compute power consumption in an industrial-scale centrally mixed digester of HoSt. The obtained results agreed well with full-scale experimental data. In parallel line of investigation a simplified model taking into account kinetics of biogas production was implemented into Ansys Fluent using UDF routines.

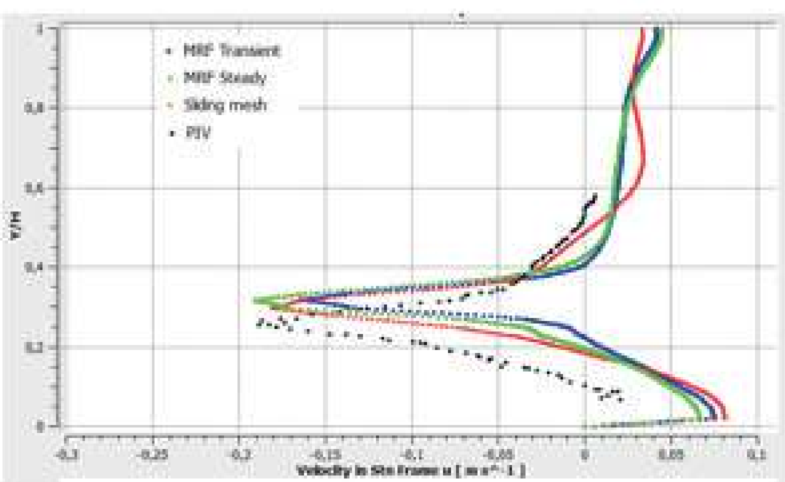
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Data comparison between CFD and lab-scale experiment



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

The MAGISTER project is formed by 15 ESR that focus on different approaches, experimental work and a predictive model of thermoacoustic instabilities in 2 combustors: atmospheric pressure and gas fuel, and high pressure (3 – 5 bars), high temperature, liquid fuel will be investigated. Experiments on self-exited high pressure oscillations at atmospheric pressure, by varying the power and air factor have been done. Their characteristics are being investigated with non-linear systems approaches like chaos theory and a predictive model based on Gaussian processes is proposed.

Dissertations

-

Scientific Publications

-

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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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
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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 models were developed to investigate the transient effects of air flow in the RMD. The results show radial oscillations of central hot air which affects position of the spray. Furthermore, the results have shown that position of the nozzle and solid outlet, hot/cold air relative ratios, central hot zone length and spray parameters are important factors for RMZD optimization.

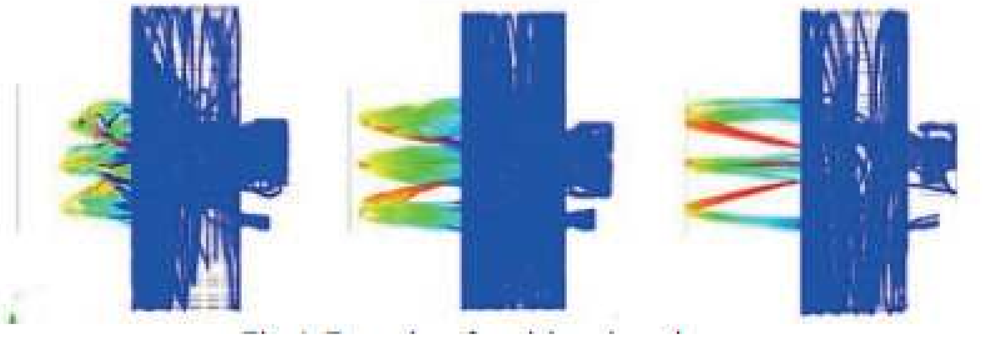
Dissertations

-

Scientific Publications

1. U.J.U. Rahman, I. Baiazitov, A.K. Pozarlik, G. Brem. CFD study of air flow patterns and droplet trajectories in a lab scale vortex chamber spray dryer, International Drying Symposium 2018, 14 Sep 2018, Valencia, Spain.

Examples of particle trajectories



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 will be made into a publication. Finally, a literature study on the conversion of acoustic power to electricity has been completed, which has resulted in a published review article.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. M. Timmer, K. De Blok, and T. Van Der Meer, "Review on the conversion of thermoacoustic power into electricity," J. Acoust. Soc. Am. 143(2) (2018) doi: 10.1121/1.5023395.

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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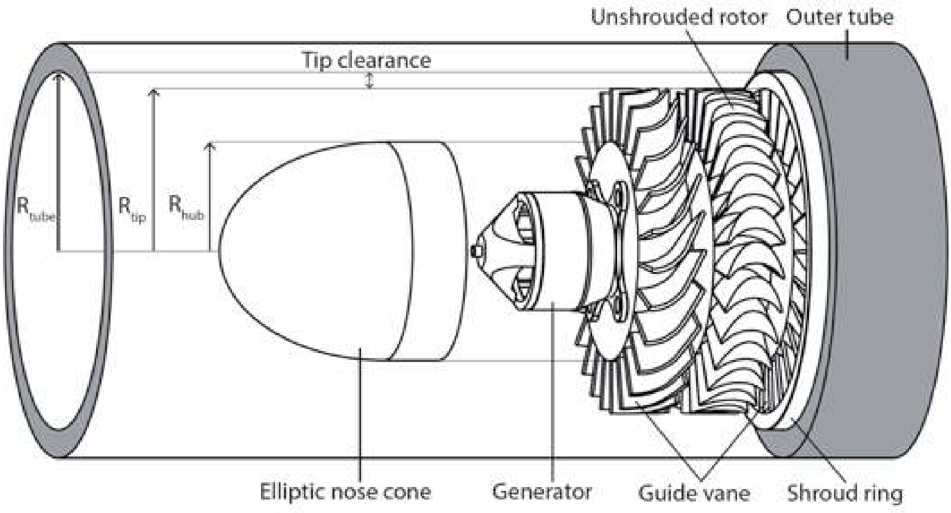

Innovative microencapsulated phase change materials for direct-absorption solar collectors

Project leaders
M. Shahi
Research theme
Complex structures of fluids
Participants
PD candidate: Dr. Sara Tahan Latibari
Cooperations
TNO, Croda, Raedthuys, Center for Renewable Energy Sources and Saving, Holland Solar
Funded by
TKI Urban Energy
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 aim of the project is to introduce and characterize novel microencapsulated PCM slurries (MEPCMS) for direct absorption solar collectors. The working fluid acts both as the HTF and energy storage medium, following two main purposes:

- to increase the efficiency,
- to increase energy storage capability of the collectors.

Progress

In this project two different types of photothermal slurries containing phase change materials were prepared. The properties of the prepared solid and slurry materials were studied. The results approved the successful fabrication of shaped stabilized phase change materials. The direct solar radiation absorption behavior of slurries was approved. The photothermal behavior of the slurry samples was investigated by using a simulated static state direct absorption solar collector. Outcomes indicated that by introducing PCM into the system the bulk temperature of the receiver and therefore the heat losses were reduced which was one of our objectives.

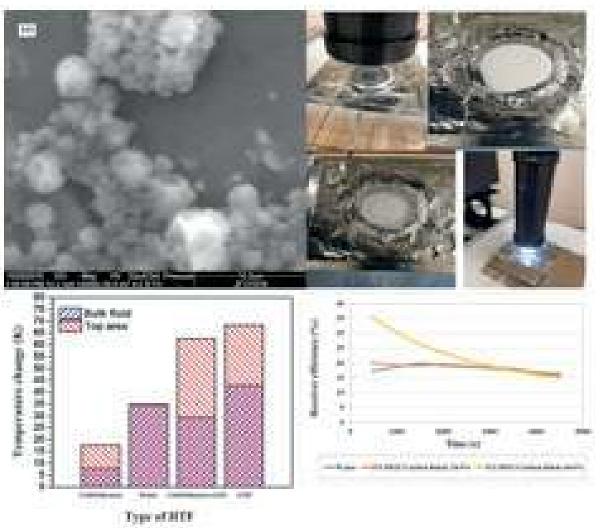
The progress and outcomes were reported in two separate reports to TKI Urban Energy.

Dissertations

-

Scientific Publications

1. Tahan Latibari, S., et al., Preparation and Characterization of Heat Transfer Fluid for Application in Direct Absorption Solar Collectors, 13th SDEWES conference, October 2018, Palermo, Italy.



MULTISCALE MECHANICS

Prof.dr.rer.nat. S Luding

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.

Examples include segregation versus mixing; non-Newtonian fluids and rheology; macro-molecules; sticky powders; wave-propagation in disordered media; solid concrete or asphalt; avalanche flows of grains, soil or snow; composite and self-healing materials. A wide range of length and time scales characterizes the relevant physical processes in these systems. At the microscopic level, the deformation behavior of the granule/atom/molecule with contact/interaction physics on the nano-meter scale determines the dynamics and statics of the particles. The mesocopic level sees the collective motions of the individual granules involving e.g. shear localization or structure formation. Finally, on the macroscopic level, a discrete, granular material behaves as a fluid with complex flow behavior involving anisotropy and non-Newtonian rheological features. 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).

Theory and experiments, supported by advanced numerical simulations, are aimed at understanding the various, multiple scales/levels and their intricate couplings. Micro-Macro theory is one way to predict and describe this hierarchy. By combining numerical simulations with theory and experiments, the MSM group is developing a comprehensive understanding of the properties of granular materials, fluids and solids. The group is also interested in mesoscale simulations (on intermediate level) of particles with attractive interactions, to study aggregation of self-assembly of patchy colloidal particles and proteins on the macromolecular scale, or to model asphalt on the stone- bitumen scale. Mesoscopic models use the small-scale information to formulate effective contact laws and allow thus to simulate much larger systems than possible with (too) detailed micro-models.

Besides helping to improve our fundamental understanding of fluids and solids, the MSM research results have also entered the open-source code: mercuryDPM.org, and late 2015 led to the founding of a spin-off company: mercuryLAB.org that since 2016 is helping industry to solve problems and improve/optimize their equipment.

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 are devices 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 an ionic liquid consisting of 512 ion pairs, the cations being 1-butyl-3-methylimidazolium ($BMIM^+$) and the anions a 50-50 mixture of Cl^- and $BF4^-$. The simulations were performed using both the Lammps and Gromacs packages, using the OPLS all-atom force field with atomic charges derived from quantum density functional theory. Several properties such as density, diffusion coefficient and radial distribution function were examined. The next step is to examine the dielectric properties of this liquid in a confined space, as relevant for energy storage.

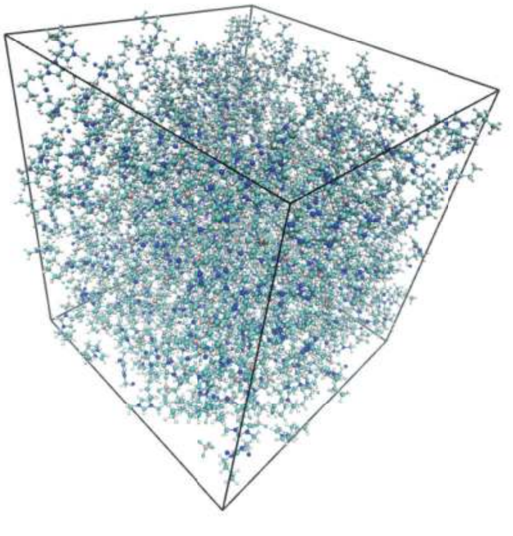
Dissertations

-

Scientific Publications

-

Snapshot of a simulation box of ionic liquid



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 (Jakkur, 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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Direct numerical simulation of wave propagation in dry and saturated granular media

PROJECT LEADERS
V. Magnanimo, S Luding

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
H. Cheng

COOPERATIONS
ENI, ESA

FUNDED BY
ENI, ESA

FUNDED %

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

START OF THE PROJECT
2016

INFORMATION
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PROJECT AIM

Understanding elastic wave propagation in dry and saturated granular media is essential for many industrial applications, such as oil exploration, geophysical tomography and non-destructive inspection of bio/composite materials. The mechanisms that play a role in the dispersion properties of granular media include the nonlinear, stress- and fabric-dependent elasticity, the interplay between particles and pore fluid, and strain softening/hardening due to hysteresis. Our goal is to use advanced particle scale modeling techniques, namely discrete element method (DEM) and lattice Boltzmann method (LBM), to explore the multi-physics behavior from the pore scale to the macro scale.

PROGRESS

The project on elastic waves in dry granular media finished in October 2018. We compared static and dynamic numerical probing, deducing wave velocities from the elastic moduli and from the dispersion relation of propagating waves (see Fig. 1). The dependence of wave velocities on key characteristics, i.e. perturbation magnitude and direction, travelled distance and inserted waveforms, was investigated. To simulate wave propagation in saturated granular media (funded by ESA), an acoustic source is implemented for the coupled discrete element-lattice Boltzmann method. The results are verified against Biot's analytical solution (see Fig. 2).

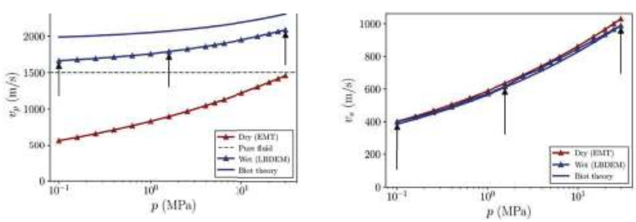
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Cheng, H., Shuku, T., Thoeni, K. and Yamamoto, H., Probabilistic calibration of discrete element simulations using the sequential quasi-Monte Carlo filter, Granul. Matter 20, 11 (2018).
2. Cheng, H., Shuku, T., Thoeni, K., Tempone, P., Luding, S. and Magnanimo, V., Grain learning: Bayesian calibration of DEM models and validation against elastic wave propagation, in Proceedings of China-Europe Conference on Geotechnical Engineering, p. 132 (Springer Verlag, 2018).
3. Cheng, H., Shuku, T., Thoeni, K., Tempone, P., Luding, S. and Magnanimo, V., An iterative sequential Monte Carlo filter for Bayesian calibration of DEM models, in Numerical Methods in Geotechnical Engineering IX: Proceedings of the 9th European Conference on Numerical Methods in Geotechnical Engineering, p. 381 (CRC Press, 2018).

Discrete element modeling of a pressure wave (left) and a shear wave (right) propagating in a granular column.



Comparison of wave velocities obtained by LBM-DEM simulations and Biot's theory, for pressure waves (left) and shear waves (right).

Shaping segregation: advanced modelling of segregation and its application to industrial processes

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 (solid lines) show remarkable good similarity to discrete particle simulations. The publication of this work, submitted in 2018, is in January 2019.

