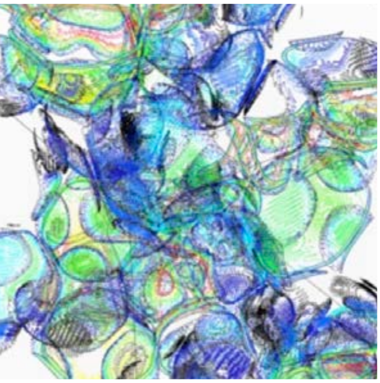
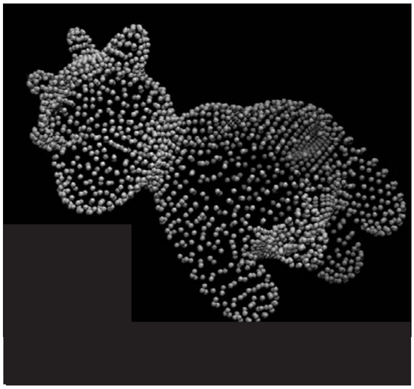
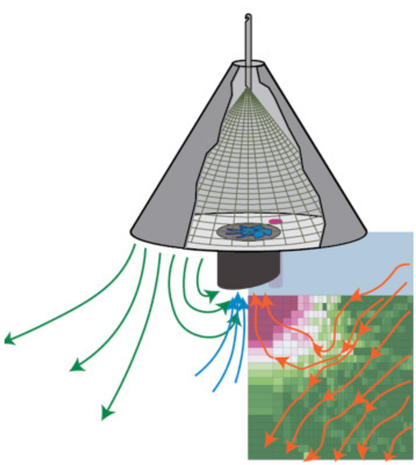




2017

Annual Report & Research Programme



J.M.Burgerscentrum

Research School for Fluid Mechanics

TUD, TUE, UT, RUG, WUR, UU

Annual Report & Research Programme 2017

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 2017. 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 (about 350). 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.

The JMBC course programme for the academic year 2017 – 2018 contains the following courses: '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' is organised jointly with the Von Karman Institute, and will be given in March 2018 in Brussels (B).

For the year 2018-2019 the following courses are planned: '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'.

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. Since the foundation of the research school, this used to be a one-day meeting, called the 'Burgersdag'. These annual meetings were usually well attended by junior and senior scientists involved in the JMBC and by many fluid-mechanics experts from industry, TNO and technological institutes. After some years it was felt that a two-day meeting would provide a much better platform for the community. As the format of the first Burgers Symposium in June 2016 in Conference Centre

‘De Werelt’ (Lunteren) was considered a great success, the second Burgers Symposium – in more or less the same format – was held 30-31 May 2017, again in ‘De Werelt’. The programme included two plenary lectures: the Burgers Lecture by Prof. Christophe Clanet (Ecole Polytechnique, Palaiseau, F) and the Evening Lecture by Prof. Vincent Icke (Sterrewacht Leiden, NL). Because in 2017 it was exactly 25 years since the JM Burgerscentrum received its first official recognition as ‘onderzoekschool’ (research school) by the Royal Netherlands Academy of Sciences (KNAW), attention to this historical fact was paid during the Symposium in a special session ’25 Years JMBC!’. Presentations were given by Prof. Jan Sengers (Burgers Program Maryland, USA) and Prof. Leen van Wijngaarden (UT), addressing some aspects of the scientist and the person Jan Burgers, after whom the JMBC is named. During this session, also a special biographical publication ‘Jan Burgers’ – prepared and edited by Prof. Jan Sengers and Prof. Gijs Ooms – was officially presented.

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 2016 (KIVI) was presented to the recipient, Dr. Joris Oosterhuis (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.

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 2017 a new group joined the JMBC: the group Urban Physics and Wind Engineering of Prof. Bert Blocken and his colleagues at the Department Civil Engineering / Built Environment at TU/e. In December 2017 this group celebrated the official opening of their Atmospheric Boundary Windtunnel, which is a unique facility that allows studying flows in the built environment on a model scale, but also full-scale studies of e.g. racing cyclists.

In 2017 the prestigious Fluid Dynamics Prize of the American Physical Society (APS) was awarded to Prof. Detlef Lohse (UT), for his outstanding role in fluid dynamics research. He received the prize at the APS Fluid Dynamics meeting 2017, which took place in November 2017 in Denver (USA).

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 receives financial support from the 4TU Federation. This support is 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. A number of calls for proposals have been issued in 2017, and the majority of the submitted applications were granted.

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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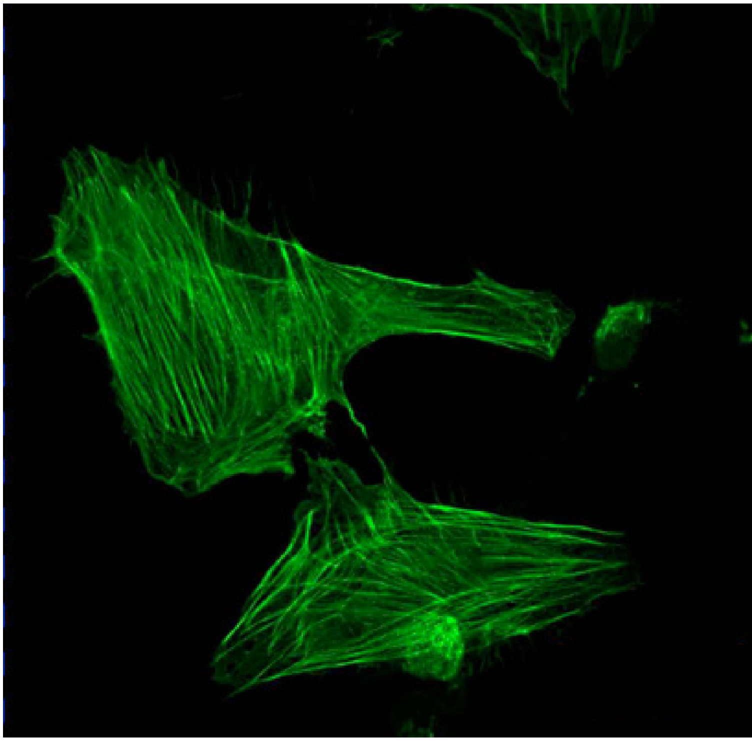
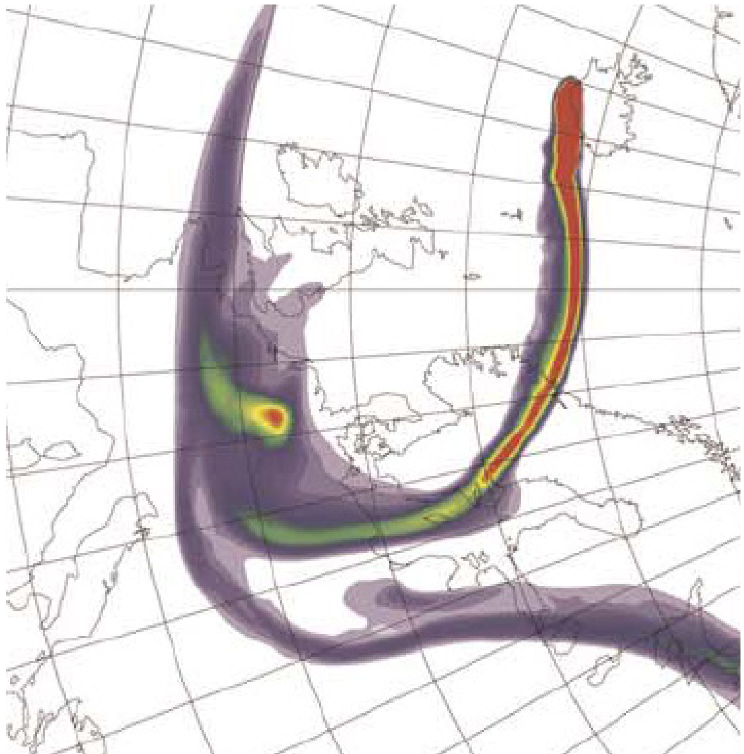


ORGANISATION



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 has been 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 Annual Meeting of the research school. Since 2016 this annual meeting was organised in the form of a two-days Burgers Symposium, which was attended by more than 250 participants (both staff, PhD students, and postdocs. At these annual meetings, a central place – in addition to the plenary Burgers Lecture and the Evening Lecture – is always given to the JMBC PhD students: at the Symposium in 2017 approximately 75 presentations were given by junior speakers in two 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	7	
J Westerweel, DJEM Roekaerts, RAWM Henkes *(p)*, W van de Water *(p)*	1.9	8	4
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)*	2.4	7	
AWH Heemink, E Deleersnijder *(p)*, M Verlaan *(p)*	2.9	4	
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	2.1	15	2
OCG Adan *(p)*	0.9	3	1
GWM Kroesen, V Banine *(p)*, U Ebert *(p)*	2.5	16	
Mechanical Engineering			
NG Deen, LPH de Goey, JGM Kuerten, M Golombok *(p)*, DJEM Roekaerts	4.8	22	5
DMJ Smeulders, EH van Brummelen, HA Zondag *(p)*	3.1	9	1
JMJ den Toonder	1.5	7	
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	17	2
M van Sint Annaland	0.7	4	
B Blocken	1.1	7	1
CWM van der Geld	0.3	1	
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)*	2.8	31	12
F Mugele	1.1	5	2
Chemical Engineering			
RGH Lammertink	0.7	8	1
Mathematical Sciences			
EWC van Groesen	0.3		1
JJW van der Vegt	0.3	1	
BJ Geurts, JGM Kuerten *(p)*	1.3	3	1
Mechanical Engineering			
CH Venner	2.3	2	2
G Brem	1.5	3	1
S Luding	1.9	5	3
Water Engineering & Management			
SJMH Hulscher	3.1	17	1
RUG			
Mathematics			
RWCP Verstappen	1.1	5	2
WUR			
Experimental Zoology			
JL van Leeuwen	0.7	4	
Agrotechnology & Food Sciences			
CGPH Schroen	0.3	1	
J van der Gucht	1.1	1	
UU			
Physics			
H Dijkstra, LRM Maas	1.2	1	

Overview of university participants

	TUD	TUE	UT	RUG	WUR	UU	Total
Scientific staff *(effective fte)*	25	21.9	15.3	1.1	2.1	1.2	66.6
PhD-students	109	113	75	5	6	1	309
Postdocs	11	16	24	2	0	0	53

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.

After the successful workshop ‘Controlling multi-phase flow’ in Amsterdam in 2014, a couple of industries took the initiative to sketch a research program regarding the rheology effects of emulsions. The program is co-developed with ISPT and NWO and will be executed with a few universities. During 2017 the project is approved and kick-off will be early 2018. The concept of a dedicated area with a limited number of participants seems to work well for all involved.

During the Burgers Symposium 2017 industries came together to discuss how the field of fluid dynamics can play a role in the area of so-called Digital Twins. A lively discussion revealed significant interest from all industries in particular in integrating knowledge on a digital platform with other disciplines. During the same symposium, a meeting was organized with NWO to discuss other topics of interest to collaborate. Several areas of common interest were identified, including particle laden flows, porous media, gas-liquid systems (including ions), and on-line diagnostic techniques. At the end of 2017 NWO confirmed interest in the mentioned fields. During 2018 a pro-active attitude will be taken in order to try to define a couple of new projects.

As can be seen from these examples, we are seeking interaction between industries, universities, and institutes, and push for interaction with other disciplines like process engineering, materials, mechanical engineering, etc.

We are looking forward to land a couple of projects in 2018 and celebrate 100 years of fluid dynamics in The Netherlands.

Ir. P Veenstra
Shell
Chairman of the Industrial Board

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.

Contact : Prof.dr.ir. RAWM Henkes (TUD), Prof.dr.ir. NG Deen (TU/e)

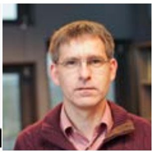
 

Contact group "Computational Fluid Dynamics (CFD)"

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.

Following the last CFD contact group meeting in 2016, which was jointly organized with Multiphase contact group, the next meeting of the CFD contact group will take 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 2017, COMBURA took place in Soesterberg on 11 – 12 October.

The theme of Combura 2017 was 'The Future of Combustion', focusing on the role of combustion within the rapidly changing energy landscape. Keynote lectures were given by dr. Kornelis Blok, TU Delft, ir. Mustapha Bsibsi, TataSteel IJmuiden and ir. Jillis Raadschelders, DNV GL Energy, 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 JMBC contact group on Lattice-Boltzmann Techniques was first established in 2002. 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.

Contact: Dr. Rene Pecnik (r.pecnik@tudelft.nl) and Dr.ir. Wim-Paul Breugem (w.p.breugem@tudelft.nl)

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.

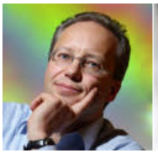
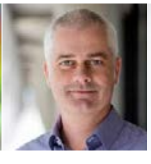
Contact: Dr.ir. S Kenjeres (TUD) and Dr.ir. F Muijres (WUR)

Contact group "Microfluidics"

The contact group "Microfluidics" was established in 2005. The purpose of the contact group is to bring together students and postdocs interested in fluid dynamic aspects of microfluidics and give them a forum for presenting their results and exchanging ideas. Also, the contact group serves as a platform to exchange information about relevant conferences, workshops, courses, and research grant opportunities. Topics of interest include wetting and capillarity-driven flows, two-phase flow, micro-mixing, drop generation and control, emulsification, contact line dynamics, flow visualization, and measurement techniques. Attention is also given to also related applications such as microfluidic devices for medical diagnostics, water quality monitoring, and advanced cell culture systems. Members of the contact group organize the JMBC course "Capillarity-driven flows in microfluidics" that has successfully taken place in May 2017 at the University of Twente. In 2018, a brand new course will be organized: "Micro- and Nanofluidics". In this course, the participant will learn about micro- and nanofluidic principles, technology, and applications, but also get extensive hands-on experience with designing, making, and testing microfluidic devices. The course will be held on 28-31 May 2018 at Eindhoven University of Technology. Students and researchers, who are interested in the activities of the group and want to attend our symposia, are invited to contact the organizers of the contact group and have their name added to the mailing list.

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

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

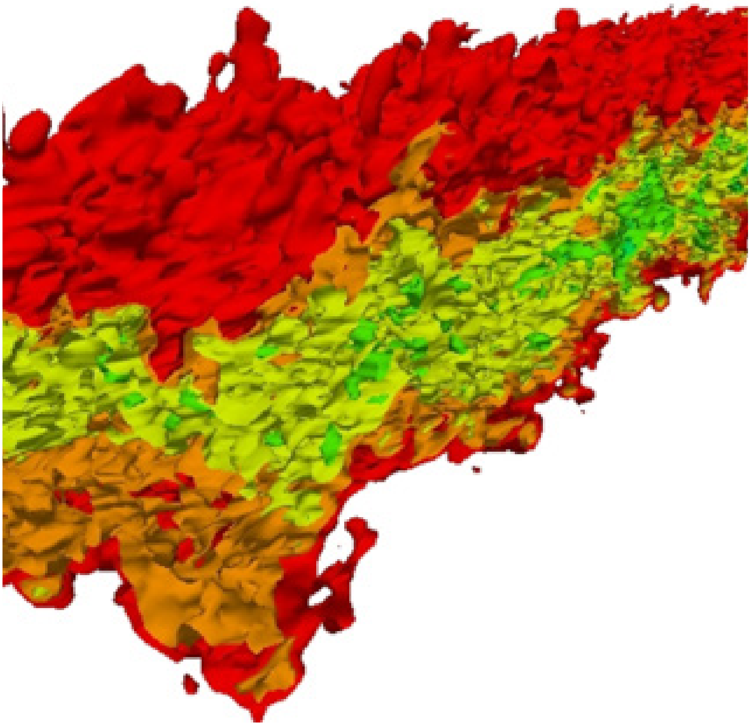
Inspired by the intellectual heritage of Johannes M. Burgers, who had a second career (1955 - 1981) at the University of Maryland after his retirement at the Technical University of Delft , the mission of the Burgers Program for Fluid Dynamics is to enhance the quality and international visibility of 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 2016 a Summer School on Non-linear Water Waves was organised, while one on Topics in Turbulence is planned for 2018.

Prof. Jim Wallace

Prof.dr. JM Wallace
University of Maryland

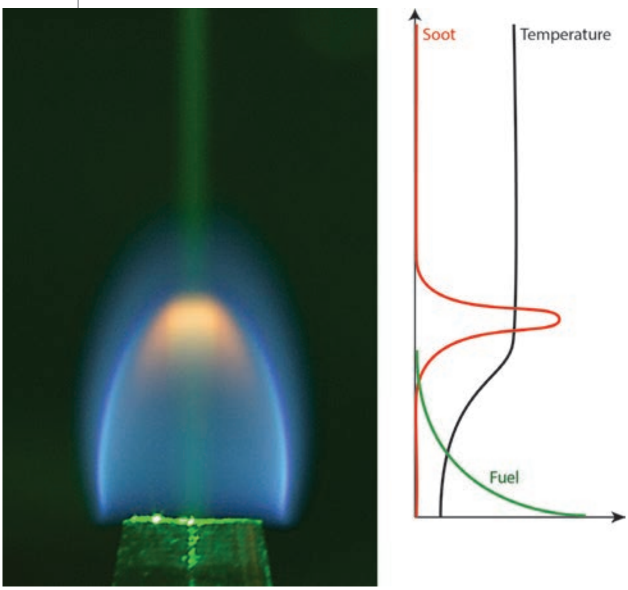
HIGHLIGHTS



How is soot formed in combustion processes?

C.J.M. Hessels, R. Doddema, N.G. Deen, N.J. Dam
Multiphase and Reactive Flows group, TU Eindhoven

Knowledge is a prerequisite for innovation. For complex processes, like the formation of soot in hydrocarbon fuel combustion, highly detailed optical measurements elucidate details of the underlying process, and provide a benchmark to calibrate numerical models.

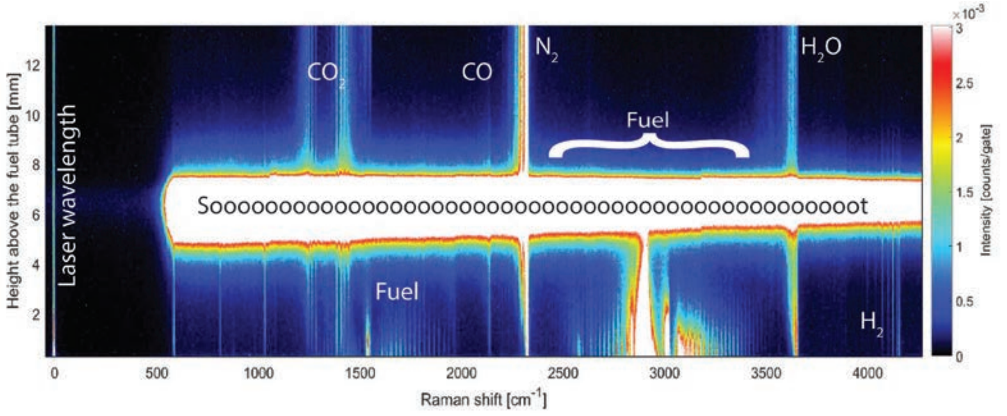


Photograph of one of the flames under study, with at the right an artist impression of the course of temperature and soot concentration along the flame axis. The faint, green, vertical line through the center of the flame corresponds to the laser beam (Rayleigh scattering).

The delightful stench of burnt meat from your neighbours' BBQ, the impenetrable black of the exhaust plume of an oldtimer pick-up truck, the warm orange glow of a camp fire. All are manifestations of a ubiquitous yet poorly understood process associated with the combustion of organic fuel, namely soot formation. The problem is one of complexity. 'Combustion' is a one-word container for a chemical soup, a blizzard of zillions of molecules of hundreds of chemical compounds flying around at the speed of sound, colliding and transforming as they go. Ideally, from the clean-combustion point of view, all fuel you feed into a flame should burn to completeness and exit as CO2 and H2O: full conversion, 100% efficiency. Soot formation, from this point of view, is an undesirable side track, a loss channel for carbon that may escape combustion when it makes it into the exhaust. Little is known, on a fundamental level, of the incipient stages of soot formation, the 'birth of soot'. What would be the smallest 'soot molecule'? How is that formed out of the initial fuel? And how does it grow? Are there bottlenecks in the process? Detailed measurements might provide some of the answers, but doing reliable and quantitative measurements on individual chemical species in the hostile environment of a flame is a challenge in itself.

What are the requirements that a suitable measurement technique should fulfil? To answer this question for this particular case, let us travel. Let us join a small fuel pocket on its way through a flame, like that of Figure 1. The particular flame under study is a stationary, non-premixed flame: pure fuel exits a stainless steel nozzle and flows into ambient air. Initially, oxygen is present only at the periphery, and there is no oxygen in the core of the fuel flow. Thus, our travel companion, the fuel pocket, grows hotter and hotter while it flows along, approaching the actual flame location, but it cannot burn because there is no oxygen. Due to the increasing temperature, however, the fuel molecules decompose anyway (pyrolysis), new carbon-rich compounds form and from these precursors soot is born, it grows, and eventually most of it burns anyway in regions where sufficient oxygen has diffused into the flame.

Our measurement technique should be able to resolve these processes in space, be able to distinguish individual chemical compounds, and to do so without affecting the flame at all. There is a particular type of optical measurement technique that admirably fulfils all these criteria, viz. Raman spectroscopy. The principle behind this technique is as follows.



False colour spectral atlas of a non-premixed methane/air flame. Each pixel in this photograph corresponds to a unique combination of colour (horizontal axis) and location along the axis of the flame (vertical direction). The colour in the picture is a measure for the intensity of the scattered light, according to the scale at the right. Contributions due to some individual chemical compounds are indicated.

When a gas (mixture) is illuminated with a beam of monochromatic light, part of the light is scattered out of the beam; not much, but easily detectable with modern equipment. Most of this scattered light has the same wavelength (colour) as the incident light (Rayleigh scattering), but a tiny fraction (about 0.1%) has acquired a different wavelength (Raman scattering). This wavelength change (called the Raman shift) is the net result of an intricate interaction between the electronic charge distribution that is set into oscillation by the incident light (an electromagnetic wave itself) and the natural vibration of the nuclear framework of the scattering molecules. The former is governed solely by the incident light, but the latter largely depends on the properties of the molecules. Strong chemical bonds are associated with high-frequency vibrations of small amplitude, whereas weak bonds lead to slow vibrations of large amplitude. Thus, the colour change, the Raman shift, is highly specific for the individual chemical species which are responsible for the scattering.

In our experiments the flame is illuminated along its central axis by a thin line of perfectly green laser light (527 nm sharp). Scattered light is collected by a so-called imaging spectrograph, a device that splits the collected light into its constituent colour components, and does so for all locations along the laser beam simultaneously. Its output is recorded by a CCD camera equipped with an image intensifier, all in all resulting in a device with nearly single photon counting capabilities. Photographs recorded by the CCD camera thus contain spectral information (the colours in the Raman-scattered light) along the horizontal direction, and spatial information (along the central axis of the flame) along the vertical direction. An example, recorded on a simple natural gas flame, is shown in Figure 2. This ‘photograph’ is presented in false-colour format, that is, the intensity of the scattered light falling on each individual pixel (that is, each wavelength/location-combination) is translated into a particular colour in the picture.

As expected, the spectra are dominated by contributions of the most prevalent compounds in the flame: fuel, nitrogen, water vapour, and the like. These give rise to detailed features at highly specific wavelengths, as indicated in the figure. There is also soot: the fat band spanning all colours. By combining spectroscopic information from literature, we were able to identify most of the spectral features and to quantitatively simulate the spectra of most major compounds in the flame. Comparison with numerical calculations performed on the same flames has shown good agreement with the experiments for natural gas, the fuel for which the ‘numerical chemistry’ is best developed. As soon as the fuel becomes a little bit more involved (ethylene rather than methane, for instance), the numerical models start to deviate from the experiment, indicating that more work needs to be done on the reaction mechanisms. This exemplifies the benchmark capabilities of our experimental setup. Having established agreement between experiment and numerical simulation in a situation where agreement is to be expected, we can trust the experimental results on more involved cases and use them to calibrate the numerics.

The backbone structure of these flames has thus been characterized in great detail. Now we can start looking for perturbations, small deviations in the spectrum that signal the presence of soot precursors.

The groundwork has been laid, the hunt is on!

Aerodynamic drag in cycling pelotons

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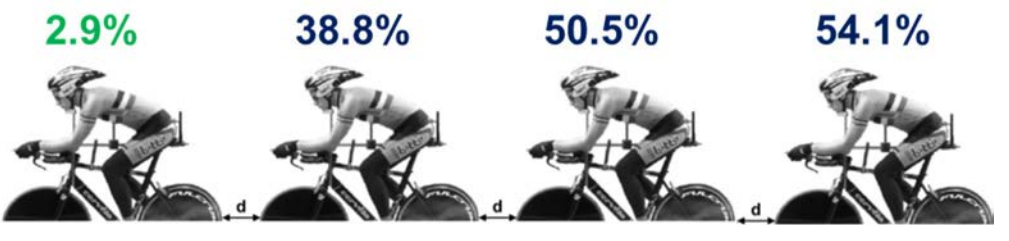
In the course of 2017, a large collaborative project between four universities, two multinationals (ANSYS and Cray) and three Dutch model-building companies was conducted to investigate in detail the aerodynamic drag for every cyclist in full pelotons of 121 riders.