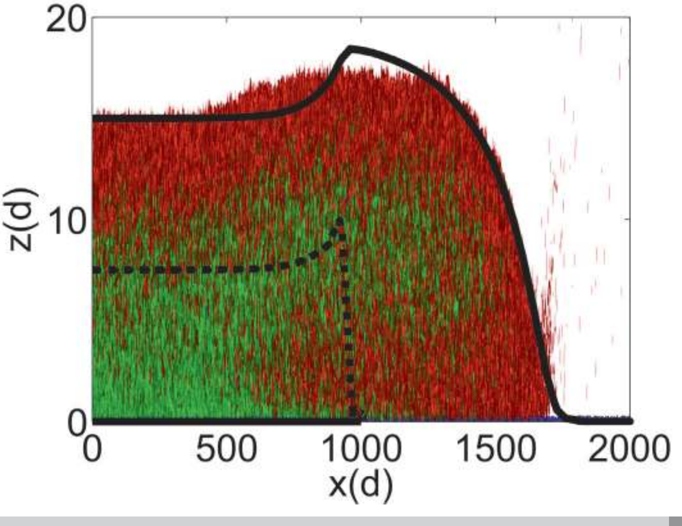
Dissertations

-

Scientific Publications

-

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

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)
N. Gray (Univ. of Manchester, UK)

Funded by

STW-NWO VIDI

Funded %

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

Start of the project

2015

Information

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Molecular dynamics simulation of ink wettability and imbibition in porous media

Project leaders
S. Luding
W.K. den Otter
H.M.A. Wijshoff (Océ and TU/e)
N. Tomozeiu (Océ and TU/e)
A.A. Darhuber (TU/e)

Research theme
Complex dynamics of fluids

Participants
A. Jarray, T. Hulikal Chakrapani

Cooperations
Océ industry B.V, TU/e

Funded by
STW – NWO-TTW

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 and imbibition of ink in paper are two key phenomena underlying the inkjet printing process. The goal of this project is to investigate the complex multiphase interactions between ink and substrate 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

On the ink formulation side, the Hansen solubility parameters or cohesive energy densities are used to predict the wettability by liquids of selected substrates as well as the affinity between liquids in binary and multi-component mixtures. On the imbibition side, a model was designed to mimic the pore structure of paper at the nanoscale and the imbibition of this pore by fluid was investigated for various pore sizes, degree of hydrophilicity and surfactant concentration (see figure).

Dissertations

-

Scientific Publications

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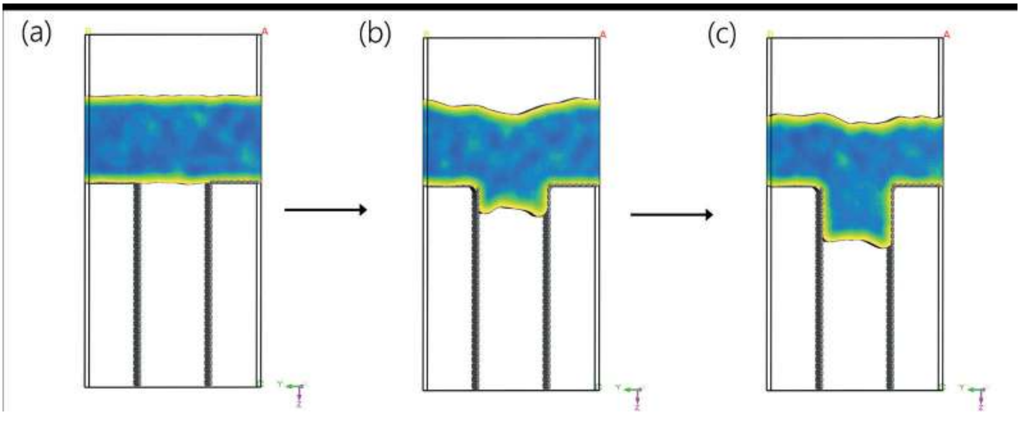

Molecular Dynamics simulation of water imbibition in a pore, with N=2556 water molecules (drawn as continuum, with color representing concentration) in the presence of a few surfactant molecules (10% by weight, explicitly depicted). The snapshots show the system at a) t = 0 ps, b) t = 50 ps, and c) t = 200 ps.

PROJECT AIM

Water-based ink for ink-jet printing on paper contains a number of 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

Multi-body Dissipative Particle Dynamics (mDPD) is used to simulate the capillary imbibition of a water-like fluid in a cylindrical nano-channel. The imbibition depth of the fluid obeys time^$^{1/2}$ scaling, as predicted by the Lucas-Washburn law (see Fig. 1, left). With the complex composition of ink in mind, the capillary imbibition of binary liquid mixtures and colloidal suspensions are being studied as well. Since paper is a compressed array of fibrils, resulting in a complex porous structure, a start has been made at simulating the imbibition of fluids into less well-defined pores, like the interstitial spaces in an array of parallel fibrils (see Fig. 1, right).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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., 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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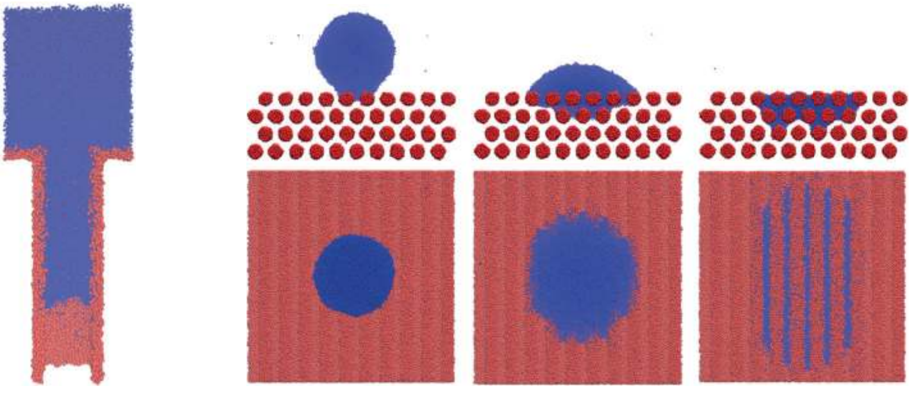

Imbibition of fluid in a cylindrical pore (left) and in the interstitial space of a hexagonal array of parallel fibrils (right).

Project leaders
S. Luding
V. Magnanimo

Research theme
Complex dynamics of fluids

Participants
A. Jarray

Cooperations
Research Center Pharmaceutical Engineering GmbH, Graz, Austria.

Funded by
EU ITN T-MAPPP

Funded %

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

Start of the project
2015

Information
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Project Aim

The aim of this work is to explore the effects of liquid-induced cohesion on the flow properties of wet granular assemblies at different particles sizes and to establish a methodology allowing to control and eventually scale the flow of wet particles in a rotating drum.

Progress

We performed several experiments to explore the effects of liquid-induced cohesion on the flow characteristics of wet granular materials. The strength of capillary forces between the particles is significantly reduced by making the granules, in this case glass beads, hydrophobic through silanization. The main results of rotating drum experiments are that liquid-induced cohesion decreases both the width of the flowing region and the velocity of the particles at the free surface, but increases the width of the creeping region as well as the dynamic angle of repose. Based on these experiments, we propose a scaling relation for coupling flow characteristics to particle size.

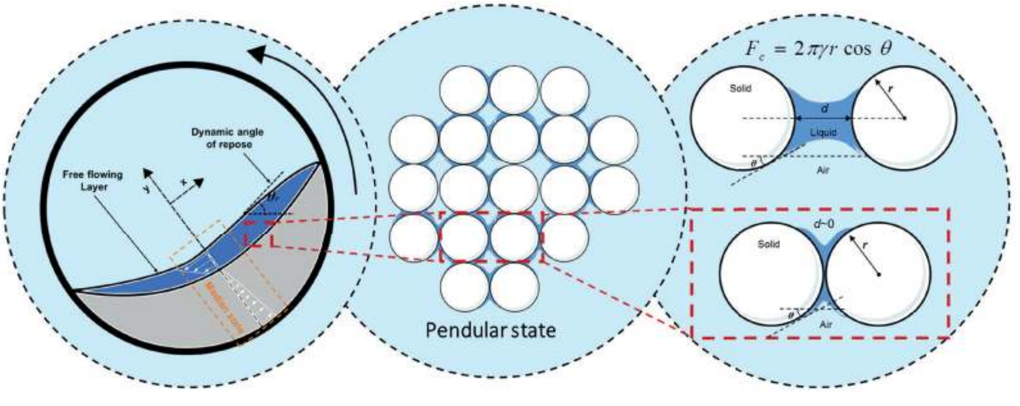
Dissertations

-

Scientific Publications

1. Jarray A., V. Magnanimo, S. Luding. Wet granular flow control through liquid induced cohesion, Powder. Tech. 341, 126-139 (2019).

Schematic of pendular liquid bridges between two identical spherical particles (right), pendular state (middle), and the flow of the particles in a rotating drum (left).



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 size ratio S>1. 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, and has entered the PhD thesis draft that will be defended in 2019. Those data were achieved by 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, see Fig. 1.

Dissertations

-

Scientific Publications

1. K. van der Vaart, M. P. van Schrojenstein Lantman, T. Weinhart, S. Luding, C. Ancey, and A. R. Thornton, Segregation of large particles in dense granular flows suggests a granular Saffman effect, Phys. Rev. Fluids 3, 074303 (2018).

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-TTW VIDI

Funded %

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

Start of the project

2015

Information

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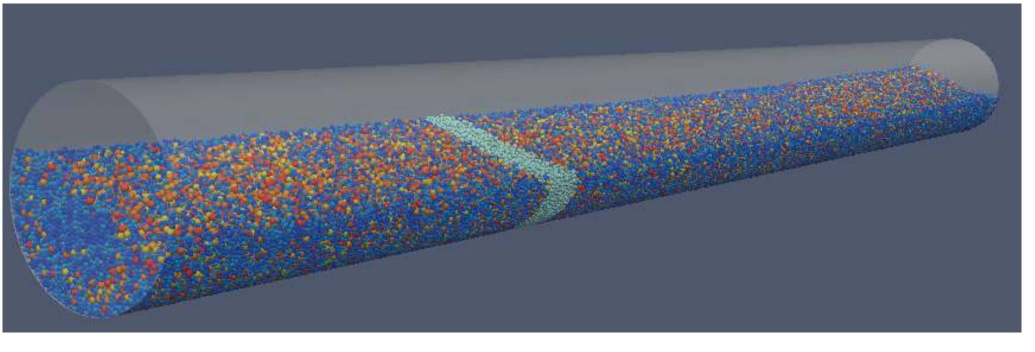

Snapshot of a bed of large (yellow/red) and small (blue) granules in a rotating drum. The simulation runs in parallel, with the white band indicating the workload of one core.

PROJECT LEADERS
W.K. den Otter
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
D. 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
D. Palanisamy
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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. The intrinsic viscosity of a dilute suspension of prolate and oblate spheroidal colloids has been studied, confirming the theoretical limits at low and high shear rate as well as mapping out the intermediate shear-thinning regime.

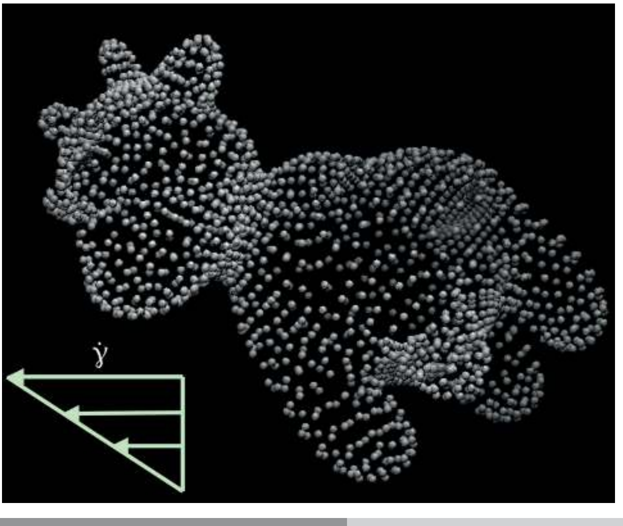
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. D. Palanisamy and W.K. den Otter, Efficient Brownian Dynamics simulations of rigid colloids in linear flow fields based on the grand mobility matrix, J. Chem. Phys. 148, 194112 (2018).

Snapshot of an arbitrarily shaped colloid tumbling in a linear shear flow (as indicated by the arrows).



Project Aim

The objective of the project is to develop a description of the flow of partially wet granular materials, based on detailed knowledge of the links between micro-scale and macro-scale material parameters. The main aims of the project are the formulation of suitable constitutive equations for the stress-strain relations of wet granular materials, the calibration of the parameters in these constitutive equations with Discrete Element Method (DEM) simulations, the validation of the micro-macro transition with data from experiments on wet granular materials, and the development of more efficient macroscopic simulation tools to model large-scale experiments.

Progress

To simulate unsaturated granular media, DEM simulations were combined with a capillary bridge model. In the Cartesian split-bottom shear cell geometry, see figure, the fluid is observed to migrate away from the shear band center. The possible dependence of the stationary state on the initial fluid distribution is a topic of ongoing research. We are also looking into fluid migration in split-bottom cylindrical shear cells. The DEM simulations are being compared against numerical solutions to continuum models of fluid migration.

Dissertations

1. S. Roy, Hydrodynamic Theory of Wet Particle Systems, University of Twente, 26th January 2018.

Scientific Publications

1. Roy, S., Luding, S., & Weinhart, T. (2018). Liquid redistribution in sheared wet granular media. Physical review E: covering statistical, nonlinear, biological, and soft matter physics, 98(5), 052906. https://doi.org/10.1103/PhysRevE.98.052906.