It is well-known that in the so-called “belly” of a cycling peloton you ride “sheltered from wind” and, therefore experience less air resistance. But how much less had not yet been thoroughly investigated. Earlier research with small groups of up to four in-line riders has shown that riders in third and fourth position encounter about 50 percent of the air resistance experienced by an isolated rider (Figure 1). Subsequently, this number has been extrapolated to the whole peloton.

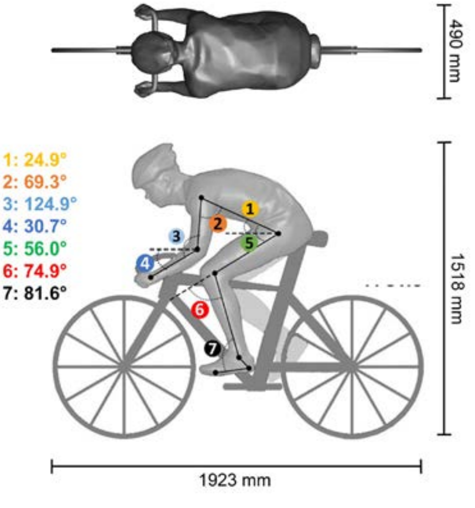


Percentage reduction in aerodynamic drag for four in-line riders due to drafting.

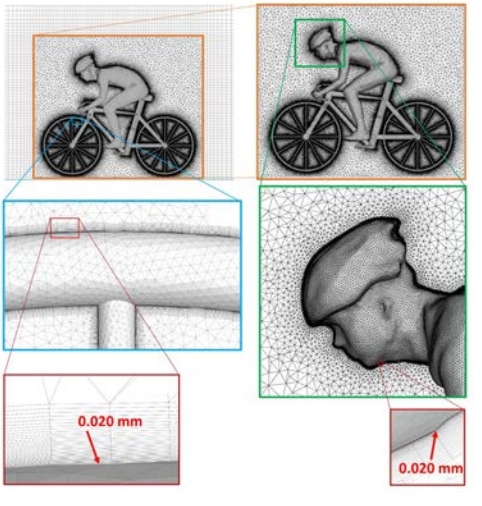
This and similar numbers (40% to 70%) referring to air resistance in the peloton can be found in numerous books on cycling science and also in scientific publications on mathematical models for cycling break-aways. However, professional riders and coaches suggest that when you are well-embedded in the belly of a tightly-packed peloton (Figure 2), you “sometimes hardly have to pedal,” so the air resistance must actually be much lower.

The study was based on numerical simulations with computational fluid dynamics (CFD) and wind tunnel measurements of two pelotons of 121 riders (Figure 3, 4, 5, 6). After intensive validation studies, the peloton CFD simulations were performed with the RANS equations and the Langtry-Menter 4-equation Transition Shear Stress Transport (SST) k-ε model (Menter et al. 2006; Langtry and Menter 2009). This model is based on the coupling of the SST k-ε transport equations with two additional transport equations, one for the intermittency and one for the transition onset criteria, in terms of momentum thickness and Reynolds number. Very high-resolution grids were employed in which the laminar sublayer was resolved with wall-adjacent cell sizes down to 0.02 mm (Figure 4). This is required to accurately model boundary-layer transition, separation and reattachment. The total cell count is nearly 3 billion, which renders this a world record as the largest CFD simulation in sports. The simulations were run with ANSYS Fluent CFD software on a Cray XC-40 supercomputer requiring 49 TB of memory and 54 hours wall-clock time for every peloton, most of which was used for writing output files.

Cycling pelotons. Sources: Left: http://johnericgoff.blogspot.com; Middle: www.danpontefract.com; Right: © Cor Vos, reproduced with permission.



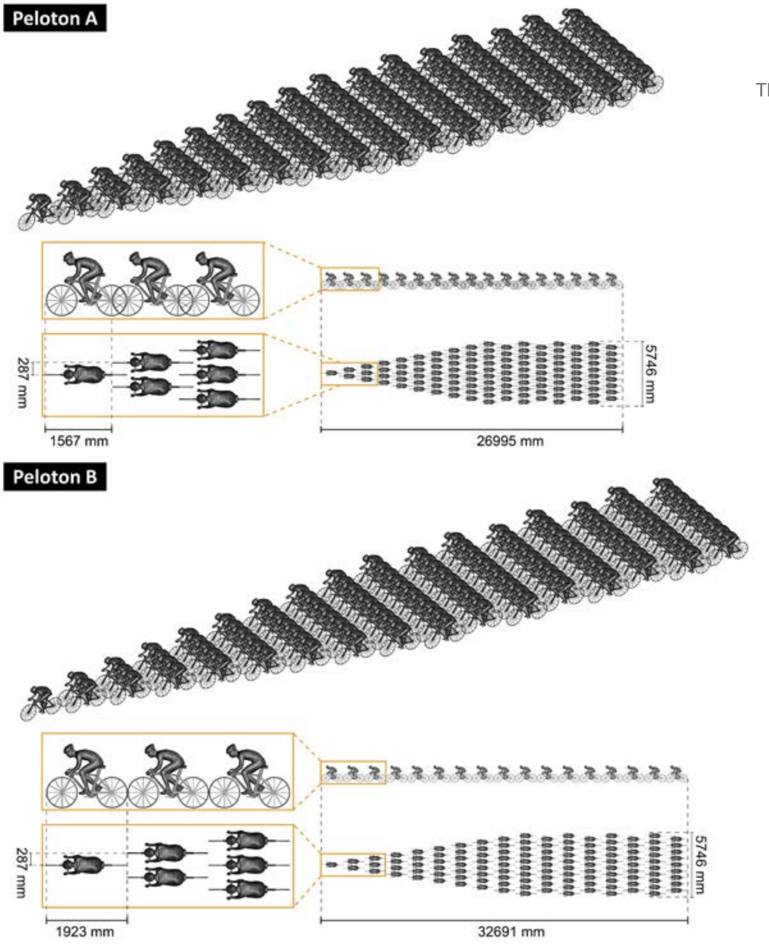
Cyclist model geometry in dropped position with definition and values of (1) sagittal torso angle; (2) shoulder angle; (3) elbow angle; (4) forearm angle; (5) hip angle; (6) knee angle; (7) ankle angle.



Details of computational grid on and around the cyclist geometry, the wall-adjacent grid cell is 20 micrometer.

The CFD simulations and the wind tunnel tests yielded the same conclusions. The best position is not in the belly of the peloton, but in the mid rear, where a rider has a drag that is 5 to 10% of a cyclist that is riding alone (Figure 7). That is up to 10 times less than previously assumed. This means that it is as if a rider is cycling at 12 to 15 km/h in a peloton that is speeding at 54 km/h.

This corresponds to the experience by professional cyclists and cycling experts. Tim Wade, at UK analytics firm Dimension Data, in a team car at the first day of the 2018 Tour de France, said: “You can see immediately, from the car beside the riders, that some are hardly pedaling at all”. It is also shown that the benefit for the leading rider can be up to 16% reduction in drag compared to a solo rider. This is a direct result of the subsonic upstream disturbance, in other words, the elliptical mathematical character of the governing partial different equations for subsonic flow. To some extent, a peloton resembles public transport: by riding together, everybody benefits.

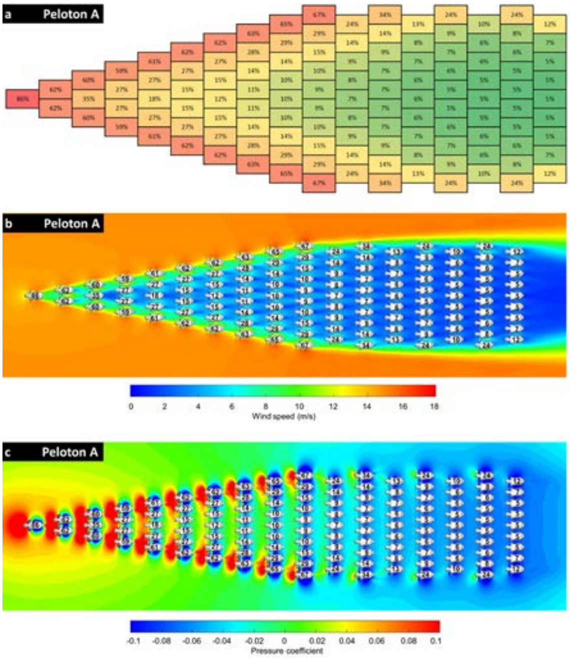


The two peloton configurations.

One should not misinterpret these results. They do not at all imply that an amateur cyclist can ride along with a peloton of professional cyclist when he or she is well embedded in the peloton. This might be possible for a short distance and under the conditions of our study, i.e. a straight, flat road and a tightly packed peloton. But as soon as the rider take a bend, the so-called accordion effect sets in, the peloton stretches out and the resistance becomes much larger. So there is no reason whatsoever for less respect for professional cyclists and their efforts. Rather, this study indicates how difficult and impressive it is for a rider to escape, stay out of the grasp of the peloton and finally prevail.

The scientific article (open access) can be downloaded here: https://www.sciencedirect.com/science/article/pii/S0167610518303751

Setup of peloton configuration A in the wind tunnel at Eindhoven University of Technology.



Drag of every cyclist in peloton A as a percentage of the drag of an isolated cyclist riding at the same speed. Background of the figures (b) and (c) are contours in a horizontal plane at 1 m height of mean wind speed (m/s) and mean pressure coefficient, respectively.

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Biomimetic vesicles in pulsed electric fields

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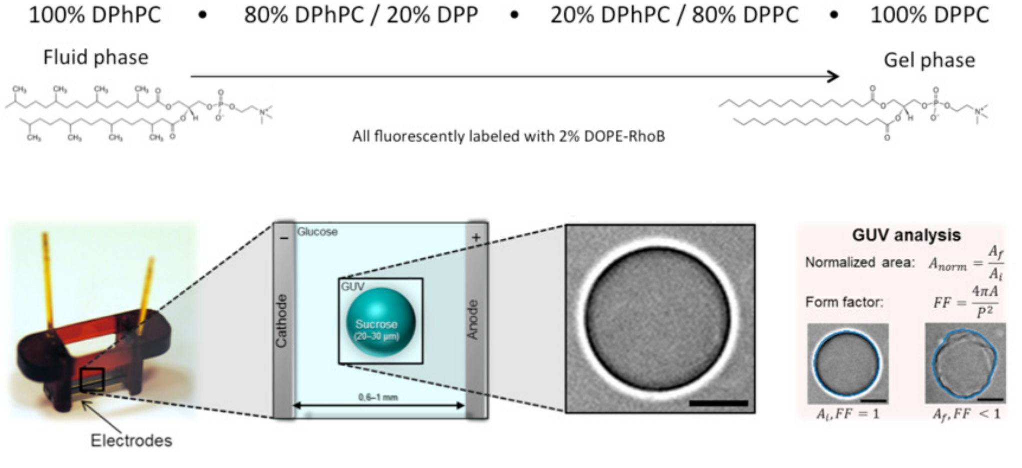
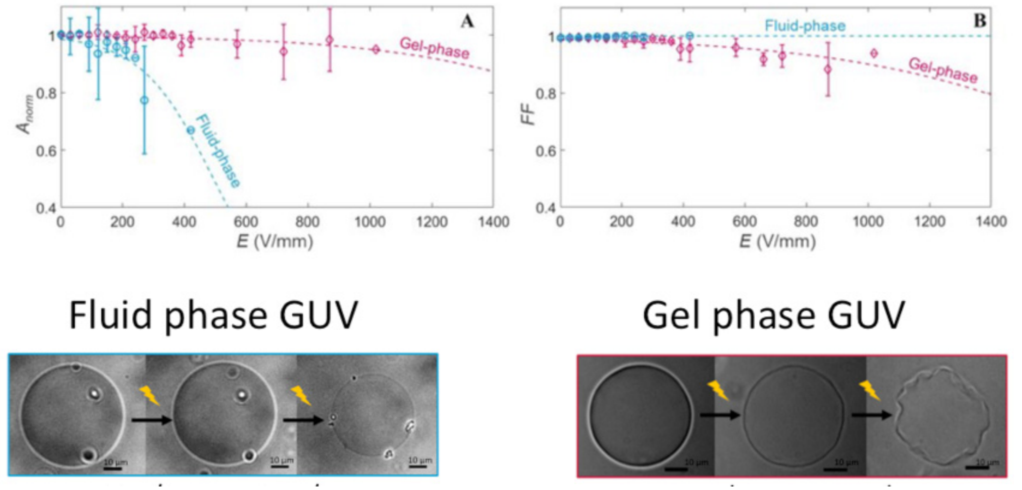
Biological cells manifest rich mechanical responses in the presence of external forces as a result of far-from-equilibrium interactions between their subcellular components and their surrounding environment. Many of the paramount functions of living cells are governed by their membrane, which encloses the cell and isolates its “inside” from the “outside”. Transient membrane permeabilization is a critical step to introduce foreign molecules (such as drugs or DNA molecules) into living cells, yet challenging for both biological research and therapeutic applications. To achieve this, electroporation has become a widely used tool due to its simplicity to deliver almost any biomolecule to any cell type. Although this non-viral method demonstrates a great promise in the field of gene delivery, the underlying physical mechanisms of the response of the heterogeneous cell membrane during electroporation process is still unknown [1-2].

In this study, we have employed giant unilamellar vesicles (GUVs) to investigate the response of heterogeneous membranes during and after electroporation (Fig. 1). First, we have studied the role of gel-phase lipids in the electroporation of binary GUVs by direct visualization of GUVs with different compositions during and after electroporation. All GUVs have been exposed to multiple electric pulses of increasing electric field strength, and their responses have been imaged using bright-field microscopy.



Chemical structures of lipids used in this work (top), and the experimental setup for the electroporation of the GUVs (bottom). A picture of the electroporation setup with a bright field image of a sucrose-filled GUV in a glucose environment. The scale bar is 1 µm. The analysis of the GUVs: the contour is tracked, after which the area, A, and the perimeter, P, are determined (bottom: from left to the right). Adopted from Perrier et al. [2]

Our results display that the fluid-phase GUVs decrease in size (with spherical shape), whereas the gel-phase GUVs become buckled and change their shape (as shown in Fig. 2). We have shown that pure fluid-phase GUVs expel lipids, due to presence of electric forces and tension during the pulse. On the other hand, these electric forces cannot overcome the strong viscous forces of the gel-phase lipids. These obtained results provide an insight on the role of the heterogeneity in the membrane of living cells during electroporation. In addition, we have shown that the gel-phase lipids can provide an increased electrical stability of the cell membrane, depending on the mixing behavior of the two phases. On the other hand, we have demonstrated that the fluid-phase lipids mainly determine the transport across the cell membrane. Furthermore, we have investigated binary GUVs prepared from both fluid-phase and gel-phase lipids. We have shown that the presence of the gel-phase lipids causes buckling of the GUVs, whereas the fluid-phase lipids are also expelled simultaneously. [2-3] At this stage, we are focusing on the role of cytoskeletal elements during electroporation of cell membranes [3]. We believe that these simplified GUV models should be modified further with cytoskeletal elements to mimic the complex nature of cellular membranes. For instance, the actin supported GUVs can be used to explore the mechanism of electro-gene transfection [1-3]. These new insights will allow us to optimize current electroporation-based treatments more efficiently for both therapeutics and biological applications.



The physical responses of the fluid-phase and gel-phase GUVs to the electric field. Top row shows the averaged normalised area and form factor of GUVs plotted versus the electric field. The bottom row shows the bright field images of GUVs with different phases after electroporation experiments. Adopted from Perrier et al. [2]

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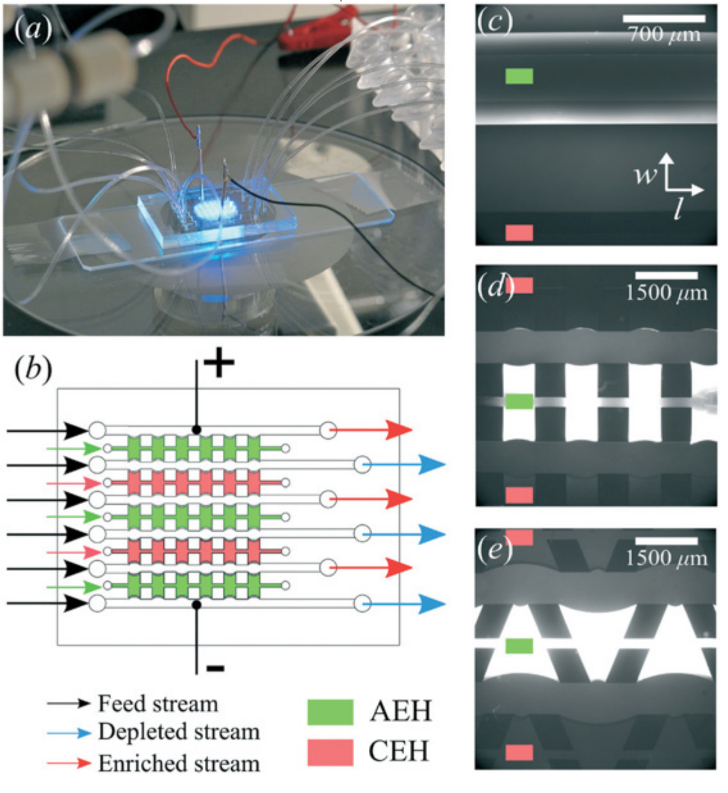
Transport phenomena near structured charge-selective interfaces

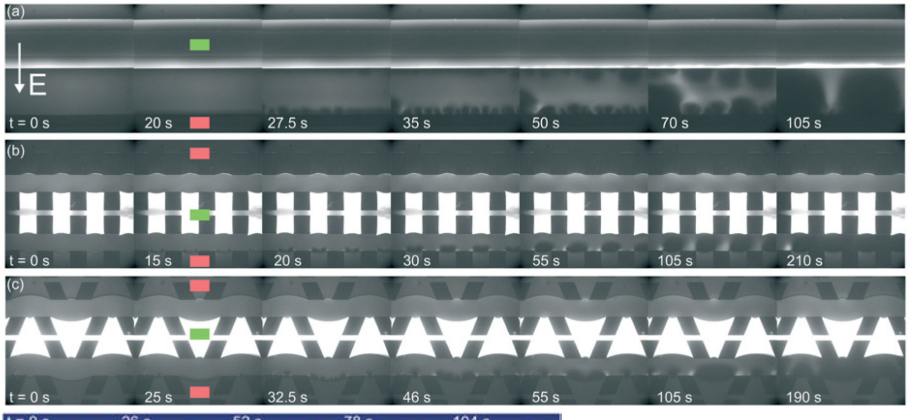
Anne Benneker, Jeff Wood and Rob Lammertink (UT/SFI) in collaboration with Burcu Gumuscu and Jan Eijkel (UT/BIOS)

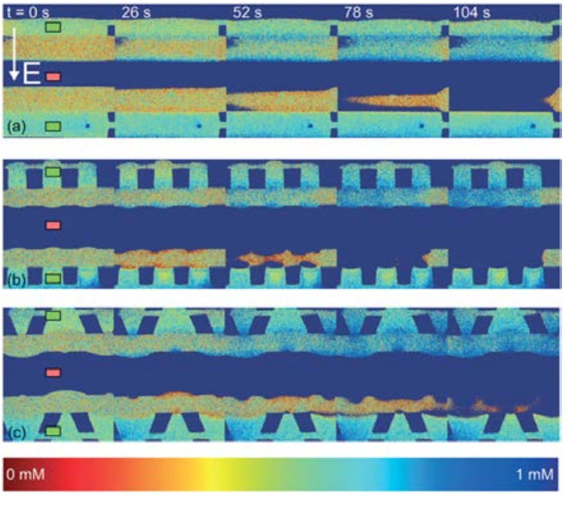
Electrodialysis is a desalination technology where ions are separated under an applied electric field, relying on ion-exchange membranes in order to separate feed streams into depleted (deionized) and enriched (concentrated) streams [1]. Due to the charge-selective interfaces involved, there is a complex interplay between applied potential and the resulting ion transport phenomena. Under high electric-field strengths, ions will deplete on one side of the interface and enrich on the other in a manner that breaks local electroneutrality [2]. Combined with the action of the electric field, this can lead to electrokinetic vortices in the bulk (electro-osmosis of the 2nd kind). This allows for operating beyond the diffusion-limited current (Ohmic regime), in what is known as the overlimiting current regime [2]. Introducing heterogeneous interfaces through geometric structuring can also play an important role, as the mismatch in zeta potential and permittivity/conductivity leads to surface electro-osmotic effects in addition to vortices [3]. A microfluidic electrodialysis stack consisting of alternating cation and anion-exchange hydrogels (shown in Figure 1) was utilized to investigate these effects through a combination of electrical measurements and visualization with fluorescence microscopy, fluorescent lifetime imaging microscopy and particle tracking velocimetry, providing an advantage as visualization would not have been possible when using a conventional ED stack [3-6].



a) perspective view of desalination system, b) schematic of ED concept, c) flat, d) rectangular and e) trapezoidal hydrogels [3]

Topology or heterogeneity in charge-selective interfaces can have a number of effects, including inducing surface electro-osmosis by distorting electric-field lines. It can also lead to pinning of ion-depletion zones as well as induced electrokinetic vortices. This was visualized by following the fluorescence intensity of the negatively charged dye, Alexa. Depletion zones develop adjacent to the hydrogels after application of an electric field, leading to the three different patterns illustrated in Figure 2. Surface electro-osmosis in the case of the rectangular and trapezoidal heterogeneous systems led to higher ion-transport than diffusional (conductivity) alone even at low potentials. Pinning of vortices also led to a higher ion-transport rate in the overlimiting regime in the case of trapezoidal geometries. In order to measure the concentration profile of anions directly, fluorescence lifetime imaging microscopy (FLIM) was carried out using the Cl- sensitive dye lucigenin, as shown in Figure 3. This allowed for direct quantification of ion-concentrations near interfaces in time. The work carried out highlights the important role of topology in ion-transport, as well as the versatility of using microfluidic systems to understand the behavior of these systems.





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Waves in anisotropic media

Leo Maas (IMAU - Institute for Marine and Atmospheric Research Utrecht, Utrecht University)

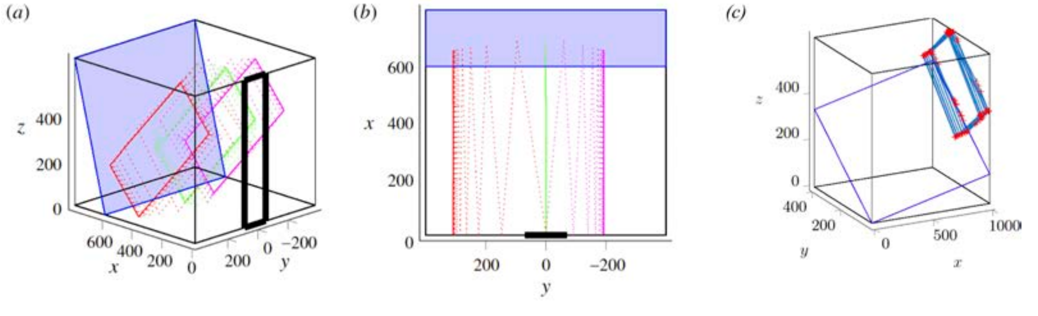
An important new field of study in geophysical and astrophysical fluid dynamics, with possible repercussions for plasma dynamics, electrodynamics and nanophotonics, is the study of perturbations of anisotropic equilibria.

Examples of anisotropic equilibria from fluid dynamics are density-stratified fluids in a field of gravity, and homogeneous density fluids subjected to uniform rotation (plus any combination of the two). Their perturbations are known as internal gravity and inertial waves respectively.

The equilibria in plasma dynamics, electrodynamics and nanophotonics are less easy to define, but their perturbations are well-known: in plasma dynamics and electrodynamics, these electromagnetic waves, influenced by an external magnetic field, are called 'whistlers' and electron-cyclotron waves respectively.

In nanophotonics, anomalous electromagnetic waves occur in metamaterials - stacked layers of material with different optical properties (such as permittivity and susceptibility). The anisotropic layering requires light to be confined to nanometer scales, much smaller than their vacuum wavelengths of several hundreds of nanometers.

In all cases, anisotropy dominates the nature of the response: anisotropy due to the preferred orientation of gravity, rotation vector, magnetic field or stacking direction of the metamaterial. In a gravitationally stable density stratification, fluid parcels are for instance easily (i.e. 'free of charge') moved within each plane perpendicular to the direction of gravity, while it is energetically costly to move them up or down the direction of gravity.