Project leaders
S. Luding, T. Weinhart

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
S. Roy

Cooperations
R. Schwarze (TU Freiberg)
S. Turek (TU Dortmund)
A. Gladkyy (TU Freiberg)
A. Ouazzi (TU Dortmund)
S. Mandal (TU Dortmund)

Funded by
STW (UT)
DFG (German side of the project)

Funded %

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

Start of the project
2013

Information
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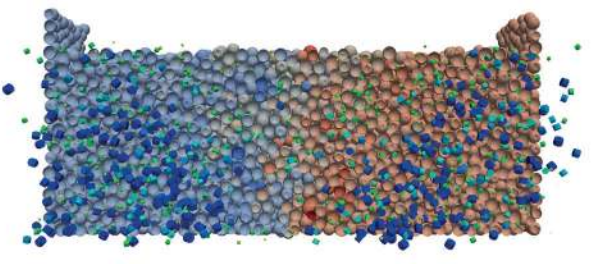
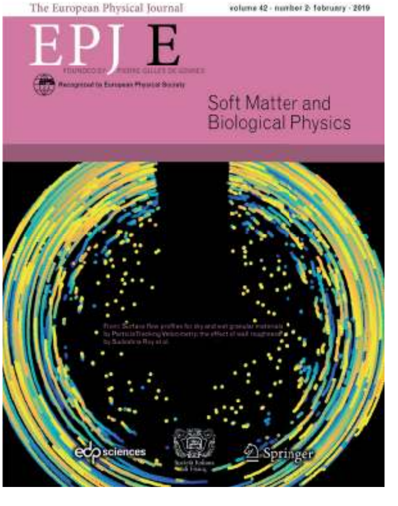
(Left) Cross-section of a granular bed in a Cartesian split-bottom shear cell, with rigid arrays of granules as walls. The spherical granules' velocities perpendicular to the cross-section are denoted by a red-blue color scheme, liquid bridges are represented as cylinders (dark blue when large and green when small in volume)[from cover of PhD thesis]. (Right) Cover page of EPJE [chosen from S. Roy et al, 2018]





PROJECT LEADERS
T. Weinhart
S. Luding
A.R. 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
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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

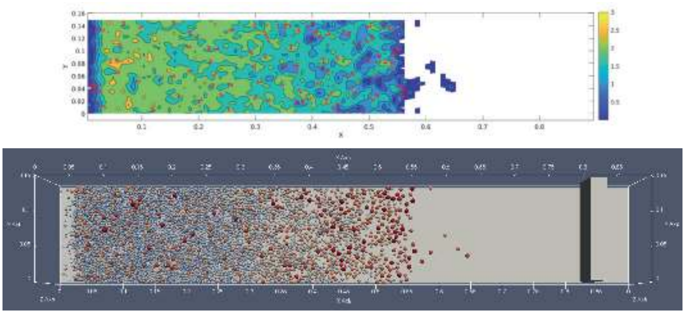
Selective Laser Sintering / Melting (SLS/SLM) is an additive manufacturing process consisting of various stages, each requiring different process parameters. Typically, the optimization of those parameters to achieve the desired final properties is done by performing costly experimental trials. We are developing a computational model that will help reduce the number of trials, thereby reducing the manufacturing costs. 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. 2), and AM-product testing (Fig. 3), to advance the development of accurate predictive models.

DISSERTATIONS

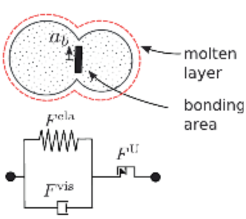
-

SCIENTIFIC PUBLICATIONS

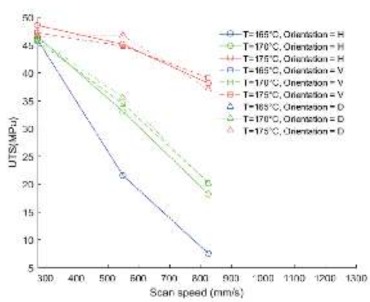
-



Spreading of powder layer. Layer density, top view of powder layer



Discrete particle model of sintering/melting



Ultimate tensile strength of PA12 samples printed by desktop SLS machine for different process parameters

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 progressing 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. The developed models will be used as the starting point for the third objective, where much larger stresses have to be considered. 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

-

Scientific Publications

1. Shi, H., Mohanty, R., Chakravarty, S., Cabiscol, R., Morgeneyer, M., Zetzener, H., Ooi, J., Kwade, A., Luding, S., and Magnanimo, V., Effect of particle size and cohesion on powder yielding and flow, KONA Powder Particle J. 35, 226 (2018).

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

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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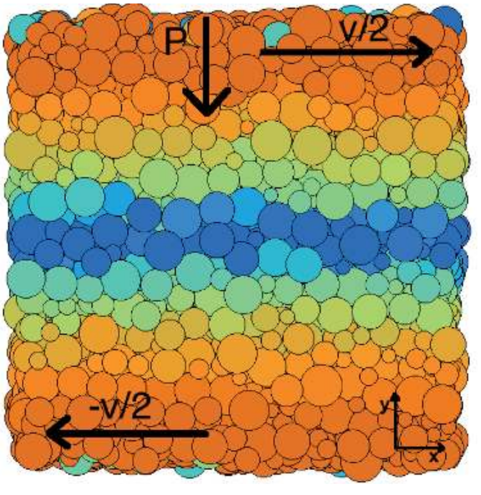
Snapshot of powder under pressure-controlled simple shear



PROJECT LEADERS
T. Weinhart, A.R. Thornton, S. Luding
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
M. J. Post, M. Y. Shaheen
COOPERATIONS
-
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

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 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 the 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

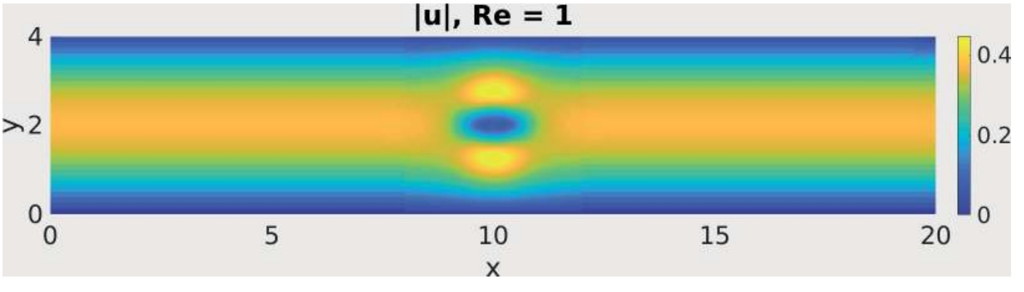
The particle-fluid coupling is incorporates using two open-source codes: MercuryDPM as the particle solver and oomph-lib as the finite element method (FEM) fluid solver. The current work focusses on unresolved coupling, using the Anderson-Jackson formulation, with the particle volume fraction extracted from discrete particle simulations via coarse-graining. The knowledge gained by performing two-way coupled simulations on the small scale will next be used to develop a pure continuum-scale model, for design optimization and large scale simulations.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Poiseuille flow around a cylinder represented by an error function in the Anderson-Jackson formulation. Color indicates absolute fluid velocity.

PROJECT AIM

Characterization of the connection between the structure of dry granular media and its signal transmission behavior at the macroscopic level requires understanding the roles of structure and contacts at the microscopic level. Propagation of stress and energy in granular systems is sensitive to even small amounts of disorder in the granular masses or the contact network. We will numerically and analytically study the effects of isolated mass-disorder and anisotropy on the energy transfer and frequency content of signals propagating in these systems.

PROGRESS

Simulations of wave propagation through three-dimensional disordered poly-disperse packings of frictional spheres show that structural disorder leads to frequency filtering effects. Energy contained in uniaxial translational motion (P-wave) is quickly scattered to shear and rotational modes in 3D, but can only be reduced by forward- and backward-scattering in 1D. Thus, to isolate the P-wave from shear and rotational modes and study the effect of mass disorder only on energy transmission and frequency propagation, a mass-disordered granular chain was used. Whereas ordered granular chains show ballistic propagation of energy, disordered granular chains exhibit more diffusive-like propagation, and high frequencies do not transmit very far. This observations are formulated as a stochastic master equation for energy transport per frequency band in space.

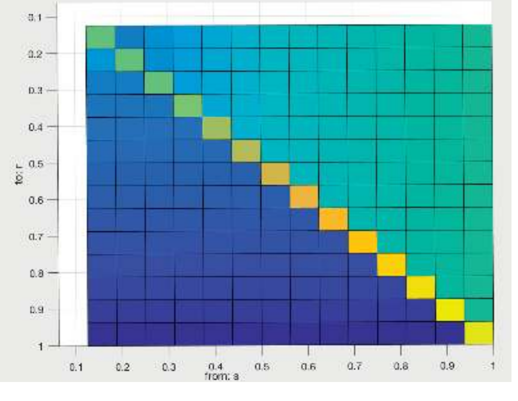
DISSERTATIONS

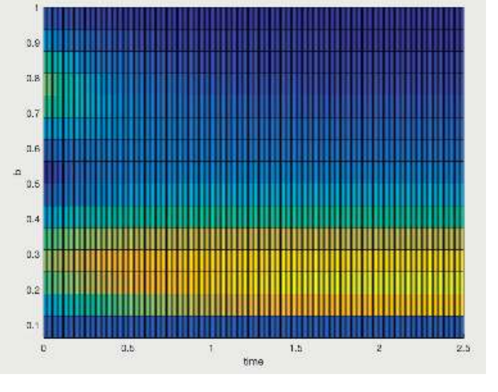
-

SCIENTIFIC PUBLICATIONS

1. Rohit Shrivastava - Towards stochastic & deterministic modeling of mechanical waves in disordered media – September 2018, University of Twente.

(Left) The transfer rate matrix qsr , from a very much simplified model, with 14 bins in energy space. (Right) Evolution of energy when inserted in low and high bands at the same time, where the energy is transported from the high bands to the low bands and remains there for long time.





PROJECT LEADERS
S. Luding

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
R.K. Shrivastava, K. Saitoh

COOPERATIONS
Shell Netherlands

FUNDED BY
NWO-FOM-Shell CSER Project

FUNDED %

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

START OF THE PROJECT
2014

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WATER ENGINEERING MANAGEMENT

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.

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

An efficient sampling-based method was developed to perform uncertainty analysis for large-scale models of (river) systems. This method was first demonstrated to intervention design of interventions to reduce flood levels during high river discharge. Second, we applied the method to quantify the uncertainty of daily siltation rates in a port approach channel using a detailed morphodynamic model. Furthermore, uncertainty reduction by parameter estimation or model calibration has been studied in two case studies: a large-scale experimental facility and the River Waal. 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. Domhof, B., Berends, K., Warmink, J., Spruyt, A., & Hulscher, S. (2018). Calibrating the Waal.: Discharge and location dependency of calibrated main channel roughness. ConcepTueel, (april), 1-4.
2. Berends, K.D., Straatsma, M.W., Warmink, J.J., Hulscher, S.J.M.H. (2018), Efficient uncertainty quantification in river intervention modelling through regression of correlated output, 9th International Congress on Environmental Modelling and Software, Fort Collins, Colorado, USA, Mazdak Arabi, Olaf David, Jack Carlson, Daniel P. Ames (Eds.)
3. Augustijn, D., Linneman, R., Berends, K., Lenssen, J. (2018), Optimizing mowing strategies for vegetated streams. 12th ISE 2018, Tokyo, Japan
4. Berends, K., Warmink, J. J., & Hulscher, S. J. M. H. (2018). Efficient uncertainty quantification for impact analysis of human interventions in rivers. Environmental modelling & software, 107, 50-58. DOI: 10.1016/j.envsoft.2018.05.021
5. Penning, E., Noorlandt, R., Berends, K., Fraaije, R., & Van den Eertwegh, G. (2018). Nieuwe overwegingen voor maaibeheer met vlakdekkende informatie over vegetatie. H2O, 1-7
6. Huismans, Y., Berends, K.D., Niesten, I., Mosselman, E. (eds.) (2018). The Future River. Book of Abstracts NCR Days 2018. NCR publication 42-2018
7. Berends, K. D., Warmink, J. J., & Hulscher, S. J. M. H. (2018). Finding common ground: uncertainty analysis made practical through Bayesian regression of correlated output. 114-115. Abstract from NCR Days 2018, Delft, Netherlands.

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

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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

An analytical model for the wave overtopping flow velocities on the crest and landward slope was developed. The model was validated with data from flume tests and tests on river dikes in the Netherlands. A paper on the derivation an validation of the analytical model is submitted to Coastal Engineering. The analytical flow model is coupled to an erosion model to calculate the maximum erosion depth along the dike profile. The erosion model is applied to two case studies. Currently, the erosion model is adapted to include the effects of transitions and to calculate the erosion depth by overtopping waves during a storm.

Dissertations

-

Scientific Publications

1. van Bergeijk, V. M., Warmink, J. J., & Hulscher, S. J. M. H. (2018). Modelling of the effect of transitions on wave overtopping flow and erosion for flood defence reliability. 85-85. Abstract from NCK-Days 2018, Haarlem, Netherlands.
2. van Bergeijk, V. M., Chen, W., Warmink, J. J., van Gent, M., & Hulscher, S. J. M. H. (2018). Wave overtopping on dikes: The effect of transitions on the flow and dike cover erosion. ConcepTueel, 27(3), 32-35.
3. Warmink, J. J., van Bergeijk, V. M., Chen, W., Aguilar Lopez, J. P., Bomers, A., & Hulscher, S. J. M. H. (2018). Modelling wave overtopping for flood defense reliability. 1-5. Paper presented at 3rd International Conference on Protection against Overtopping 2018, Grange-over-Sands, United Kingdom.
4. Warmink, J. J., van Bergeijk, V. M., Chen, W., & Hulscher, S. J. M. H. (2018). Modelling wave overtopping for flood defence reliability, the outline of a research project.. 1. Abstract from 36th International Conference on Coastal Engineering 2018, Baltimore, United States.
5. Warmink, J. J., Van Bergeijk, V. M., Chen, W., Van Gent, M. R. A., & Hulscher, S. J. M. H. (2018). Modelling wave overtopping for grass covers and transitions in Dike Revetments. International Conference Proceedings of Coastal Engineering, 1(36), 53. https://doi.org/10.9753/icce.v36.papers.53
6. van Bergeijk, V. M., Warmink, J. J., & Hulscher, S. J. M. H. (2018). An idealised model to study the effects of transitions on wave overtopping flow and dike cover erosion. Abstract from Physics of Estuaries and Coastal Seas Meeting 2018, Galveston, United States.

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., Hulscher, S. J. M. H., Lammersen, R., & Schielen, R. M. J. (2018). The effect of dike breaches on downstream discharge partitioning near a river bifurcation. In A. Armanini, & E. Nucci (Eds.), New Challenges in Hydraulic Research and Engineering: Proceedings of the 5th IAHR Europe Congress (pp. 805-806). Research Publishing. https://doi.org/10.3850/978-981-11-2731-1_070-cd
2. Bomers, A., Schielen, R. M. J., & Hulscher, S. J. M. H. (2018). Flood patterns in the Old IJssel Valley. 126-127. Abstract from NCR Days 2018, Delft, Netherlands.
3. Van der Meulen, B., Deggeller, T. S., Bomers, A., Cohen, K. M., & Middelkoop, H. (2018). The historical river: morphology of the Rhine before river normalization. 44-45. Abstract from NCR Days 2018, Delft, Netherlands.

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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The great and terrible flood 1651 (Bayer. Staatbib. Munich, 1651)

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
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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. Poppema, D.W., Willemsen, P.W.J.M., de Vries, M.B., Zhu, Z., Borsje, B.W., Hulscher, S.J.M.H., 2018. Experiment-supported modeling of salt marsh establishment: Applying the Windows of Opportunity concept to the Marconi pioneer salt marsh design. Ocean & Coastal Management.
2. Best, Ü.S.N., Van der Wegen, M., Dijkstra, J., Willemsen, P.W.J.M., Borsje, B.W., Roelvink, D.J.A., 2018. Do salt marshes survive sea level rise? Modelling wave action, morphodynamics and vegetation dynamics. Environmental Modelling & Software 109, 152-166.
3. Willemsen, P.W.J.M., Borsje, B.W., Hulscher, S.J.M.H., Van der Wal, D., Zhu, Z., Oteman, B., Evans, B., Möller, I., Bouma, T.J., 2018. Quantifying bed level dynamics at the transition of tidal flat and salt marsh: can we understand the lateral location of the marsh edge? Journal of Geophysical Research.
4. Vuik, V., Suh Heo, H.Y., Zhu, Z., Borsje, B. W., Jonkman, S.N., 2018a. Stem breakage of salt marsh vegetation under wave forcing: A field and model study. Estuarine, Coastal and Shelf Science 200, 41–58.
5. Vuik, V., Van Vuren, S., Borsje, B.W., van Wesenbeeck, B.K., Jonkman, S.N., 2018b. Assessing safety of Nature-based Flood Defenses : dealing with extremes and uncertainties. Coastal Engineering 139, 47–64.

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 1 (G.H.P. Campmans): Two journal papers and his PhD Thesis were successfully finished and defended. The first paper was on the effect of storm processes on finite amplitude sand wave dynamics using a newly developed nonlinear model. The second paper investigated the effect of a typical North Sea storm climate on sand wave dynamics by combining a statistical approach with the earlier developed linear stability model.

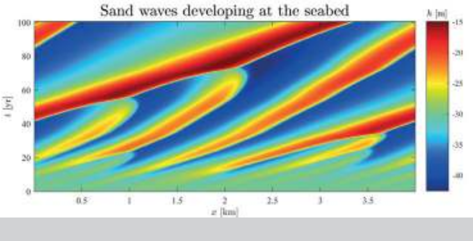
Subproject 2 (J.M. Damen): Paper on spatially varying environmental properties controlling observed sand wave morphology using data analysis has been published.

Dissertations

1. Campmans, G. H. P. (2018). Modeling storm effects on sand wave dynamics. Enschede: University of Twente. https://doi.org/10.3990/1.9789036546003.

Scientific Publications

1. Campmans, G. H. P., Roos, P. C., de Vriend, H. J., & Hulscher, S. J. M. H. (2018). The influence of storms on sand wave evolution: a nonlinear idealized modeling approach. Journal of geophysical research. Earth surface, 123(9), 2070-2086. https://doi.org/10.1029/2018JF004616.
2. Campmans, G. H. P., Roos, P. C., Schrijen, E. P. W. J., & Hulscher, S. J. M. H. (2018). Modeling wave and wind climate effects on tidal sand wave dynamics: A North Sea case study. Estuarine, coastal and shelf science, 213, 137-147. https://doi.org/10.1016/j.ecss.2018.08.015.
3. Zhou, J. Q., Roos, P. C., Wu, Z. Y., Campmans, G. H. P., & Hulscher, S. J. M. H. (2018). Modelling sand wave fields on the Taiwan banks, Northern South China sea: The formation of two-scale sand waves in different periods. 59-59. Abstract from NCK-Days 2018, Haarlem, Netherlands.
4. Damen, J. M., Van Dijk, T. A. G. P., & Hulscher, S. J. M. H. (2018). Spatially Varying Environmental Properties Controlling Observed Sand Wave Morphology. Journal of geophysical research. Earth surface, 123(2), 262-280. https://doi.org/10.1002/2017JF004322.
5. Campmans, G.H.P., Roos, P.C., Hulscher, S.J.M.H. (2018). Modeling tidal sand wave recovery after dredging. Abstract from PECS2018, Galveston, Texas, USA.



Project leaders

Dr.ir. P.C. Roos

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

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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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., NIOZ

Funded %
STW

University	-
FOM	-
STW	-
NWO Other	89,5 %
Industry	10,5 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

Information
Ir. Johan H. Damveld
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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.

In collaboration with the DISCLOSE project, camera transects were analyzed which revealed that benthic organisms favor habitats in sand wave troughs compared to sand wave crests.

Finally, ongoing work aims to couple a biogeochemical model to a process-based morphological model (Delft3D).

Dissertations
-

Scientific Publications
1. van Gerwen, W., Borsje, B. W., Damveld, J. H., & Hulscher, S. J. M. H. (2018). Modelling the effect of suspended load transport and tidal asymmetry on the equilibrium tidal sand wave height. Coastal Engineering, 136, 56-64. doi:10.1016/j.coastaleng.2018.01.006.
2. Damveld, J. H., K. J. van der Reijden, C. Cheng, L. Koop, L. R. Haaksma, C. A. J. Walsh, K. Soetaert, B. W. Borsje, L. L. Govers, P. C. Roos, H. Olff and S. J. M. H. Hulscher (2018). Video Transects Reveal That Tidal Sand Waves Affect the Spatial Distribution of Benthic Organisms and Sand Ripples. Geophysical Research Letters. doi:10.1029/2018gl079858.
3. Damveld, J. H., K. J. van der Reijden, C. Cheng, L. Koop, L. R. Haaksma, C. A. J. Walsh, K. Soetaert, B. W. Borsje, L. L. Govers, P. C. Roos, H. Olff and S. J. M. H. Hulscher (2018). Replication Data for: Video transects reveal that tidal sand waves affect the spatial distribution of benthic organisms and sand ripples (Publication no. hdl/10411/4OARYB). from DataverseNL https://hdl.handle.net/10411/4OARYB.
4. Damveld, J. H., Maris, H. L., Borsje, B. W., Roos, P. C., & Hulscher, S. J. M. H. (2018). Self-organisation in a two-way coupled numerical model of benthic organisms and tidal sand waves. Paper presented at the ECSA 57, Perth.

RiverCare towards self-sustaining multifunctional rivers
Communication programma outcome: knowledge base, visualisation and virtual river

Project Aim

Subproject G1: “A serious gaming environment to support collaborative decision-making in river management” (den Haan)

Subproject G2: “The potencial of web-collaborative platforms to support knowledge exchange in river management” (Cortes Arevalo)

Progress

For subproject G1, a new concept was developed for the serious game, in development under the title of Virtual River, and a prototype is in development at the time of writing. The prototype covers a tangible user interface; an interface that uses physical objects to interact and manipulate digital information. This way, players are provided with an easy to use interface to interact with a hydrodynamic model, enabling non-expert players to work with hydrodynamic models and learning about their inner workings. Regarding academic output, two journal papers were published in the last year. The first publication, published in Sustainability, covers a literature review on how social learning outcomes of collaborative serious games have been evaluated. The second publication, published in the International Journal of River Basin Management, covers a social-constructivism analysis of river management challenges and the perspectives that different actors hold towards these challenges.

For subproject G2, we redesigned the rivercare website according to the usability tests that were carried out last year. The website is now available at www.rivercare.nl From this March onwards, we are inviting interested professionals from partner organizations to the RiverCare Symposium. Using the feedback of 44 participants about the storyline effectiveness, we created two storylines more about biodiversity recovery and biomass growth in the Rhine delta. The publication about the storylines evaluation will be submitted by the end of March to the Journal of Sustainability Science. Finally, two publications about the rivercare desing proces are under preparation. One is based on interview results to define priorities and the other is about the actual design process and evalation of the website effectiveness.

Dissertations

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Scientific Publications

1. Cortes Arevalo, V. J., Verbrugge, L. N. H., Haan, R.-J. den, Baart, F., van der Voort, M. C., & Hulscher, S. J. M. H. (2018). Users’ Perspectives About the Potential Usefulness of Online Storylines to Communicate River Research to a Multi-disciplinary Audience. Environmental Communication, 1–17. https://doi.org/10.1080/17524032.2018.150409.
2. den Haan, R. J., Fliervoet, J. M., van der Voort, M. C., Cortes Arevalo, V. J., & Hulscher, S. J. M. H. (2018). Understanding actor perspectives regarding challenges for integrated river basin management. International Journal of River Basin Management, 1–14. https://doi.org/10.1080/15715124.2018.1503186.
3. den Haan, R.-J., & van der Voort, M. (2018). On Evaluating Social Learning Outcomes of Serious Games to Collaboratively Address Sustainability Problems: A Literature Review. Sustainability, 10(12), 4529. https://doi.org/10.3390/su10124529.

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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Project leaders
SJMH Hulscher
Dr. K.M. Wijnberg
Research theme
Complex dynamics of fluids
Participants
Ir. L. Duarte Campos
Cooperations
Closely linked to:
NatureCoast Project
CoCoChannel Project.
Funded by
CONICYT Chile (National Commission of Scientific and Technological Research)
Funded %

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

Start of the project
2013
Information
Leonardo Duarte Campos
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Project Aim

The objective of this study is to understand and model the exchange of sand, between the nearshore zone and the dunes on a time scale of years to decades. As the accretionary part of the exchange is the least understood, an important part of this study will be to determine to what extent different characteristics of the intertidal beach influence the rates of aeolian sand transport. This project focuses on providing a better understanding of the extent to which the intertidal zone properly works as a sediment source for onshore aeolian transport. This zone is expected to be a crucial element in the relationship between dune development and the dynamics of nearshore bars in the long-term.

Progress

During this period the main focus of the project was the final submission of the thesis and the Phd thesis defence. Additionally, two papers were published in peer-reviewed scientific journal (Aeolian Research and Journal of Marine Science and Engineering).

Dissertations

1. Duarte Campos, L. A. (2018). Quantification methods for aeolian sand transport on beaches. https://doi.org/10.3990/1.9789036546676.

Scientific Publications

1. Goossens, D., Nolet, C., Etyemezian, V., Duarte Campos, L., Bakker, G. & Riksen, M. Field testing, comparison, and discussion of five aeolian sand transport measuring devices operating on different measuring principles. Aeolian Res., Volume 32 (2018), 1-13.
2. Duarte Campos, L., Wijnberg, K.M. & Hulscher, S.J.M.H. (2018). Estimating annual onshore aeolian sand supply from the intertidal beach using an aggregated-scale transport formula. J. Mar. Sci. Eng. 2018, 6, 127.

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. The PhD thesis has also been submitted and will be defended in April 25th.

Dissertations

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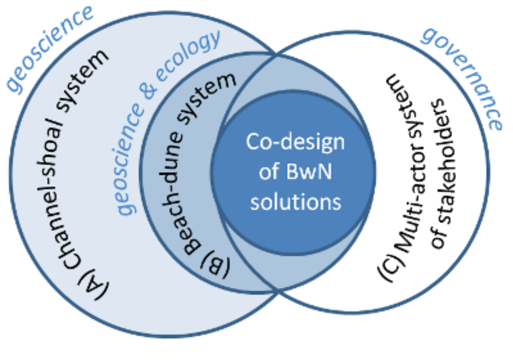
Scientific Publications

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. ; Groot, A. V. ; Hulscher, S. J. H. M. (2018). The influence of groundwater depth on coastal dune development at sand flats close to inlets. Ocean Dynamics. v. 1, p. 1-13.
3. Galiforni Silva, F.; Wijnberg, K. M.; Hulscher, S. J. H. M.. (Subm.). Storm-induced sediment supply to coastal dunes on sand flats.
4. 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).
5. Galiforni Silva, F.; Wijnberg, K. M. ; Groot, A. V. ; Hulscher, S. J. H. M. (2018) Analyzing the effect of beach width changes on coastal dune development using a Cellular automata model. In: 10th International Conference on Aeolian Research - ICAR X, 2018, Bordeaux. Book of Abstracts of the 10th International Conference on Aeolian Research.



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
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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

An one-dimensional hydraulic SOBEK model of the Dutch Rhine branches was adapted and applied to estimate the effects of main channel roughness uncertainty due to bedform dynamics on the water levels in the downstream river branches. Results show that local water level uncertainties propagate throughout the entire system through the bifurcation points.

DISSERTATIONS

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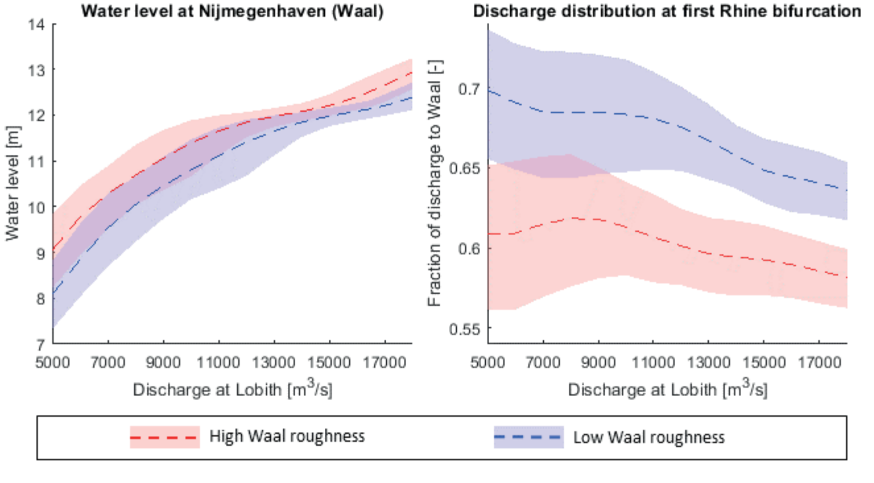
SCIENTIFIC PUBLICATIONS

1. Gensen, M.R.A. (2018). Large-scale uncertainties in river water levels: Literature report. CE&M research report 2018-001/WEM-001. Enschede: University of Twente.
2. Gensen, M.R.A., Warmink, J.J., & Hulscher, S.J.M.H. (2018). Large-scale uncertainties in river water levels. 122-123. Abstract from NCR Days 2018, Delft, Netherlands.



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

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SCIENTIFIC PUBLICATIONS

1. Harezlak, V., Augustijn, D. C. M., Geerling, G. W., Leuven, R., & Hulscher, S. J. M. H. (2018). Is the trait concept applicable to floodplains of regulated, temperate, lowland rivers?. 56-58. Abstract from NCR Days 2018, Delft, Netherlands.
2. Harezlak, V., Augustijn, D. C. M., Leuver, R., & Geerling, G. W. (2018). Measuring and modelling plant traits in floodplains of regulated rivers. Abstract from International Symposium on Ecohydraulics, Tokyo, Japan.

PROJECT LEADERS

SJMH Hulscher, DCM Augustijn

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

V. Harezlak, RSEW Leuven

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. S.J.M.H. Hulscher

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
H.Holzhauer
dr. ir. B.W. Borsje
prof. dr. S.J.M.H. Hulscher
prof. dr. P.M.J. Herman
dr. ir. K.M. Wijnberg

COOPERATIONS
Delft University of Technology
Utrecht University

FUNDED BY
STW

FUNDED %

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

START OF THE PROJECT
2016

INFORMATION
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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

Habitat mapping and selection sample locations in preparation of the field campaign. September 2017 large field campaign. March 2018 field campaign update nourishment location. Based on the multivariate analysis of the species abundance data retrieved during the field campaign last year in the Ameland ebb tidal delta. We see that the species assemblages match rather well with the pre-defined habitats, suggesting a strong relationship with the environmental parameters defining the habitat. However, there are exceptions to this pattern, indicating that other factors also play a role. Unravelling these factors is subject of further study.