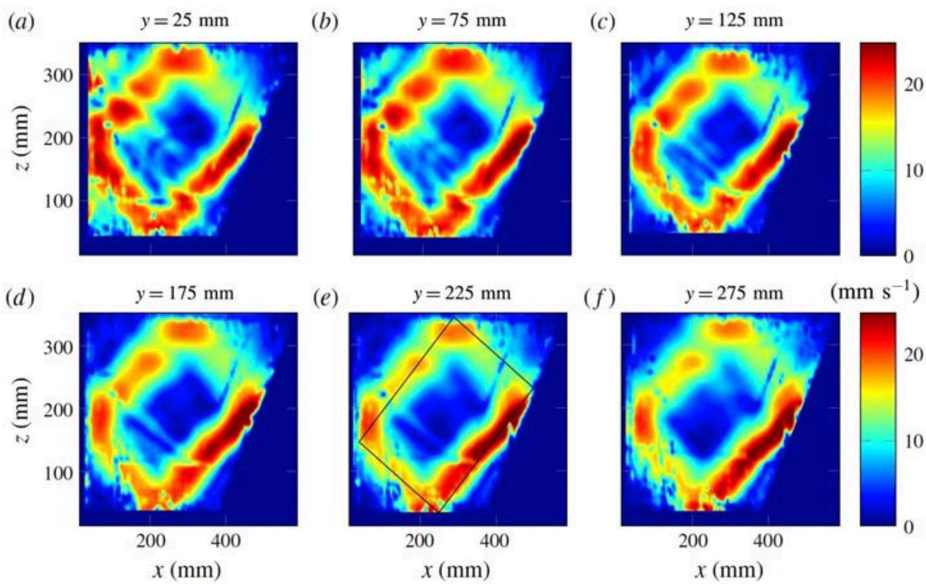


Uniformly-stratified basin, having one side sloping (blue) in a quasi-2D (a,b) or truly 3D setting (c). Internal waves are forced in black square region, seen in perspective (a) and from above (b). When reflecting from the slope, internal gravity waves get focused and diffract towards a direction normal to the slope, ultimately being trapped on a wave attractor (solid red, green and purple lines) in a single perpendicular plane, whose location is determined by the initial horizontal launching direction. Together these build a two-dimensional attracting manifold [2]. (c) In 3D, the waves focus onto a nearly one-dimensional attracting manifold: a 'superattractor' [3].

Interestingly, in each of these media, anisotropy leads to perturbations (waves) that all obey an anomalous dispersion relation in which wave frequency relates to wave vector inclination relative to the anisotropy direction, rather than to wave vector magnitude, as is commonly the case in isotropic media. Its consequences for the perturbations are profound. For a symmetry-breaking shape of the cavity (i.e. a cavity having at least one boundary oriented neither parallel nor perpendicular to the anisotropy direction), it leads to multiscale behavior of linear wave solutions, a feature otherwise found only in the manifestly nonlinear field of turbulence. However, it should be mentioned that this property pertains to spatial scales only and not, as for turbulence, to time scales as well. These results are found for small-amplitude perturbations and not, as for turbulence, just at a nonlinear level for large-amplitude perturbations. This implies that conditions on the magnitude of the disturbance are much milder than required for invoking a nonlinear response. Quite generically, the waves will approach a wave-attractor - a highly predictable and persistent location where amplified motions and exchange processes will take place, regardless of the precise location inside the cavity where these perturbations originate from [1,2].

Localization of wave energy on an attractor is interesting as its multiscale property signifies a natural route between the largest scale, at which energy is usually entering a system coherently, towards the smallest scales, where energy is dissipated. The large-scale structure is often associated with a slow manifold, which is typically modelled as being disjoint from the fast (i.e. small scale) manifold, at which dissipation occurs. By contrast, the simultaneous presence of these two disparate scales is found to be an integral property of a wave attractor. Perhaps more remarkable is the fact that while the underlying dynamical problems are all linear -- after all they describe perturbations to an equilibrium state --, the resulting wave fields have properties normally associated with nonlinear dynamics (such as selfsimilarity in physical, Fourier and parameter spaces). There is however good reason for the presence of nonlinear features inside a dynamically linear problem setting: the path of characteristics that are employed in solving these linear anisotropic problems is based on a nonlinear map of the boundary onto itself. Thus, the nonlinear shape of the cavity boundary determines the presence of attracting orbits (Figs. 1,2) and of the selfsimilar shape of the wave field [2,3].

The study of waves in anisotropic media invites further investigation in future studies as it may have applications in oceanographical, meteorological and also in planetary and stellar exchange processes. To illustrate this in the latter context, it is remarkable that lithium depletion was found to occur strictly in stars that are accompanied by big planets. The implied presence of tidal forces in the rotating and stratified stellar atmosphere can tangibly be expected to open a venue for rapid chemical transport via the periodic bands constructed by wave attractors.



Experimental manifestation of wave attractors in a uniformly-stratified fluid contained in a tank with one sloping wall as in Fig. 1a,b. (a-f) show magnitude of velocity field in cross-sections occurring at several transverse y-positions. Waves are forced as shown, in Fig. 1a,b, only over the range -60mm < y < 60mm. Wave diffraction, occurring upon focusing reflection, guarantees wave spreading and wave capture onto wave attractors in planes that are oriented perpendicular to the slope: [2], experiments by Grimaud Pillet.

Similarly, wave attractors are speculated to be relevant to the presence of striped patterns on the surface of icy moons, as Saturn's moon Enceladus. These 'tiger stripes' possibly betray the action of sustained shearing motion onto the ice cover, produced by focused internal gravity or inertial waves in an underlying ocean [4].

This topic may also be of interest to industrial applications involving rotating fluids and gasses in rotating or revolving machinery. For instance, we can speculate that wave attractors might be relevant in bioreactors, which consist of fluids containing several species of algae and nutrients. These species, that may produce new pharmaceutical chemicals/food, are however difficult to keep in cultures because of conflicting demands on mixing. Fluid inside such a reactor needs to be stirred sufficiently strong so as to bring algae into contact with dissolved nutrients, yet to do this gently enough so as to not destroy fragile exotic algae species, due to excessive shearing motion.

Likewise, the presence of wave attractors may potentially have an application for light trapping in metamaterials and hence to a new line of data storage and data retrieval in chip-industry.

To return to geophysical fluids, the topic of wave structures produced by anisotropy is of direct interest to oceanography - a stable and continuously-stratified fluid - as the concept of wave-attractors offers a paradigm in which an amplified, localized isopycnal (an iso-density pleth) as well as cross-isopycnal transport of heat, momentum, oxygen, plankton and nutrients can possibly be rationalized. As such, this is not only of academic interest, but also of concern to deep-sea life and deep-sea mining activities. Its detection in the ocean is however presently hampered by lack of subsurface, spatially-resolving instruments. Given that theoretical and consonant laboratory experimental [2] and numerical [1] work all suggest the existence of wave attractors in the sea, the developments of sensors that will be able to resolve the spatial structure of the internal wave field at sea, should be promoted.

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3. Internal Wave Attractors in 3D Geometries: a dynamical systems approach. G. Pillet, L. R. M. Maas and T. Dauxois. (2018) Submitted to European Journal of Mechanics - B/Fluids.
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Experimental and numerical investigation of cavitating flow in a venturi

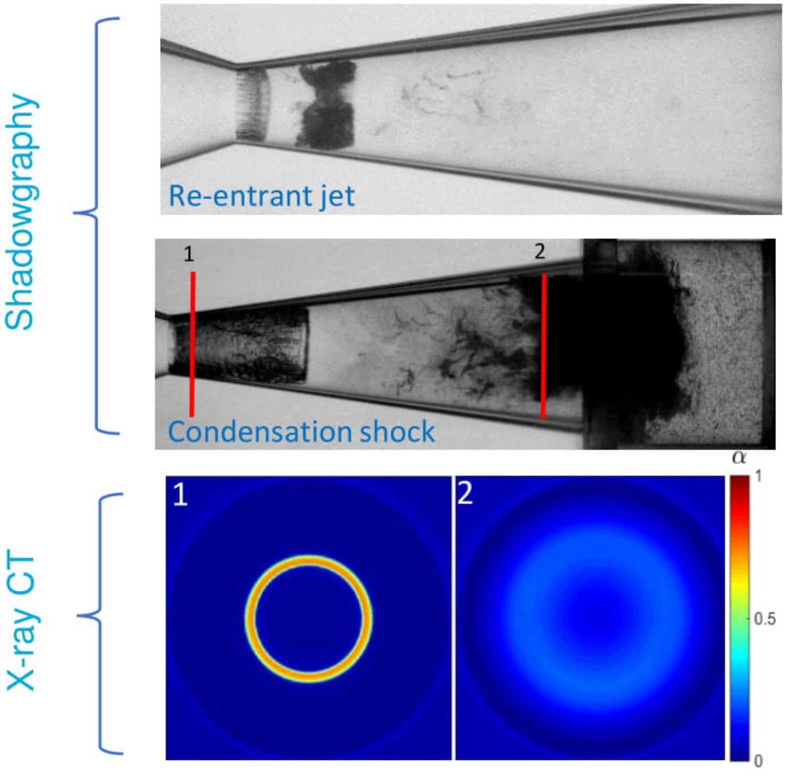
Saad Jahangir, Willian Hogendoorn, Christian Poelma (3mE - Process & Energy - TU Delft);
In collaboration with Benoit Cointe, Soren Schenke (3mE - Maritime technology - TU Delft);
Evert C. Wagner and Robert F. Mudde (Chemical Engineering - TU Delft)

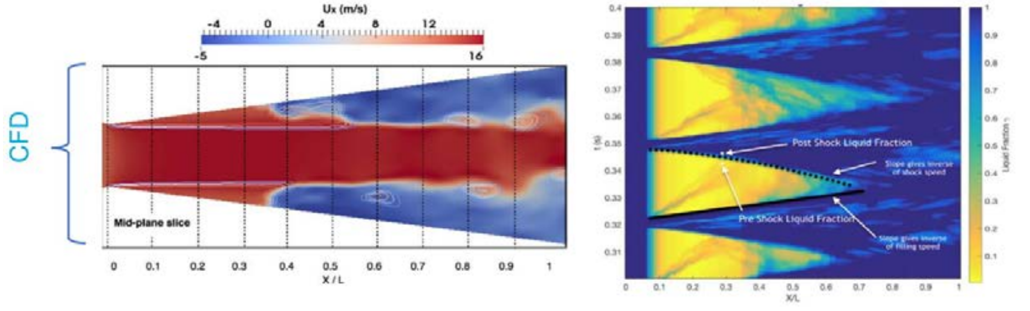
Cloud cavitation is an interesting and complex phenomenon, as different mechanisms cause the periodic shedding of vapor clouds. Analysis of these mechanisms will result in a better understanding of the negative effects of cavitation, which occur in a wide variety of applications.

In this project, partial cavitation regimes in an axisymmetric converging-diverging nozzle ('venturi') are investigated. State of the art techniques such as high-speed shadowgraphy and X-ray computed tomography are used on a portable test rig [1,2]. Using such techniques, we are able to unveil the hidden flow features which underlie the cavitation dynamics.

The present study characterizes the flow phenomena in the venturi, capturing the re-entrant jet mechanism, bubbly shock structures, vapor fractions and shock wave velocities.

Following these experiments, numerical investigations are performed to reproduce the characteristic shedding mechanisms. The geometry of the venturi is reproduced, and a mass transfer model combined with inviscid flow is implemented. The re-entrant jet mechanism and especially bubbly shock structures with the liquid fraction and shock wave velocities are reproduced.





References

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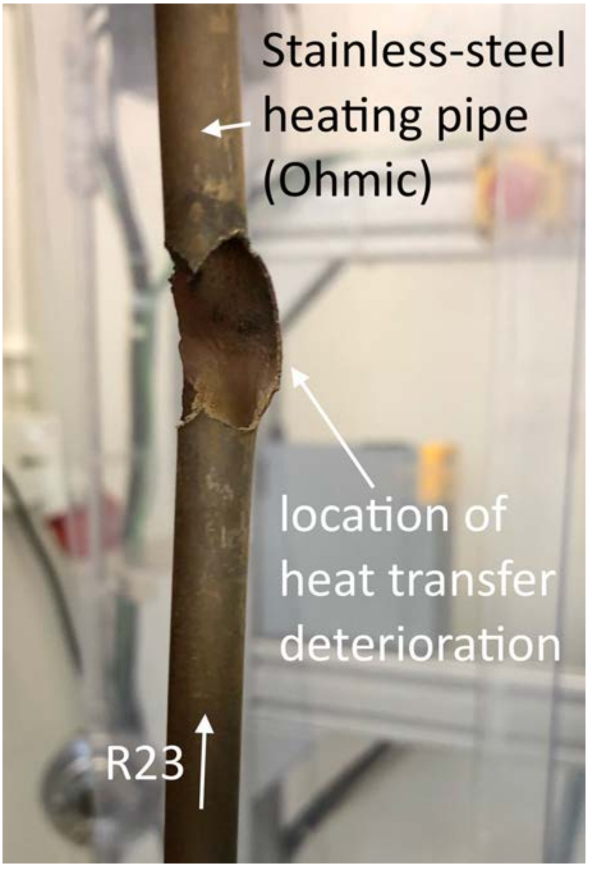
2. S. Jahangir, E. C. Wagner, R. F. Mudde and C. Poelma. “X-ray computed tomography of cavitating flow in a converging-diverging nozzle.” Presented at the 10th International Cavitation Symposium (CAV2018), May 14-16, 2018, Baltimore, Maryland, USA.

Particle image velocimetry measurements in a thermally convective supercritical fluid

M Rohde, Radiation Science and Technology, TUD

Supercritical (SC) fluids are widely used in industry. Power plants, refrigeration, chemical and pharmaceutical industry and waste disposal are some examples of their application. In the energy production sector, SC fluids can be used as cooling fluids for power plants (PPs) because they allow to increase their thermal efficiency. They are already in use in coal-fuelled power plants, while research is going on to design a new kind of nuclear reactor cooled by supercritical water. SC fluids are used also in food industry for the extraction of chemical compounds, e.g. for decaffeination.

One of the main challenges with the use of SC fluids is the understanding of near wall heat transfer and its modelling (turbulence models, heat transfer correlations). At SC conditions fluids experience a sharp change of material properties. As a result, the heat transfer behaviour of SC fluids becomes very different with respect to the one at sub-critical pressures. Under certain condition (which varies per geometry, flow conditions, pressure, type of fluid and boundary conditions), heat transfer can significantly deteriorate and cause severe damage. An example can be found in Figure 1, showing a damaged, stainless-steel pipe in our Freon R23 loop that ran under supercritical conditions. Local temperatures went high enough to melt the steel pipe wall!

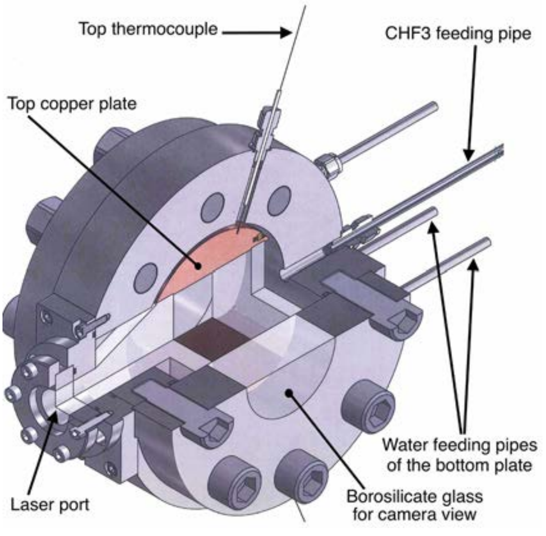


Effect of local deterioration of heat transfer in a supercritical fluid (R23).

Several heat transfer correlations have been proposed in the past for SC fluids. However, most of them are based on empirical data that cannot be generalized to a wide range of experimental conditions. The only way to develop physically sound models for heat transfer would be a bottom-up approach, i.e. by looking at phenomena on small scales by experiments and Direct Numerical Simulations [1].

To this purpose, Valori [2] explored the possibility of performing non-intrusive local velocity measurements in supercritical fluids with Particle Image Velocimetry (PIV). The experiments were performed in a Rayleigh-Bénard (RB) cell at SC conditions, with the goal of providing instantaneous and time-averaged velocity fields with strongly changing fluid properties. This study turned out to be a challenge, as the large density gradients (up to 42% difference) cause significant refraction of the laser light and influence the path of the seeding particles. Moreover, the RB cell had to be optically accessible at a high pressure (57 bar), leading to a range of practical difficulties to overcome.

The high-pressure RB-cell was composed of a cube with two horizontal copper plates and four glass lateral walls. This cube was inserted inside a stainless-steel cylinder with three sight-glass flanges made of borosilicate to allow optical access to the flow. A drawing of the RB-cell is shown in Figure 2.



Drawing of the Rayleigh-Bénard high-pressure cell, with indications of: copper plates, thermocouples, laser port, borosilicate glass wall, water feeding pipes, and CHF3 feeding pipe

Inside each horizontal copper plate, a conduct for water was made to fix the temperatures of each plate. For insulation purposes, the copper plates were not in direct contact with the stainless steel, but there was an insulating gap between them as shown in the above Figure. The working fluid used was Trifluoromethane (R23, CHF3) because of its experimentally accessible critical point (4.8 MPa at about 26 oC). For each experimental condition, tracer particles were selected considering the density of the fluid at the average temperature in the cell, as well as the fluid densities at the top and bottom plate temperatures. The light source used was a diode pumped solid state laser (continuous, 5W, 532 nm), the camera was a LaVision Imager MX, with a resolution of 2048 X 2048 pixels and a pixel pitch of 5.5 µm.

A preliminary background oriented schlieren (BOS) study was performed to quantify the effects of strong density changes within the flow. It was found that, except very close to the walls, an upper bound for the PIV velocity error due to optical distortions was estimated at approximately 2.5%.

Some of the PIV results can be found in Figure 3. The time-averaged velocity fields showed strong asymmetries that are not visible under non-Boussinesq conditions in liquids [2]. More details of the work of Valori can be found in her PhD thesis [2].

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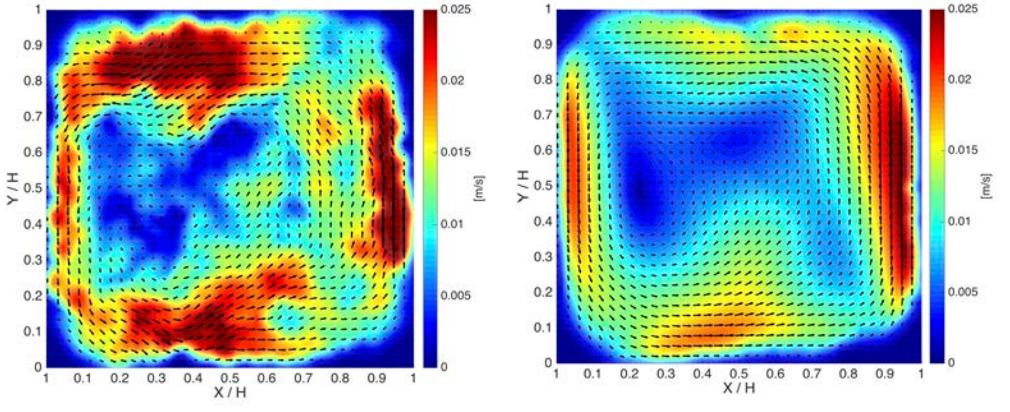


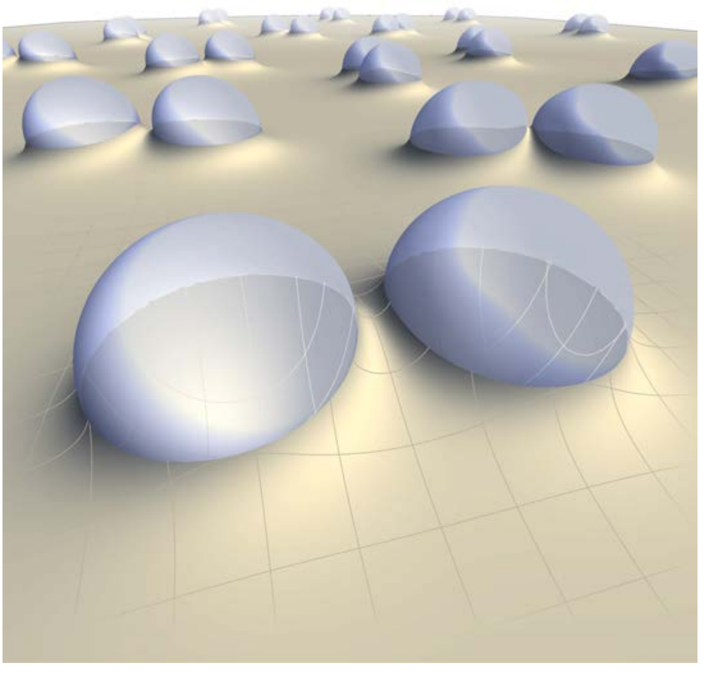
Instantaneous flow field (left), time-averaged flow field (right) in supercritical R23. The color scale indicates the magnitude of the velocities. Only one vector every four data points is plotted.

Drop interactions on soft layers: Beyond the Cheerios effect

Jacco H. Snoeijer (Physics of Fluids Group, University of Twente)

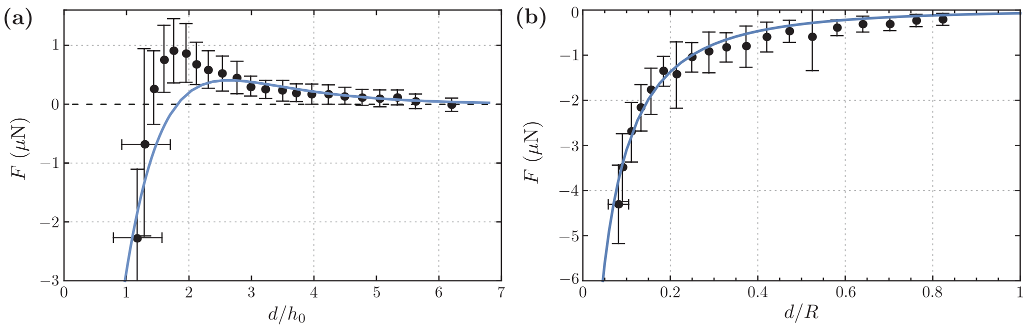
Particles floating at a liquid surface exhibit long-ranged interactions, mediated by deformations of the interface. This phenomenon is popularly known as the “Cheerios effect”, named after the clustering of breakfast cereals in a milk bowl [1]. The Cheerios effect can be explored for particle self-assembly at liquid interfaces and is important when living organisms or fine particles float on the surface of water. We recently found that similar interactions arise between liquid drops, on a broad variety of soft, deformable surfaces (Fig. 1). Drop-drop interactions emerge for wetting on soft gels [2-4] and on thin viscous films [5], and play an important role for condensation on polymer films or for wet-on-wet printing.

We experimentally observed how the trajectories of mm-sized drops sliding down a soft elastic substrate are deflected when another drop is in close proximity [2]. Subsequently, the interaction could be quantified as a force that depends on the distance between the drops. Surprisingly, the force between two drops can be attractive or repulsive depending on the thickness of the substrate: Droplets always attract each other on thick layers (Fig. 2b), while for thin layers droplets repel when spaced more than a few times the layer thickness (Fig. 2a). These force-distance laws can be understood in detail by computing the elastic deformation induced by a single drop, and subsequently accounting for the deformation’s action on the second drop [3,4]. Figure 2 shows the quantitative comparison between theory and experiment, both on thick and on thin layers. The theory is also able to predict the velocity of the attractive or repulsive motion, which turns out to be governed by the rheology of the PDMS gel [3].

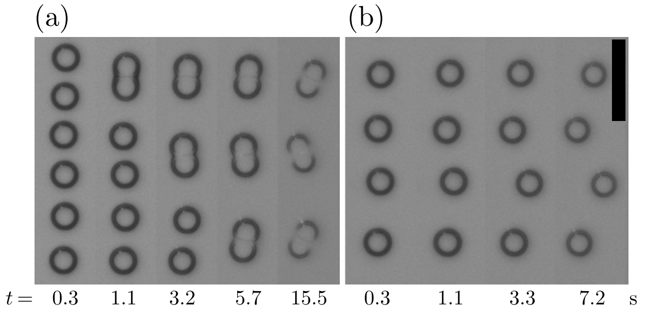


Interactions between liquid drops on a soft elastic layer. Each drop deforms the interface, which induces a force on drops in close proximity.

In another series of experiments [5], we considered the interaction between small droplets (water, radius 45 μm) on a thin viscous film (oil, thickness 10-50 μm). This study was in collaboration with Océ Technologies, since Cheerios-like interactions can arise when droplets are printed on a previously deposited viscous layer. As illustrated in Fig. 3, the droplets can again exhibit attractive or repulsive interactions: The droplets in the printed line of panel (a) form clusters, while in panel (b) the droplets push each other out of the initially straight line. The only difference between the two experiments is the initial spacing between the drops. While this scenario of attraction versus repulsion is reminiscent of drops on elastic layers, the viscous nature of the supporting film leads to a dynamical evolution of its surface. By consequence the interaction law evolves slowly over time. This dynamics is accurately described by the lubrication equation for the viscous film, which reveals that the range of attraction increases with time as t1/4. Hence, the drop-drop interactions become very long-ranged, reaching much beyond the size of the drops and the thickness of the layer.