DISSERTATIONS

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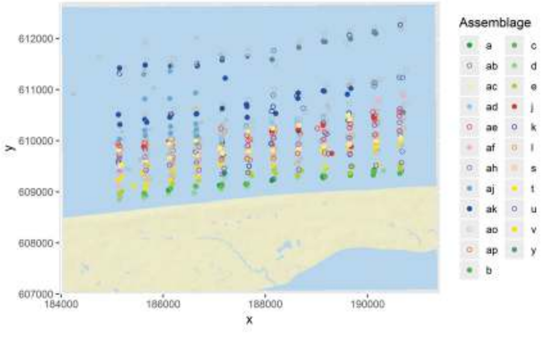
SCIENTIFIC PUBLICATIONS

1. Holzhauer, H. (2018). Ecology and bed composition of the Amelander Zeegat, Presentation NCK-themadag: Sediment sorting, 11 jan 2018, Delft, The Netherlands.
2. Schipper, C., Holzhauer, H. & van Hal, R. (2018). Ecologisch onderzoek van de pilot suppletie buitendelta Ameland. Presentation at Midterm congres: de Tussenstand, 18-10-2018, Amersfoort, Netherlands.
3. van Prooijen, B. C., de Looff, H., Holzhauer, H., Mol, J., van Maarseveen, M. C. G., de Wit, F. P., Wang, Z. B. (2018). Kustgenese 2.0/SEAWAD - Ameland inlet field campaign. 45-45. Abstract from NCK-Days 2018, Haarlem, Netherlands.
4. Holzhauer, H., Verduin, E., Borsje, B. W., Hulscher, S. J. M. H., & Herman, P. M. J. (2018). The ebb-tidal delta: bare or rare?. 76-76. Abstract from NCK-Days 2018, Haarlem, Netherlands.



Distribution of benthic species in the near shore of the barrier island Ameland in the Netherlands. Gray dots are benthic species assemblages with a frequency less than 1 percent of all locations, grey cross are the assemblages with less than five locations in a morphological zone, coloured circles are representative assemblages present in one or more morphological zones, coloured dots are the key assemblages in the near shore.

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 the past year:

- Presenting the results of the paper "Quantifying Bed Level Change at the Transition of Tidal Flat and Salt Marsh: Can We Understand the Lateral Location of the Marsh Edge?" at the ECSA conference in Perth, Australia.
- Publishing the paper: "Quantifying Bed Level Change at the Transition of Tidal Flat and Salt Marsh: Can We Understand the Lateral Location of the Marsh Edge?" in JGR: Earth Surface.
- Publishing multiple papers as co-author.
- Progress has been made on the long-term wave attenuation of foreshores in the Westerschelde, a manuscript containing a data analysis will be finalized. Modelling attempts with a 1D equilibrium model and a 2D process-based model are successful and will be the input for two other manuscripts.

Dissertations

-

Scientific Publications

1. Taillardat, P., Willemsen, P. W. J. M., Marchand, C., Friess, D. A., Widory, D., Baudron, P., ... Ziegler, A. D. (2018). Assessing the contribution of porewater discharge in carbon export and CO2 evasion in a mangrove tidal creek (Can Gio, Vietnam). Journal of hydrology, 563, 303-318. https://doi.org/10.1016/j.jhydrol.2018.05.042.
2. Best, Ü. S. N., Van der Wegen, M., Dijkstra, J., Willemsen, P. W. J. M., Borsje, B. W., & Roelvink, D. J. A. (2018). Do salt marshes survive sea level rise? Modelling wave action, morphodynamics and vegetation dynamics. Environmental modelling & software, 109, 152-166. https://doi.org/10.1016/j.envsoft.2018.08.004.
3. Willemsen, P. W. J. M., Borsje, B. W., Hulscher, S. J. M. H., Van Der Wal, D., Zhu, Z., Oteman, B., ... Bouma, T. J. (2018). Quantifying Bed Level Change at the Transition of Tidal Flat and Salt Marsh: Can We Understand the Lateral Location of the Marsh Edge?Journal of geophysical research. Earth surface, 123(10), 2509-2524. https://doi.org/10.1029/2018JF004742.

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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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
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

A data paper has been published in Earth System Science Data. The paper describes the Raam regional soil moisture measuring network. Corresponding data is published at 4TU.Datacentre. Furthermore, a paper on the information use in Dutch regional operational water management was published end of 2018 in Environmental Science & Policy. The main findings are that experiential information is still an important aspect in regional operational water management, while hydrological model output does not significantly contribute to decision-making. Furthermore, a presentation was given at the EGU General Assembly on the use of remotely sensed surface soil moisture information for increasing the accuracy of a root zone soil moisture model.

DISSERTATIONS

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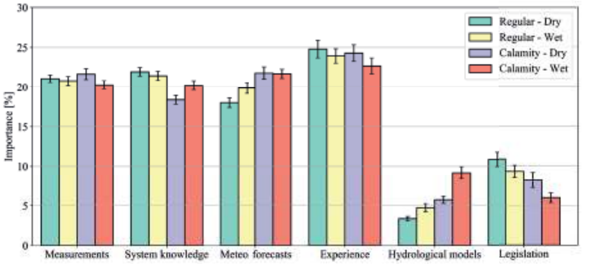
SCIENTIFIC PUBLICATIONS

1. Benninga, H.F., Carranza, C.D., Pezij, M., Van der Ploeg, M.J., Augustijn, D.C.M., Van der Velde, R. (2018) Regional soil moisture monitoring network in the Raam catchment in the Netherlands - 2017-04 / 2018-04. University of Twente. Dataset. DOI: 10.4121/uuid:afb36ac8-e266-4968-8f76-0d1f6988e23d
2. Benninga, H. J. F., Carranza, C. D. U., Pezij, M., van Santen, P., van der Ploeg, M. J., Augustijn, D. C. M., & van der Velde, R. (2018). The Raam regional soil moisture monitoring network in the Netherlands. Earth Syst. Sci. Data, 10(1), 61-79. doi:10.5194/essd-10-61-2018.
3. Pezij, M., Augustijn, D. C. M., Hendriks, D., & Hulscher, S. J. M. H. (2018). Application of Sentinel-1 soil moisture information for improving groundwater simulations. Abstract from EGU General Assembly 2018, Vienna, Austria.
4. Pezij, M., Augustijn, D. C. M., Hendriks, D. M. D., & 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.



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 geometry on the long-term morphological evolution of barrier coasts. This allows us to study the effect of basin geometry on the size and spacing of tidal inlets. Furthermore, we developed a barrier coast model that includes storm-induced breaches to study the effect of these breaches on the long-term morphological evolution of barrier coasts. Next, we will study the effect of climate change induced changes in storm climate on the long-term morphological evolution of barrier coast.

Dissertations

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Scientific Publications

1. Reef, K.R.G., Andringa, T.E., Roos, P.C., Dastgheib, A, S.J.M.H. (2018). Long-term morphological behavior of barrier coasts: influence of storm-induced breaches using stochastic modelling. In: book of abstracts NCK days 2018. 21-23 March 2018. Haarlem, the Netherlands.
2. Reef, K.R.G., Roos, P.C., Schuttelaars, H.M., Hulscher, S.J.M.H. (2018). WADSnext! Morphodynamic modelling tools for the sustainable management of barrier coasts. In: book of abstracts ISISA 2018. Islands of the world conference 2018. 10-14 June 2018. Leeuwaarden-Terschelling, the Netherlands.

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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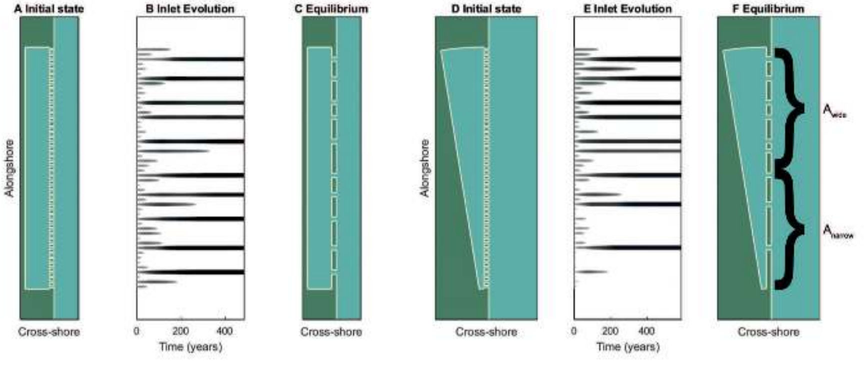

Figure 4: Two example runs, one with rectangular tidal basin (panels A-C) and the other with conically shaped tidal basin (panels D-F), with indication for the total inlet area in the wide part of the basin A_{wide} and the narrow part of the basin A_{narrow}. Panels A and D show a saturated coast in the initial state. Panels B and E show the evolution of the tidal inlets during the model run. Panels C and F show the equilibrium state in which each inlet no longer evolves over time.

PROJECT LEADERS
Prof. dr. S.J.M.H. Hulscher
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
R.P. van Denderen, MSc
Dr. R.M.J. Schielen
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, due to erosion and sedimentation processes in the side channel, regular maintenance is required. An optimal design of a side channel minimizes the costs of maintenance, but the knowledge of the processes in and around a side channel is yet not sufficient. The goal of this research is to reduce the amount of required maintenance in side channels and to gain a better understanding of the hydrodynamic and morphodynamic processes in a side channel system.

PROGRESS

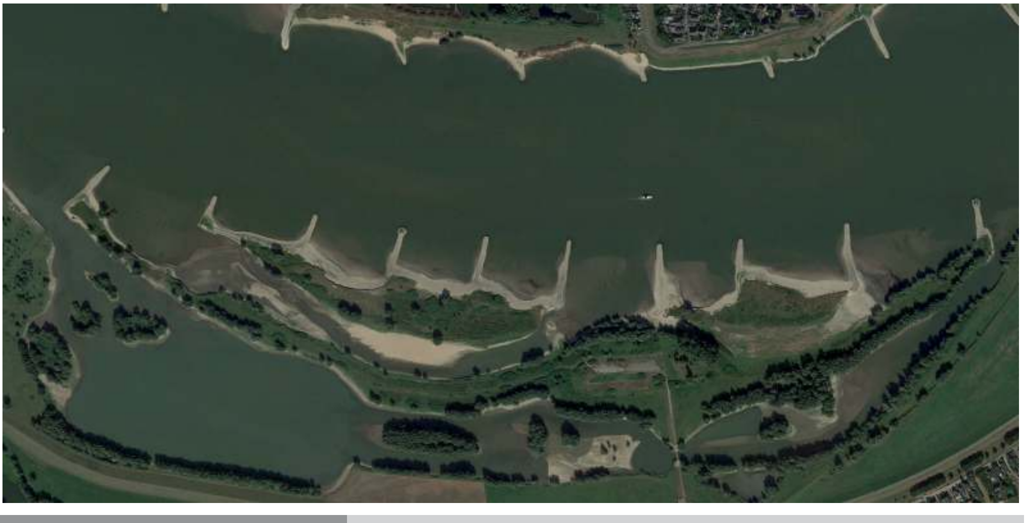
We carried out measurements in a Dutch side channel system. We mainly looked at morphodynamic changes and sediment characteristics in this side channel system. Based on these and other measurements we characterize the development of side channel using three categories. For each of these categories we use simple relations to estimate the development of side channel systems. This method can support river managers in their design, operation and maintenance of side channel systems.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Van Denderen, R. P., R. M. J. Schielen, A. Blom, S. J. M. H. Hulscher, and M. G. Kleinhans, 2018: Morphodynamic assessment of side channel systems using a simple one-dimensional bifurcation model and a comparison with aerial images. Earth Surface Processes and Landforms, 43, 1169¬¬-1182, doi:10.1002/esp.4267.
2. Van Denderen, R. P., Hulscher, S. J. M. H., & Schielen, R. M. J., 2018: A simple estimation of side channel development. In A. Armanini, & E. Nucci (Eds.), New Challenges in Hydraulic Research and Engineering: Proceedings of the 5th IAHR Europe Congress, Trento, Italy, 471-472. doi:10.3850/978-981-11-2731-1_106-cd.



The effect of mega-nourishment projects on sand supply to the dunes

Project Aim

Recently, a mega-nourishment (21 Mm3 of sand) has been built at the Dutch coast. This is an innovative way of nourishing and is expected to protect the coast for approximately 20 years. The aim of the study is to describe and explain the impact of mega-nourishments on spatial and temporal variation in aeolian sediment supply (i.e. wind-driven) towards the upper beach and foredunes on a medium long time scale (e.g. 20 years). Currently, it is still unresolved how to estimate longer term and larger scale dune behavior, although this knowledge is essential for assessing coastal dune safety. The research is part of an "STW Perspectief Programma" NatureCoast.

Progress

A method has been developed which allows for the automated detection of wind-driven sediment transport events in video images. The method compares favorably with manually labeled images. Identified transport events correspond with significant peaks in measured transport. The methodology was published in a peer-reviewed scientific journal, and the code has been published open source through GitHub (https://github.com/iw108/coastal-images.).

Dissertations

-

Scientific Publications

1. Williams, I. A., Wijnberg, K. M., & Hulscher, S. J. M. H. (2018). Detection of aeolian transport in coastal images. Aeolian research, 35, 47-57. https://doi.org/10.1016/j.aeolia.2018.09.003.
2. Wijnberg, K., J. Limpens, C. Nolet, M. van Puijenbroek, M. Riksen, I. Williams (2018). Mega-nourishments and aeolian developments: lessons learned six years into the Sandmotor Pilot project. Proceedings of 36th Conference on Coastal Engineering, Baltimore, Maryland, USA. https://doi.org/10.9753/icce.v36.sediment.55.

Project leaders
Dr. K.M. Wijnberg

Research theme
Complex dynamics of fluids

Participants
Isaac Williams MSc
Prof. Dr. S.J.M.H. Hulscher

Cooperations
Wageningen University
Delft University of Technology
Utrecht University
VU University of Amsterdam
NIOZ
Alterra
United States Geological Service (USGS)
Deltares

Funded by
STW

Funded %

University	40 %
FOM	-
STW	60 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

Information

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The influence of roughness, berms and oblique waves on wave overtopping erosion at dikes

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

(This research project focuses on the wave overtopping at flood defences, which is affiliated with Project D3 of All-Risk program. (a) Experiments on the overtopping over a dike with berms and roughness elements will be conducted and the influence of berms and roughness on wave overtopping discharges will be studied (b) Numerical model of wave overtopping and overtopping flow parameters on the seaward slope will be performed (c) Combined influence of berms, roughness and oblique waves will be studied by analyzing the existing data.

Progress

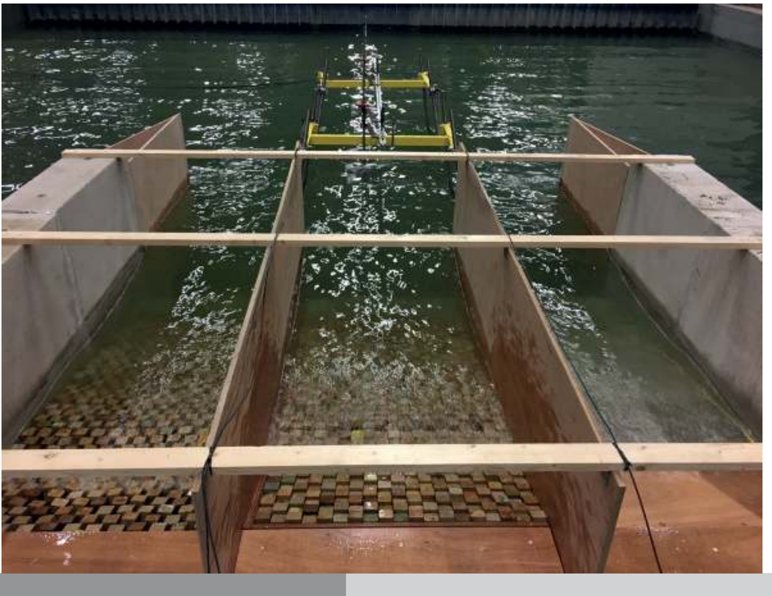
- Writing the literature report and research proposal
- Finished the experimental plan about the effect of roughness on the overtopping discharge
- Finish the literature report and research proposal
- Finish the qualifier
- Finish the experiments on the influence of berms and roughness on the wave overtopping and data analysis of the experimental data
- Finish the first paper and ready for submission.

Dissertations

-

Scientific Publications

1. Warmink, J. J., van Bergeijk, V. M., Chen, W., & Hulscher, S. J. (2018). Modelling wave overtopping for flood defence reliability, the outline of a research project. In 36th International Conference on Coastal Engineering 2018.



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

The PhD candidate has written a proposal and literature review. Also, the candidate has started with some basic modelling of the hydrodynamics in the swash zone.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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

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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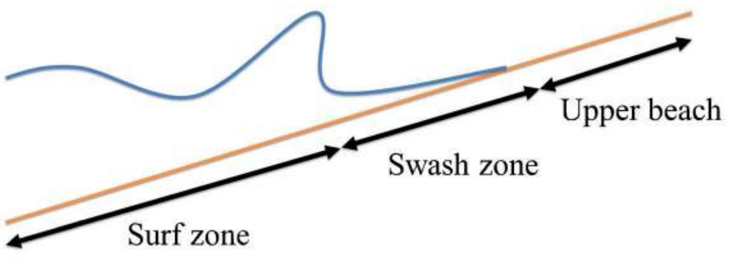

Experiment-supported modelling of beach-dune evolution in interaction with the built environment

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
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 finished my research proposal and qualifier, conducted a first round of field experiments to answer the first research question and recently submitted a conference paper. Currently, I am preparing a second field experiment.

Dissertations

-

Scientific Publications

-

CFD Modeling of airflow over urbanized beaches and the impact of built environment on aeolian sediment transport

Project Aim

Coastal urbanization is rapidly developing in many countries around the world. Rapid urbanization in coastal zones has the potential to affect the local airflow patterns. The impact of airflow variations on coastal dunes are still not fully known. The main objective of this project is to understand the effect of the buildings and their configuration, including geometry, orientation, spacing as well as their distance to the dunefield on aeolian sediment transport.

Progress

The PhD student started in November 2018 and she is still working on her literature review and research proposal.

Dissertations

-

Scientific Publications

-

Project leaders

prof. dr. S.J.M.H. Hulscher
prof. dr. K.W. Wijnberg
dr. G.H.P Campmans

Research theme

Complex dynamics of fluids

Participants

P. Pourteimouri, MSc

Cooperations

NWO
Delft University of Technology

Funded by

NWO, University of Twente

Funded %

University	15 %
FOM	-
STW	-
NWO Other	85 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2018

Information

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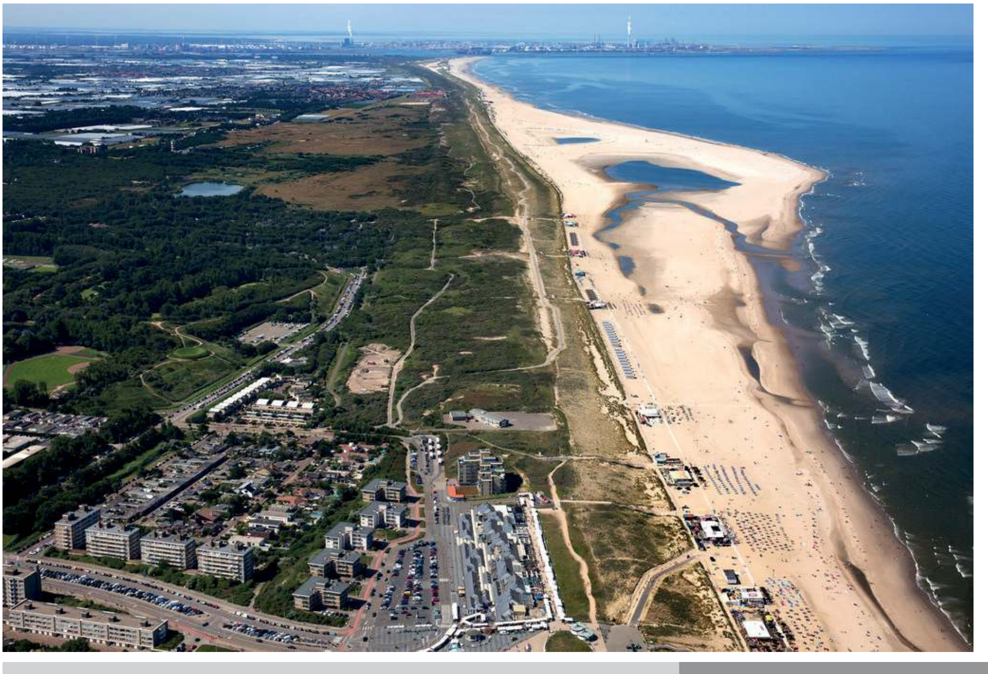

APPLIED ANALYSIS

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 nonlinear 2HD pseudo-spectral AB-code, with applications for waves in harbours and Jakarta bay 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. Lawrence, D. Adytia & E. van Groesen, Variational Boussinesq model for dispersive strongly nonlinear waves, Wave Motion 76 (2018) 78–102.
2. R. Kurnia, M. R. Badriana, E. van Groesen, Hamiltonian Boussinesq Simulations for waves entering a harbour with access channel, J. Waterway, Port, Coastal, Ocean Eng., 2018, 144(2): 04017047 1-14.

PROJECT LEADERS

E. van Groesen

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

R. Kurnia (PD-TUD, LMI)
A. P. Wijaya (LMI)
Lawrence (LMI)
P. Turnip (LMI)
Dr. Andonowati (LMI);

COOPERATIONS

LabMath-Indonesia, Bandung Indonesia (LMI)
TUD Ship hydromechanics & structures

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, Prof. C.H. Slump, Prof. B. Geelkerken

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
M. Koenrades

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 is a central problem in flow-structure interaction. Developments will 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

A systematic study of a large number of patients over several years was collected to provide reference material for statistical and modeling analysis. The registration of medical images was analyzed on the basis of a fluid-mechanical analogy, yielding a quantitative assessment of the resolution limits below which the data become no longer trustworthy.

Dissertations

-

Scientific Publications

1. Koenrades, M. A. , Klein, A. , Leferink, A. M. , Slump, C. H. , & Geelkerken, R. H. (2018). Evolution of the Proximal Sealing Rings of the Anaconda Stent-Graft After Endovascular Aneurysm Repair. Journal of Endovascular Therapy, 25(4), 480-491. https://doi.org/10.1177/1526602818773085.

Project Aim

Weather and ocean prediction requires solving the equations of fluid dynamics. However, our incomplete understanding of turbulence and other subgrid scale effects, 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 [Holm2015] in the equations of geophysical fluid dynamics we will try to improve weather forecasting, but more importantly also provide a proper 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.

Dissertations

-

Scientific Publications

1. Stochastic Lorenz 63 Equations, BJ Geurts, DD Holm, E Luesink, 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

-

Funded by

IC London, EPSRC

Funded %

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

Start of the project

2017

Information

Erwin Luesink
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PROJECT LEADERS
Prof. B.J. Geurts, Dr. J. Mikhal

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
A Hoving

COOPERATIONS
-

FUNDED BY
NWO, Veni

FUNDED %

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

START OF THE PROJECT
2016

INFORMATION
Julia Mikhal
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PROJECT AIM

The objective of this research is to develop experimental and computational methods to analyze the flow in realistic diseased vessel structures in the carotid and in the brain, with and without the placement of a precision stent to divert the flow away from affected areas. Healing patients with aneurysms is done more and more via endovascular surgery – predicting the outcome of surgery ahead of actual operation is a main goal, with focus on short-term effects of stent placement and long-term effects of stent integration. High-performance simulation methods were developed to capture flow down to the smallest details of flow diverting stents, and compared directly with experimental findings.

PROGRESS

To improve carotid artery stenting (CAS), more information about the functioning of the stent is needed. Therefore, a method that can image the flow near and around a stent is required. The aim is to evaluate the performance of high-frame-rate contrast-enhanced ultrasound (HFR CEUS) in the presence of a stent. In addition, numerical simulations were performed to quantify the flow and the experimental findings.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Astrid M Hoving, Jason Voorneveld, Evelien E De Vries, Erik Groot Jebbink, Michel Versluis, Johan G Bosch, Nico De Jong, Julia Mikhal, Gert J De Borst, Cornelis H Slump, In vitro high-frame-rate contrast-enhanced ultrasound particle image velocimetry in a carotid artery stent, Medical Imaging 2018: Ultrasonic Imaging and Tomography, Volume 10580.

High-performance simulation methods for turbulence modulation in bubbly flows

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.

Progress

A Volume-of-Fluid approach was adopted and a simulation method with excellent parallel performance was developed. More than 10^4 individual deformable bubbles can be successfully simulated in a turbulent channel flow in downflow configuration.

Dissertations

-

Scientific Publications

1. Highly scalable DNS solver for turbulent bubble-laden channel flow P Cifani, JGM Kuerten, BJ Geurts, Computers & Fluids 172, 67-83.

Project leaders

Prof. B.J. Geurts, Dr. P. Cifani

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

S. Ephrati, J. Froehlich

Cooperations

-

Funded by

NWO

Funded %

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

Start of the project

2018

Information

Bernard Geurts
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REPORTS OF INDIVIDUAL RESEARCH GROUPS

university of groningen

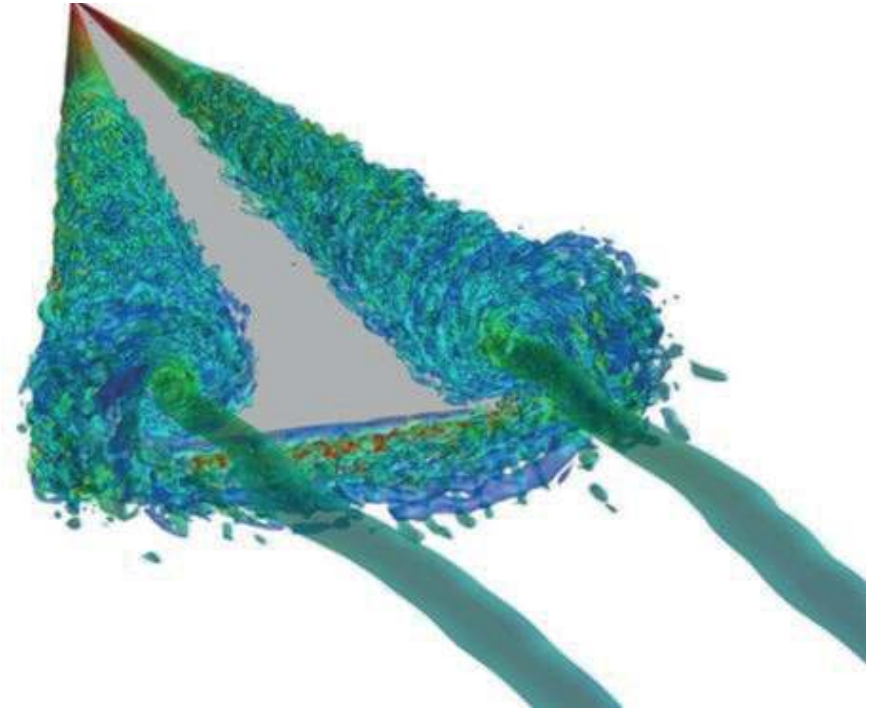
COMPUTATIONAL MECHANICS AND NUMERICAL MATHEMATICS (CMNM)

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. For the numerical coupling between the solid mechanics and the fluid dynamics a quasi-simultaneous class of methods has been developed that is stable for any added-mass ratio. The dispersive absorbing boundary conditions now do allow for current. Applications are e.g. free-fall life boats, dock ships, floating buoys and elastically deforming objects. Much effort has been spent in testing the code and preparing it for final release to the project partners.

Dissertations

-

Scientific Publications

1. A.E.P. Veldman, H. Seubers, S. Matin Hosseini Zahraei, P. van der Plas, Peter R. Wellens. Rene H.M. Huijsmans. Preventing the added-mass instability in fluid-solid coupling for offshore applications. 37th Int. Conf. Ocean, Offshore and Arctic Eng., Madrid, 17-22 June, 2018. paper OMAE2018-77308, 10 pages.
2. P. van der Plas, A.E.P. Veldman, Joop Helder, Ka-Wing Lam. Adaptive grid refinement for two-phase offshore applications. 37th Int. Conf. Ocean, Offshore and Arctic Eng., Madrid, 17-22 June, 2018. paper OMAE2018-77309, 10 pages.

Project leaders

A.E.P. Veldman

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

P van der Plas, H Seubers, AEP Veldman (RUG), M Hosseini, X Chang, I Akkerman,P Wellens, RHM Huijsmans (TUD), J Helder, T Bunnik (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	90 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	10 %

Start of the project

2014

Information

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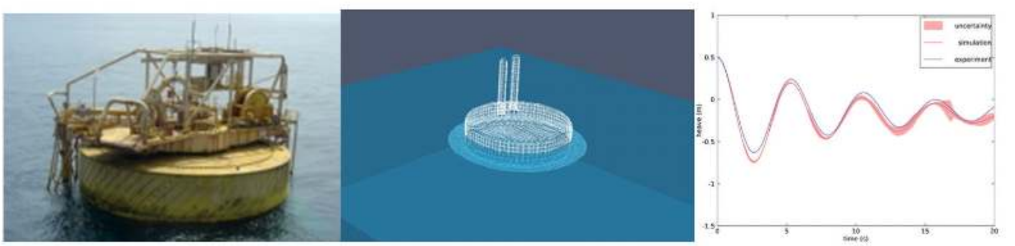
Left: a CALM buoy at sea. Middle: its representation in a numerical simulation. Right: validation of the heave motion with experiment



Project leaders
A.E.P. Veldman
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
RA Remmerswaal, AEP Veldman (RUG), M Kaminski (TUD), H Bogaert (MARIN), L Brosset (GTT) + many more
Cooperations
MARIN, TU Delft, TU Eindhoven, Univ Twente, GTT (France) + many more
Funded by
STW
Funded %

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

Start of the project
2016
Information
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Project Aim

The SLING project studies liquid sloshing in cargo tanks for liquid natural gas (LNG). Of particular interest is the flow just before and during impact with the tank wall. Flow instabilities and phase transition have to be modelled. The CFD method is based on the ComFLOW code developed in a parallel project.