Interaction force F between liquid drops (ethylene glycol, radius R=700 μm) on a soft elastic substrate (PDMS) as a function of drop spacing d. (a) Attractive and repulsive forces on a thin substrate (h0 = 40 μm). (b) Interactions are purely attractive on a thick substrate (h0 = 8 mm). Experiments can be understood by modeling the elasto-capillary deformations.



Printing wet-on-wet: Interaction of water drops on a thin film of viscous silicone oil. Scale bar represents 400 μm. The interactions can be attractive (panel a) or repulsive (panel b), depending on the initial spacing between the droplets.

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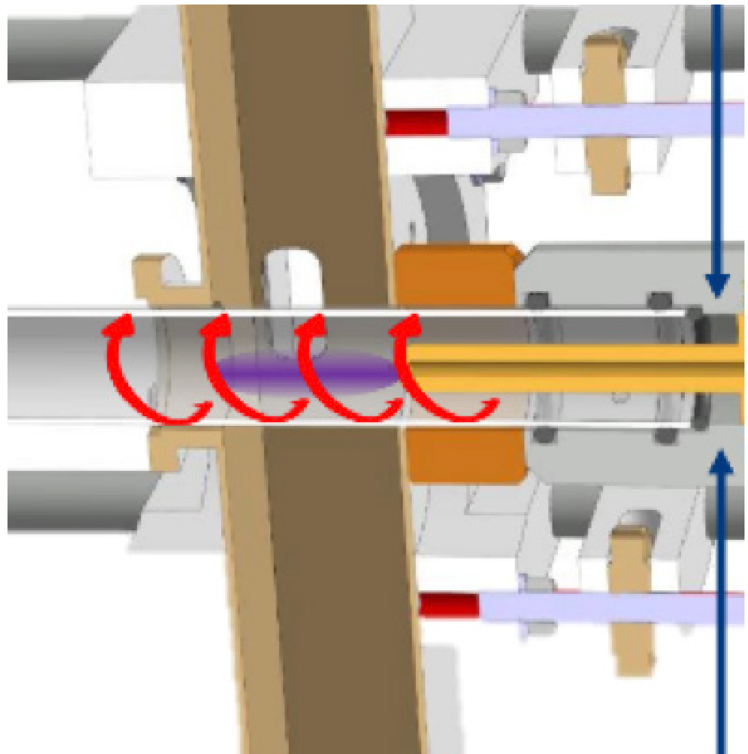
RESEARCH



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

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)

Process & energy

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

Multiphase systems

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.

Prof.dr.ir. C Poelma

PROJECT AIM

Investigation of cavitation in a converging-diverging axisymmetric nozzle using experimental techniques, i.e., high-speed imaging, X-ray densitometry, PIV and erosion paint tests.

PROGRESS

Partial cavitation regimes are identified using high-speed imaging and explained using cavitation and Strouhal numbers. Furthermore, X-ray densitometry experiments are performed to extract quantitative void fraction information.

1: Presented my work at Multiphase flow application (Paris) 2017.

2: Presented my work at IICR (Channia) 2017.

2: Presented my work at JMBC Multiphase contact day (Deltares) 2017.

4: Presented my progress at two project meetings organized in the framework of Marie Curie project CaFE.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Poster presentation "Dynamics of partial cavitation", IICR, Channia 2017.

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

FUNDED BY

EU (Marie Sklodowska-Curie Actions)
TU Delft

FUNDED %

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

START OF THE PROJECT

2015

INFORMATION

Saad Jahangir
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http://delftpe.nl/node/933

Mitigation of flow-induced vibrations in corrugated pipes by means of liquid addition

Project leaders
C. Poelma, J. Westerweel
Research theme
Complex dynamics of fluids
Participants
A.C. van Eckeveld, C. Poelma,
J. Westerweel
Cooperations
Shell
Funded by
Shell
Funded %

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

Start of the project
2013
Information
A.C. van Eckeveld
06 12644266
a.c.vaneckeveld@tudelft.nl
http://delftpe.nl/node/792

Project Aim

Development of physical understanding on sound mitigation in corrugated pipes, with a focus on industrial circumstances. Aimed at providing input for design purposes of corrugated risers.

Progress

Continuation of experiments in corrugated pipe set-up. Results indicate that liquid filling of the corrugations is the main contributor to the mitigation of whistling in annular corrugated pipes. Furthermore, work has been done on droplet formation in these pipes.

Dissertations

-

Scientific Publications

1. van Eckeveld, A. C., Westerweel, J., & Poelma, C. (2017). Mitigation of whistling in vertical corrugated pipes by liquid addition. Experiments in Fluids, 58(9), 107.
2. Eckeveld, A. V., Westerweel, J., & Poelma, C. (2017). Flow-induced noise in corrugated pipes-why does liquid reduce whistling?. In 23rd AIAA/CEAS Aeroacoustics Conference (p. 3002).

PROJECT AIM

To measure the gas (or vapour) flow in front of and the instabilities on top of a single impact wave and relating this to the variability observed in impact pressures. To achieve this the vapour-liquid free surface will be dynamically mapped in 3D while instabilities develop. The measurements are used to relate the variability in impact pressure to the free surface instabilities.

PROGRESS

A system to measure free surface instabilities over a wide range of scales has been set-up. The system uses a stereo camera set-up and laser induced fluorescence to detect the free surface over a single plane. In future work the set-up will be extended to include a scanning strategy to obtain a three-dimensional map of free surface instabilities.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

Jerry Westerweel, Christian Poelma

RESEARCH THEME

Complex structures of fluids

PARTICIPANTS

Mike van Meerkerk, 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

Mike van Meerkerk
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M.vanMeerkerk@tudelft.nl

Project leaders
Jerry Westerweel
Research theme
Complex dynamics of fluids
Participants
Gerrit E. Elsinga
Cooperations
-
Funded by
FOM which became a part of NWO
Funded %

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

Start of the project
2014
Information
Melika Gul
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Project Aim

To investigate the hysteresis behaviour of turbulent Taylor-Couette flow, which can be associated to the existence of multiple turbulent states in a Taylor-Couette system. To investigate turbulent structures, scale interaction between these structures and their spatial organizations in a turbulent pipe flow (covering both steady and unsteady cases).

Progress

The first part of the project which is about the hysteresis behavior of Taylor-Couette flow is finished. For the pipe flow, the research on internal shear layers and the large energy motions bounded by them is almost done. The experiments on the unsteady turbulent cases where the mean flow is subjected to a uniform acceleration/deceleration has already been conducted. Only, the processing & analyzing part is left.

Dissertations

-

Scientific Publications

1. Gul, M., Elsinga, G., & Westerweel, J. (2018). Experimental investigation of torque hysteresis behaviour of Taylor–Couette Flow. Journal of Fluid Mechanics, 836, 635-648. doi:10.1017/jfm.2017.809.

Flows Unveiled: Multimodal Measurement in Opaque Two-Phase Flows ("OpaqueFlows")

Project Aim

Dispersed multiphase flows are encountered in nearly every process in nature and industry; examples include sediment in rivers, catalysts in reactors and blood flow. Despite their relevance, it is currently difficult to accurately and efficiently model these flows. The opacity of the flows, even at moderate volume fractions, renders the common optical flow measurement tools useless. As a result, very little high-quality data is currently available to develop (numerical) models. In this project, I lift the veil that covers multiphase flows. I do this by bringing together four flow measurement modalities, based on ultrasound, magnetic resonance, X-ray and advanced optical imaging. These are each applied to three benchmark flows, impenetrable to common (optical) techniques. This project will be the first focused effort to systematically apply these techniques to the same three benchmark flows. These benchmarks are: (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 behaviour. These three flows represent archetypical flows from nature and industry, each pertaining to particular open questions in the field of fluid mechanics. The combined velocity and concentration field data resulting from this set of experiments will be vital in assessing and improving each of the techniques: direct comparison will allow evaluation of the performance and show the effect of acquisition and processing parameters on the accuracy. Detailed simulations using the exact same conditions will serve as further reference. Combined with the multi-modal experimental data, this will give breakthrough insight in the underlying physics of each of the benchmark flows. This in turn will lead to better multiphase flow models, which are demanded by a wide range of application areas (e.g. process technology, dredging, food and cosmetics industry, and hemodynamics research).

Progress

Recruitment of the first three PhD candidates ended in the fall of 2017. The project is in the startup phase.

Dissertations

-

Scientific Publications

-

Project leaders

prof. dr. ir. C. Poelma

Research theme

Complex dynamics of fluids

Participants

Christian Poelma, Willian Hogendoorn
Amitosh Dash, Cenk Çetin,
+vacancies

Cooperations

-

Funded by

ERC Consolidator Grant

Funded %

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

Start of the project

2017

Information

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PROJECT LEADERS
prof. dr. ir. C. Poelma
prof. dr. ir. J. Westerweel
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Partners in STW SLING project
COOPERATIONS
Partners in STW SLING project
FUNDED BY
STW SLING
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 project focuses on the interaction between microbubbles and pressure waves in the context of liquid loads during sloshing events. The project objective is to understand the influence of liquid compressibility (LC) on the liquid loads during sloshing events with and without phase transitions (PT) by varying the density ratio, gas compressibility, liquid compressibility and phase transitions.

PROGRESS

The PhD-project started last year July. In the first months methods have been designed and exploratory experiments have been performed to study the interaction between microbubbles and pressure waves. A method has been developed to generate microbubbles and to locally determine the void fraction inside a bubble cloud accurately. Pressure waves propagating through an aerated liquid have been visualized and the interaction between the pressure wave front and microbubbles has been recorded with very high frame rate.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Project Aim

The aim of this PhD project is two-fold: 1) develop a state-of-the-art computational method for fully resolved simulations of dense particle-laden turbulent flows and 2) study the structure and dynamics of these flows with the developed method.

Progress

In 2017 two papers were published in the Journal of Fluid Mechanics. Another paper has been accepted by the same journal for publication in 2018. The PhD student (PS Costa) successfully defended his thesis on December 19 2017. The image below shows the turbulent transport of a dense suspension of 640,000 neutrally-buoyant spheres in a plane channel at a bulk Reynolds number of 12,000, obtained from an interface-resolved Direct Numerical Simulation. The particle diameter is 72 times smaller than the channel height, corresponding to approximately 10 viscous wall units. The color denotes the velocity of the particles (red high, blue low). The flow is from left to right.

Dissertations

1. P. Simões Costa. Interface-resolved simulations of dense turbulent suspension flows. PhD thesis, Delft University of Technology, 2017.

Scientific Publications

1. M. Niazi Ardekani, P. Costa, W.-P. Breugem, F. Picano and L. Brandt. Drag reduction in turbulent channel flow laden with finite-size oblate spheroids. J. Fluid Mech., vol. 816, 43-70, 2017.
2. I. Lashgari, F. Picano, P. Costa, W.-P. Breugem and L. Brandt. Turbulent channel flow of a dense binary mixture of rigid particles. J. Fluid Mech., vol. 818, 623-645, 2017.

Project leaders

WP Breugem, BJ Boersma, J Westerweel

Research theme

Complex dynamics of fluids

Participants

PS Costa, WP Breugem, BJ Boersma, J Westerweel

Cooperations

-

Funded by

FCT, The Portuguese Foundation for Science and Technology

Funded %

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

Start of the project

2013

Information

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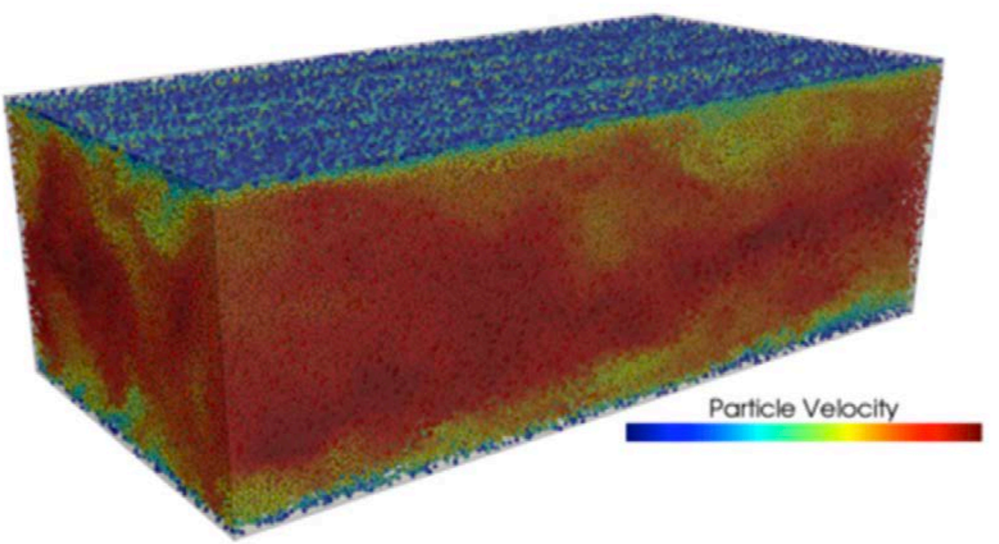

Origins of Collective Motion in Active Biofluids

Project leaders
Daniel Tam
Research theme
Complex dynamics of fluids
Participants
Abel-John Buchner, Parviz Ghoddoosi Dehnavi, Guillermo Amador
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 C. Reinhardtii, and checks for gravitaxis and phototaxis have been performed.
- Preparations have been made to compare C. Reinhardtii swimming dynamics with another, “pusher” based organism A. Carterae.
- Statistics of the kinematics of suspended cells and their interaction with wall boundaries have been calculated and are being further accumulated under varying conditions.