Progress

The RUG contribution to the project focusses on the simulation of flow instabilities, like Kelvin-Helmholtz, Rayleigh-Taylor and Rayleigh-Plateau. Capillary forces and turbulence also play a role. These delicate physical processes require high numerical accuracy. After reduction of the spurious velocities, the calculation of the curvature-related surface tension effects has been improved. As the thin shear layer along the free surface cannot be resolved by the grid, the solution is allowed to be discontinuous in the tangential velocity component and, correspondingly, in the pressure gradient. The illustration clearly shows this discontinuous character of the velocity field.

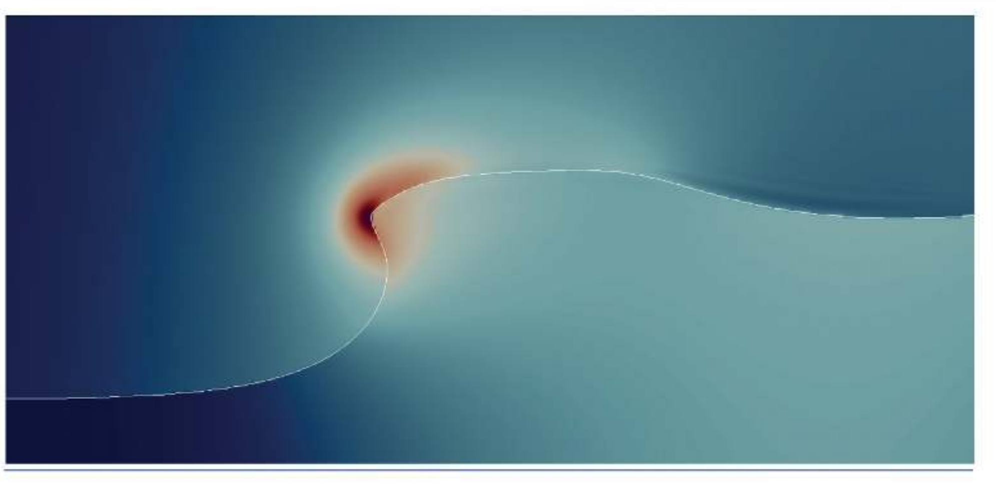
Dissertations

-

Scientific Publications

-

Two-phase simulation of a breaking wave. The color shows the velocity, which changes rather abruptly across the free surface.



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

-

Scientific Publications

1. Optimal Dual-VENC (ODV) Unwrapping in Phase-Contrast MRI. H. Carrillo, A. Osses, S. Uribe, C. Bertoglio. IEEE Trans. Medical Imaging, 2018. DOI. Preprint.
2. Relative pressure estimation from 4D velocity measurements in blood flows: state-of-the-art and new approaches. C. Bertoglio, R. Nuñez, F. Galarce, D. Nordsletten, and A. Osses. Int.J.Num.Meth.Biomed.Eng., 34:e2925, 2018. DOI
3. Benchmark problems for numerical treatment of backflow at open boundaries. C. Bertoglio, A. Caiazzo, Y. Bazilevs, M. Braack, V. Gravemaier, A. Marsden, M. Moghadam, O. Pironneau, I. Vignon, and W. Wall. Int.J.Num.Meth.Biomed.Eng., 34:e2918, 2018. DOI

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

Funded by

Chilean Science Foundation (Conicyt)

Funded %

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

Start of the project

2016

Information

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Project leaders
RWCP Verstappen
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
MH Silvis, LB Streher, J Parekh, HJ Bandringa, RA Remmerswaal, AEP Veldman, FX Trias (UPC), A Oliva (UPC), HJ Bae (CTR), P Moin (CTR)
Cooperations
Polytechnica University of Catalunya (UPC), Stanford University (CTR)
Funded by
NWO
Funded %

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

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

Our joint work with Stanford University (Center for Turbulence Research) and UPC Barcelona focused on the performance of subgrid-scale models for (rotating) turbulent flows and definition of length scales for large eddy simulations on highly anisotropic grids. A nonlinear subgrid-scale model was developed for rotating flows and successfully tested for rotating channel flows. A new subgrid characteristic length was proposed for turbulence simulations on anisotropic grids..

Dissertations

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Scientific Publications

1. R. Verstappen, A discrete scale-truncation model for LES In Direct and Large Eddy simulation X, D. Grigoriadis et al (eds) pp 157-164 Springer, 2018.
2. M.H. Silvis, R. Verstappen, Nonlinear subgrid-scale models for large-eddy simulation of rotating turbulent flow. In Direct and Large Eddy simulation XI, M. Salvetti al (eds) pp 129-134 Springer, 2018.
3. R. Verstappen, On closing large-eddy simulations, ERCOFTAC Bulletin 116, 26-31, 2018.
4. L.B. Streher, M.H. Silvis, R. Verstappen, Mixed modeling for large-eddy simulation: the minimum-dissipation-Bardina model, arXiv:1806.11317, 2018 Also: Proceedings 7th European Conference on Computational Fluid Dynamics, R. Owen et al (eds) page 335-345, 2018.
5. W. Rozema, R.W.C.P. Verstappen, A.E.P. Veldman, J. Kok, Low-dissipation simulation models for turbulent subsonic flow, Archives of Computational Methods in Engineering, 1-32, 2018.
6. L.B. Streher, P. Cifani, R.W.C.P. Verstappen, Application of the minimum-dissipation model to turbulent bubble-laden flows, In: Proceedings 12th Int Ercoftac Symposium on Engineering Turbulence Modeling and Measurement ETMM12, 6 pp. Montpelier, 26-28 Sept. 2018.
7. R. Verstappen, How much eddy dissipation is needed to counterbalance the nonlinear production of small, unresolved scales in a large-eddy simulation of turbulence? Computers & Fluids, 176, 276-284, 2018.
8. R. Verstappen, A minimum-relaxation model, In Turbulence and Interactions TI2015, M.O. Deville et al (eds) 255-262, Springer, 2018.
9. R. Verstappen, A minimum-relaxation model, In Turbulence and Interactions TI2015, M.O. Deville et al (eds) 255-262, Springer, 2018.
10. M.H. Silvis, R. Verstappen, Constructing physically consistent subgrid-scale models for large-eddy simulation of incompressible turbulent flows, In Turbulence and Interactions TI2015, M.O. Deville et al (eds) 241-248, Springer, 2018.

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

Tests with the parallel implementation of the dynamical orthogonal field method (DO method) on the quasi-geostrophic (QG) model are still in progress. With this method, we can compute the influence of noise on the solution, which, especially near bifurcation points, is very challenging. First results were obtained with a projected version of Trajectory-Adaptive Multilevel Sampling method to compute transition probabilities in quasi-geostrophic flow. The projected version makes it feasible to compute the transition probabilities for PDE problems. Hardware problems of Cartesius are hindering scaling experiments with our linear equation solver for incompressible Navier Stokes equations. Hopefully we can performe the desired experiments in due time..

Dissertations

-

Scientific Publications

1. Mulder, TE, Baars, S, Wubs, FW & Dijkstra, H 2018, ‘Stochastic marine ice sheet variability’ Journal of Fluid Mechanics, vol. 843, pp. 748-777. https://doi.org/10.1017/jfm.2018.148.
2. Song, W, Wubs, F, Thies, J & Baars, S 2018, ‘Numerical bifurcation analysis of a 3D turing-type reaction–diffusion model’ Communications in nonlinear science and numerical simulation, vol. 60, pp. 145-164. https://doi.org/(...)/j.cnsns.2018.01.003.

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

Funded %

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

Start of the project

1994

Information

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Reports of Individual Research Groups

Wageningen University & Research

Experimental Zoology (EZ)

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 fruit flies control rapid banked turns when escaping looming objects [1]. Based on previous research, we hypothesized that fruit flies use a proportional-integral (PI) controller based on haltere feedback to modulate roll and pitch torques throughout the banking maneuver, and that yaw is not controlled at all. We tested these hypotheses by programming the suggested PI-controller in a bio-inspired aerial robotic flapper developed at MAVlab, TU Delft. The resulting maneuvers of the robot were strikingly similar to those of the fruit flies, suggesting that fruit flies use a similar controller. The robot simulations also allowed us to show that yaw is not actively controlled, but that sideslip-reducing yaw rotations observed in both the robot and fruit fly are the result of a newly identified aerodynamic torque coupling mechanism..

Dissertations

-

Scientific Publications

1. Karásek M, Muijres FT, De Wagter C, Remes BDW, De Croon GCHE. 2018 A tailless aerial robotic flapper reveals that flies use torque coupling in rapid banked turns. Science 361, 1089–1094.

Project leaders
FT Muijres

Research theme
Complex dynamics of fluids

Participants
JL van Leeuwen, promotor

Cooperations
MH Dickinson (Caltech, USA)
Dr. GCHE de Croon (TU Delft)

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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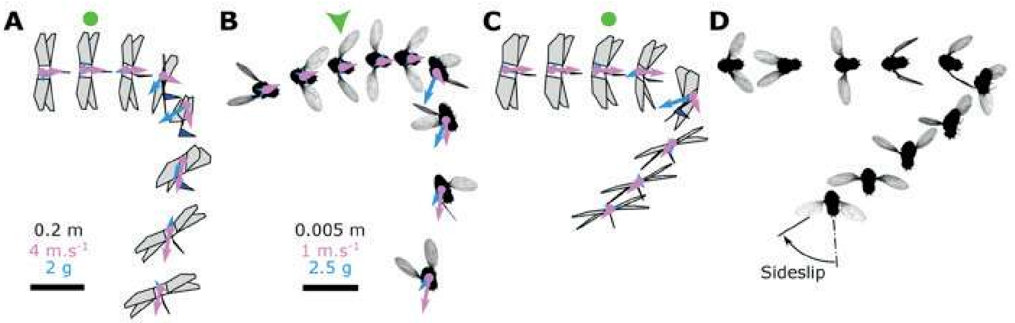
http://wur.eu/ezo



The robotic flapper mimics the banked turns of evading fruit flies, as shown by the photomontages of the robotic flapper (A,C) and two fruit flies (B,D), viewed from above. Sizes, flight velocity vectors (pink), and weight-normalized forces (blue) for the robot and flies are scaled according to the scale bars in (A) and (B), respectively. (A,B) Banking maneuvers dominated by roll rotations; (C,D) Banking maneuvers dominated by pitch up rotations. The robot maneuvers were reconstructed using recorded data. 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

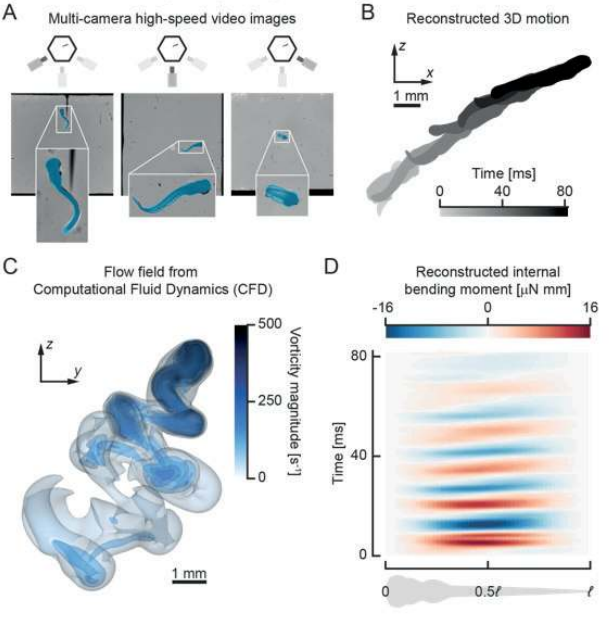
We published a review on the biomechanics of swimming in developing larval fish, discussing the challenges of swimming in the intermediate Reynolds number regime. Furthermore, we calcu¬lated internal bending moment distributions of a large data set of swimming zebrafish larvae. This was done from reconstructed kinematics and 3D computational fluid dynamics with a state-of-the-art inverse dynamics approach. An article about the results is currently in preparation, as well as an article on the swimming motion and hydrodynamic forces during escape responses.

Dissertations

-

Scientific Publications

1. Voesenek CJ, Muijres FT, Van Leeuwen JL. (2018) Biomechanics of swimming in developing larval fish. Journal of Experimental Biology. 221(1): jeb149583.
2. Fleuren, M., Van Leeuwen, JL, Quicazan-Rubio, EM, Pieters, RPM, Pollux, BJA, Voesenek, CJ. (2018) Three-dimensional analysis of the fast-start escape response of the least killifish, Heterandria formosa. Journal of Experimental Biology. 221(7): jeb168609.



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 malaria 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

In collaboration with industrial designers from TU Delft, a new and improved odor-baited trap (figure 1) has been designed and successfully tested in the lab (Wageningen) and in semi-field condition (Tanzania). The modification of the trap's canopy as well as the addition of heat and moisture around the trap lead to improved capture rates up until 4.9 times the one the baseline trap. Finally, we build a flight arena capable of running experiments automatically while tracking free-flying mosquitoes in the dark. It will be used to study mosquitoes escape dynamics in various light conditions when swatted by a piston simulating a threat.

Dissertations

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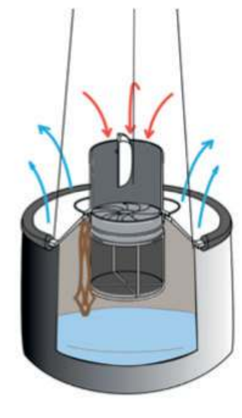
Scientific Publications

1. Cribellier A, van Erp JA, Hiscox A, Lankheet MJ, van Leeuwen JL, Spitzen J, Muijres FT. 2018 Flight behaviour of malaria mosquitoes around odour-baited traps: capture and escape dynamics. R. Soc. open sci. 5: 180246.

M-Tego I (left) and M-Tego II (right). M-Tego I has been tested both in the lab and in semi-field condition and showed greatly improved capture rates. Preliminary experiment with M-Tego II suggest that it has similar capture rates as the first but with an overall design that is more context appropriate.



Project leaders

FT Muijres

Research theme

Complex dynamics of fluids

Participants

A Cribellier (PhD candidate)
JL van Leeuwen (promotor)
MJM Lankheet (advisor)
A Hiscox (advisor)
J Spitzen (advisor)
W Takken (advisor)
RPM Pieters (technician)

Cooperations

J Casas (external advisor)
M Geier (external partner)
MH Dickinson (external advisor)
R Dudley (external advisor)

Funded by

Graduate School Wageningen Institute of Animal Sciences (WIAS)

Funded %

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

Start of the project

2016

Information

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To be as nimble as a bee: A bio-inspired sensory-motor system for gust control of Micro Air Vehicles

Project leaders
FT Muijres

Research theme
Complex dynamics of fluids

Participants
P Goyal (PhD candidate)
JL van Leeuwen (promotor)
MJM Lankheet (advisor)
RPM Pieters (technician)

Cooperations
G H C E de Croon (TU Delft)
B W van Oudheusden (TU Delft)
MH Dickinson (Caltech)

Funded by
NWO/STW

Funded %

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

Start of the project
2017

Information
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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. In contrast, insects easily navigate through complex environments in the presence of wind gusts. The aim of this project is to understand the gust rejection capabilities of insects (bumblebees and blowflies). As a first step towards understanding their gust rejection capabilities, we conducted experiments following the methods used in the domain of system identification wherein we recorded the closed-loop response of insects (kinematic states and wingbeat motion) to well-defined wind inputs (steady wind and sinusoidal wind profiles). This will provide insights into their variety of responses to wind gusts and how do they mitigate the effect of wind gusts.

Progress

The experimental apparatus for studying the gust rejection capabilities of insects has been designed, build and tested. This involved developing a method of training bumblebees to elicit a consistent flight behavior that can be replicated, calibrating an airspeed sensor (hot-wire CTA anemometer) using a custom-built apparatus, characterization of flow in the wind-tunnel from two different sources, setting-up and calibrating a stereoscopic high-speed videography system. Using this system, we then performed our experiments whereby we recorded the flight dynamics of bumblebees in 25 different wind conditions: a no wind case, five steady wind conditions (0.25, 0.7, 1.7, 2.7, 3.4 m/s), 16 sinusoidal varying wind cases (at 1, 2, 4 and 8Hz), and three multi-sine wind conditions (containing 2, 4 and 8 Hz wind profiles). Analysis of the resulting data is currently in progress.

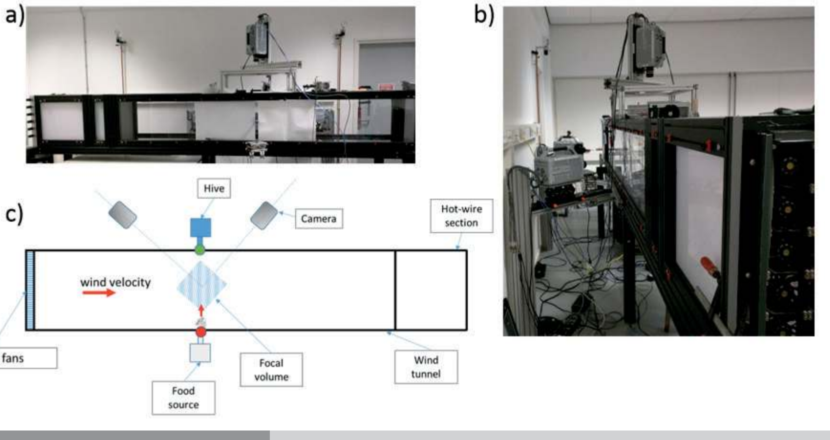
Dissertations

-

Scientific Publications

-

Experimental set-up a) side view b) front view c) schematic of top view, bumblebees flying from hive to food source and vice-a-versa are exposed to different wind profiles in mid-air and their response is captured by three high-speed cameras – two on the side and one at the top (not shown) - operating at 7200 fps.



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

We performed a detailed computational fluid dynamics investigation of the take-off of the mosquito. In a previous study the kinematics of the mosquito were captured in detail, which we used combined with the open-source immersed boundary method solver (IBAMR) to compute the aerodynamic forces and torques during the take-off. Our results show that the majority of forces and pitch-up torques generated by the mosquitoes during push-off are produced by the legs pushing off from the surface, and not by the wings. This suggests that during take-off mosquitoes use their wings primarily as a motor system, and the legs are used for control. Furthermore, we showed that the substrate from which the mosquito takes off does not affect aerodynamic force production, thus aerodynamic ground effects are negligible throughout the take-off of mosquitoes (figure 1).

Dissertations

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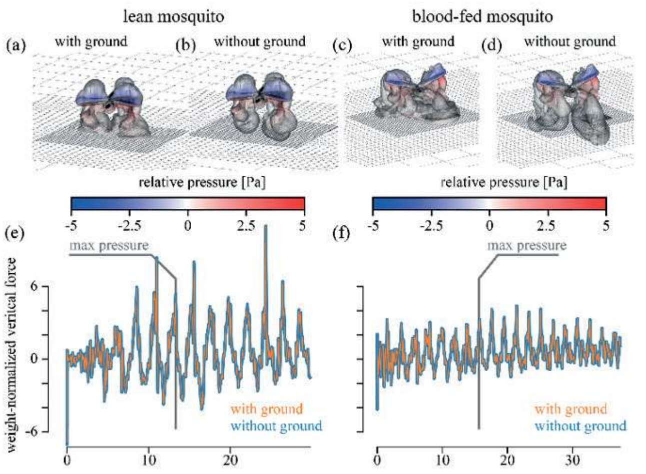
Scientific Publications

-

Ground effects are negligible throughout the take-off maneuver of a lean mosquito (left column) and blood-fed mosquito (right column). (a¬¬–d) Wake structure at the point within the take-off maneuver when pressure on the ground surface is maximum (see (e–f) for time), visualized using vorticity iso-surfaces at the vorticity level of 1000 s-1, color-coded with relative pressure. (e,f) Weight-normalized vertical aerodynamic forces produced by the lean mosquito (e) and blood-fed mosquito (f) throughout the take-off, when ground is present (blue) and without a ground (orange).



Project leaders

Dr. Ir. FT Muijres

Research theme

Complex dynamics of fluids

Participants

W.G. van Veen (PhD candidate)
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.

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

1. Simulation of shear-induced diffusion based separation processes. (Ivon Drijer; defended 10 October 2018, in Wageningen).

Scientific Publications

1. From highly specialized to generally available modelling of shear induced particle migration for flow segregation based separation technology, I Drijer, T van de Laar, HM Vollebregt, C Schroën, Separation and Purification Technology 192, 99-109.
2. Modelling Shear Induced Diffusion Based Particle Segregation: A Basis for Novel Separation Technology I Drijer, K Schroën, Applied Sciences 8 (6), 1008.

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	50 %
Industry	50 %
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

The ISPT-IPP Industrial Partnership Programme aims at understanding the rheology of complex emulsions and their stability under flow. We aim to do so by addressing the following questions: (i) How do the rheological properties and stability of emulsions depend on the interactions between the droplets, on the nature of the interfaces, and on the nature of the two liquid phases? (ii) How do these complex emulsions behave in confined flows, for example in porous media? (iii) How do different flow conditions affect the stability of the emulsions?

Progress

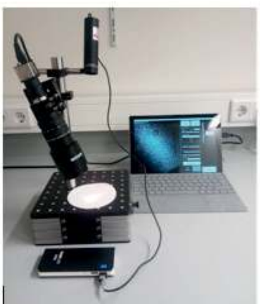
The project is mostly in a startup phase, in which we are exploring the novel experimental techniques needed for measuring aspects of emulsion rheology. PhD student Jesse Buijs is engaged in A quantitative analysis method for Laser Speckle Imaging (LSI) has been developed which is orders of magnitude faster than existing quantitative methods. We run this algorithm on a tablet connected to a portable LSI set-up to perform real-time quantitative flow imaging in opaque media. PhD student Bob Mulder is exploring to measure and understand the spatiotemporal microstructure in emulsions subject to flow within a confined microfluidic environment.

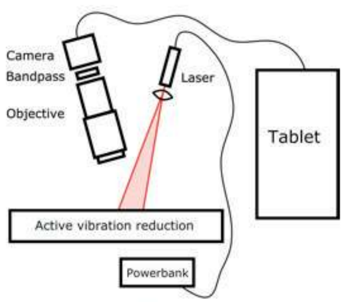
Dissertations

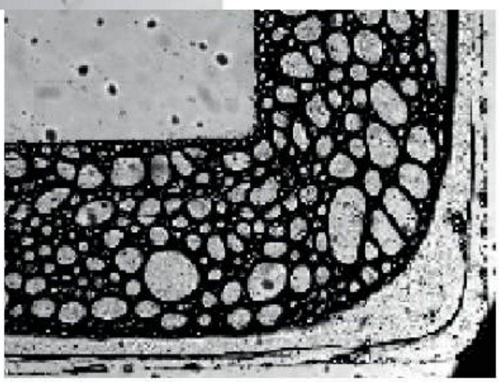
-

Scientific Publications

-







Project leaders

J van der Gucht

Research theme

Complex dynamics of fluids

Participants

Prof Dr Ir Jasper van der Gucht
Dr Joshua Dijksman
Prof Dr Ir Joris Sprakel
Jesse Buijs MSc
Bob Mulder MSc

Cooperations

Evodos, Unilever, Shell, UvA, UU, TUD

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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Utrecht University

Reports of Individual Research Groups

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

A statistical test has been developed to address the null hypothesis that sea-level fluctuations in the open ocean are solely due to additive noise in the wind stress. The effect of high-frequency wind stress variations can be represented as a correlated additive and multiplicative noise (CAM) stochastic model of sea-level variations. The good performance of this test has been shown using altimeter data at several locations in the open ocean. Current focus is on transition probabilities of the MOC under noise forcing using Trajectory adapted Multilevel Splitting methods.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. D. Castellana, F.W. Wubs and H. A. Dijkstra, A statistical significance test for sea-level variability, Dynamics and Statistics of the Climate System, 3, 1-16 doi:10.1093/climsys/dzy008, (2018).

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	-

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2016

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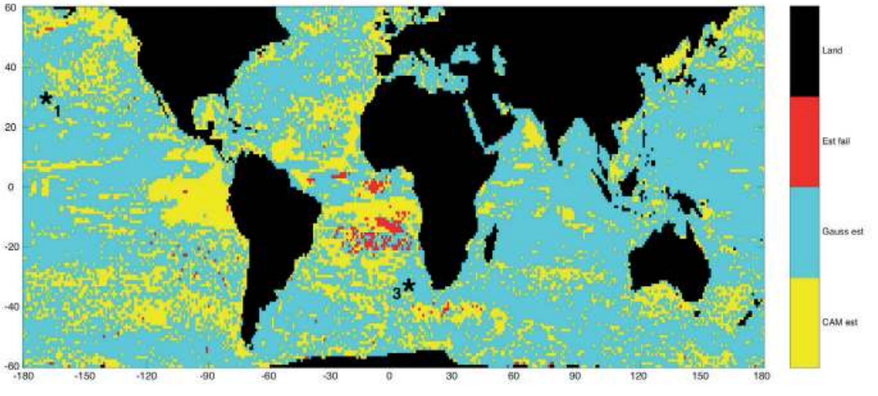
Overview of locations over the global ocean where Gaussian (blue) or CAM (yellow) noise better represent sea surface height variability as observed by satellite observations.



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	-

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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

1. Pillet, G., Ermanyuk, E.V., Maas, L.R.M., Sibgatullin, I.N. and Dauxois, T., 2018. Internal wave attractors in three-dimensional geometries: trapping by oblique reflection. Journal of Fluid Mechanics, 845, pp.203-225.
2. Pillet, G., Maas, L.R.M. and Dauxois, T., 2019. Internal wave attractors in 3D geometries: A dynamical systems approach. European Journal of Mechanics-B/Fluids. In press.

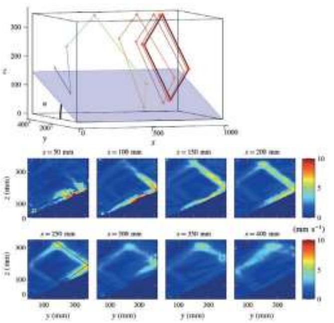


Figure 1: (a) Ray path of an internal wave beam that is launhed into a uniformly-stratified channel at x=0 into down-channel (positive x-) direction, showing trapping (and focusing) in perpendicular plane at some distance from its launching location. (b) Experimental observation of internal wave induced density perturbations in transverse (y,z) planes at increasing (x) distances from launching position. Figure from Pillet et al 2018.

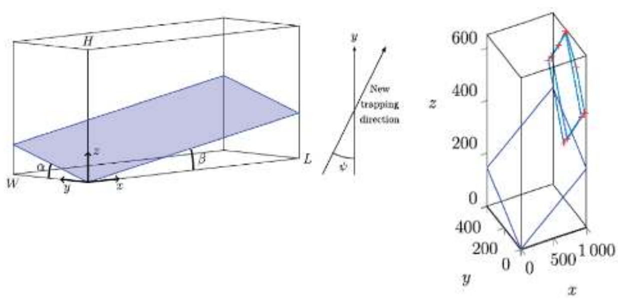
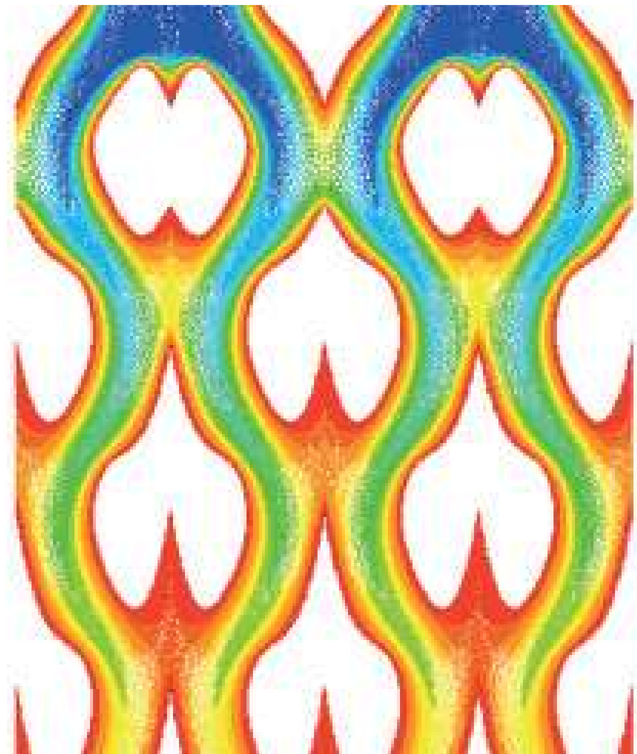


Fig. 2 (a) Uniformly-stratified channel having a bottom sloping both in cross-channel as well as along-channel direction, leading to (b) focusing of internal wave beams on a single limiting orbit (wave attractor). Figure from Pillet et al 2019.

Who & Where



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