Dissertations

-

Scientific Publications

1. Abel-John Buchner, Koen Muller, Daniel Tam. Hydrodynamic interactions in swimming Chlamydomonas Reinhardtii (poster). Dutch BioPhysics 2-5 October 2017.

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 developed a calibration method for highly accurate camera calibration at the Rotterdam Zoo.

We are further improving a robust tracking method to track individual fish that is based on previous work.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. 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.

PROJECT LEADERS

Daniel Tam, Jerry Westerweel

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Koen Muller, Guillermo Amador

COOPERATIONS

Prof. Charlotte Hemelrijk (RUG)
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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Experimental and numerical study of turbulent combustion in a lab-scale furnace

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

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

Start of the project
2013
Information
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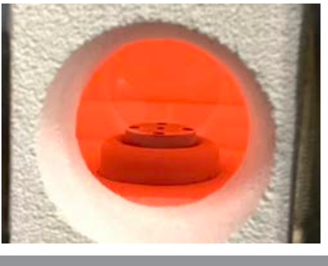

Project Aim

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

MILD combustion in the lab-scale furnace has been experimentally and numerically studied. Measurements of velocity and temperature statistics during operation with power 9 kW at equivalence ratio 0.7, 0.8 and 0.9 were obtained respectively using LDA and CARS. Visible flames were not observed confirming the operation in the MILD regime. The flow field in the furnace, which is mainly driven by the air jets, is very turbulent enhancing entrainment and accelerating internal burnt gases recirculation. The air jets surrounding the fuel jet play an important role in preventing early ignition and flame propagation due to immediate reactions between fuel and recirculated burnt gases in lean operating conditions. This indicates that the distance between fuel and air jets is of importance in a burner nozzle design to achieve stable flameless combustion. Temperature histograms in the reaction zone show no bimodal behavior, indicating that no stable flame front like structure are present in the reaction zone. The temperature rise in the reaction zone due to reactions was quite low resulting in suppressed peak temperature and ultra low NOx emissions. To characterize the dilution effects of burnt gases on reactions numerically, flamelets generated with diluted fuel and diluted air, instead of flamelets based on pure fuel and air, were applied in an extended Flamelet Generated Manifold (FGM) approach. Burnt gases at stoichiometric mixture fraction rather than those at global equivalence ratio were considered as diluent, which is more appropriate for furnaces operating at lean condition. The numerical simulations were performed using the open source CFD package -- OpenFOAM. The PhD Thesis will be completed in the coming year.

Dissertations

-

Scientific Publications

1. X. Huang, M. J. Tummers, D.J.E.M. Roekaerts, Experimental and numerical study of MILD combustion in a lab-scale furnace. In proceedings of the 11th European Conference on Industrial Furnaces and Boilers (INFUB 11), Energy Procedia, Volume 120, Pages 395-402 (August 2017), Volume editors: Viktor Scherer, Neil Fricker and Albino Reis.
2. X. Huang, M. J. Tummers, D.J.E.M. Roekaerts, MILD combustion in a lab-scale furnace: ignition and flame behavior, in proceedings of the European Combustion Meeting, Dubrovnic, April 18-21, 2017.

Project Aim

Spray flames are widely used in industrial furnaces, power generation system, etc. and there is a need for computational models to predict their properties. The objective of this project is to develop and validate accurate and efficient modeling approaches for turbulent spray combustion. The models should describe the main physical and chemical processes, notably phase change, turbulence, chemical reaction and radiation and their mutual interactions. Models will be developed for dilute spray combustion and for the coupling between dense spray and dilute spray regions.

Progress

We have reported results of a computational study of oxy-fuel spray jet flames. An experimental database on flames of ethanol burning in a coflow of an O2–CO2 mixture, created at CORIA (Rouen, France), was used for model validation. Depending on the coflow composition and velocity the flames in these experiments start at nozzle (type A), just above the tip of the liquid sheet (type B) or are lifted (type C) and the challenge is to predict their structure and the transitions between them. The two-phase flow field is solved with an Eulerian–Lagrangian approach, with gas phase turbulence solved by Large Eddy Simulation (LES). The turbulence-chemistry interaction is accounted for using the Flamelet Generated Manifolds (FGM) method. It is found that for the type C flame, which is stabilized far downstream the dense region, some major features are successfully captured, e.g. the gas phase velocity field and flame structure. The flame lift-off height of type B flame is over-predicted. The type A flame, where the flame stabilizes inside the liquid sheet, cannot be described well by the current simulation model.

Project leaders
D.J.E.M. Roekaerts

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Likun Ma

Cooperations
-

Funded by
China Scholarship Council

Funded %

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

Start of the project
2012

Information
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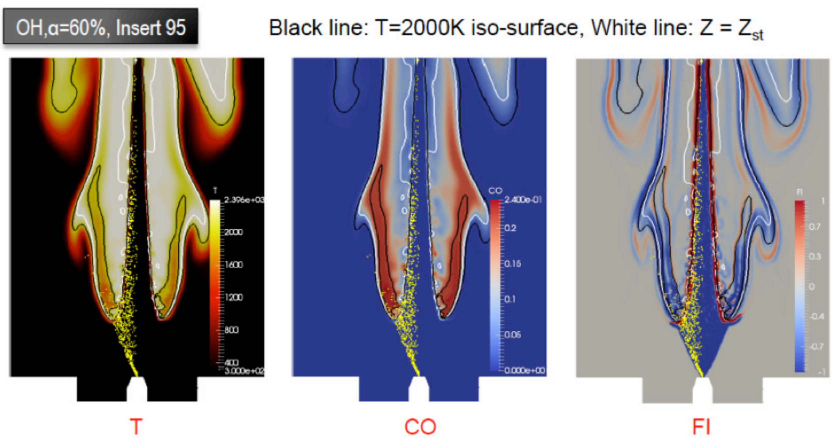
Dissertations
-

Scientific Publications

1. Likun Ma, Xu Huang and Dirk Roekaerts. Large Eddy Simulation of CO2 diluted Oxy-Fuel Spray Flames Fuel, Volume 201, 1 August 2017, Pages 165-175. http://dx.doi.org/10.1016/j.fuel.2017.02.050.
2. L. Ma, D. Roekaerts, Numerical study of the multi-flame structure in spray combustion, Proceedings of the Combustion Institute, volume 36, issue 2, pages 2603-2613, 2017.http://dx.doi.org/10.1016/j.proci.2016.06.015.



Coupled Radiative and Convective heat transfer in high temperature turbulent flows

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

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

Start of the project
2016
Information
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Project Aim

Many occurrences show that radiative heat transfer in turbulent flows lead to Turbulence Radiation Interactions (TRI), modifying the turbulent structures of the fluid. In our recent work we have shown that the interactions grow in relevance in optically intermediate to thick systems where radiation is absorbed and emitted extensively, dominating heat transfer within the flow. High pressure flows can be characterized by a large optical thickness (as for high pressure CO2 or water), therefore, our aim is to investigate the physical mechanism underlaying TRI to advance predictive models for these systems.

Progress

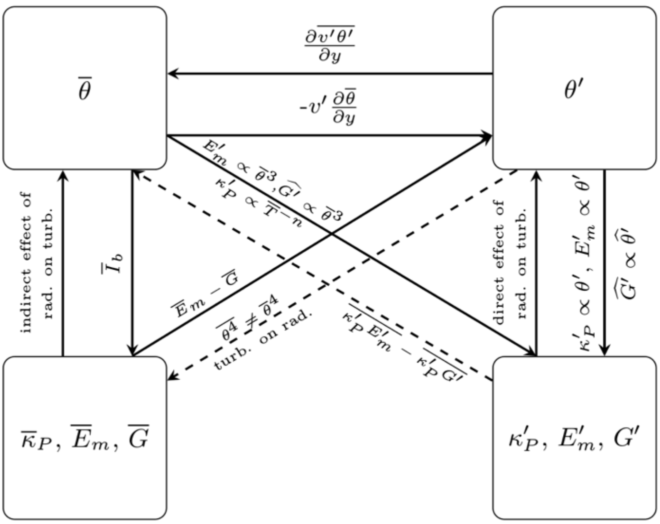
So far we have (1) fully characterized the mechanism of TRI in a grey gas; (2) Investigated and unveiled the dependency of TRI on optical thickness. (3) Developed a fast GPU implementation of a spectral Monte Carlo solver to couple accurate radiative heat transfer simulations with a DNS solver. (4) Discovered the effects of real gas spectra in the modification of TRI. (5) Effectively modelled effects of radiation on convective heat transfer in the RANS framework for both grey and non-grey gases.

Dissertations

-

Scientific Publications

-



Schematic of TRI pathways between radiative quantities (absorption coefficient , emission and incident

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

The potential for overdriving dust combustion with pyrotechnical igniters in the 20-l sphere has been recognized, discussed and analyzed for many years, notably in the determination of the minimum explosible and limiting oxygen concentrations, which has led to specific guidelines regarding the ignition source strength in ASTM standards. We have presented new experimental evidence that the energy provided by pyrotechnical igniters may, in some instances, physically alter the dust being tested in the 20-l sphere. Because of this, values of the deflagration index KSt can be several times greater in the small vessel compared to those measured in the 1-m3 chamber. Further visual evidence was provided to show that high energy ignition can produce a turbulent flame region, possibly consisting of a hybrid mixture of flammable gas (or vapor) and dust, which can propagate faster than the corresponding pure dust. The experiments suggest that KSt values measured in the 20-l sphere may no longer be representative of a dust deflagration in a real process environment. We recommend additional tests in a 1-m3 chamber when a dust exhibits a low flash point, or when it's KSt is above 300 bar m/s in the 20-l sphere. First steps towards realization of an experimental approach using a dust burner as an alternative methodology to the closed vessel experiments have been made. Publications have been prepared on metal dusts deflagration hazards, metal dusts deflagration incidents, dust explosion propagation in small pipes, and scaling of metal dust explosion severity.

Dissertations

-

Scientific Publications

1. Taveau, J., Going, J., Hochgreb, S., Lemkowitz, S., & Roekaerts, D.. Igniter-induced hybrids in the 20-l sphere. Journal of Loss Prevention in the Process Industries, 49:348-356, 2017 https://doi.org/10.1016/j.jlp.2017.07.014.

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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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

The manoeuvrability of high speed craft in following waves is a challenging topic for researchers in the field of marine and ship technology. The characteristics of these vessels when sailing in a seaway are highly dependent on the fluid dynamic interaction of the hull body and appendages and the flow stream. This projects investigates the behaviour of high speed craft in the following seas. This is a coupled manoeuvrability/seakeeping problem which involves both the steering and course keeping ability of the ship and its behaviour in a seaway. The objective is to understand the physical mechanism behind those dynamic course instabilities and the most important factors causing them. Furthermore, focus is directed to the implementation of mathematical tools, such as potential flow panels boundary element methods, which must reliably predict the motions of the ship in these conditions.

Progress

The investigation within this project is carried out both experimentally and numerically. Experimental captive model tests have been carried out at Delft University of Technology Towing Tank and at MARIN Seakeeping and Manoeuvring Basin in order to quantify the manoeuvring loads acting on the KNRM SAR NH1816 induced by heel and drift. The experiments were conducted in calm water and in waves. The results of the experiments were implemented in the mathematical model to investigate the manoeuvring behaviour of the high speed craft in waves.

Dissertations

-

Scientific Publications

1. Bonci, M., Renilson, M.R., de Jong, P., van Walree, F., Keuning, A.J. and Huijsmans, R.H.M. (2017). Experimental and numerical investigation on the heel and drift induced hydrodynamic loads of a high speed vessel, 14th Conference on Fast Sea Transportation, Nantes (France), 27-29 September.
2. Bonci, M., Renilson, M.R., De Jong, P., Van Walree, F., Keuning, A.J. and Huijsmans, R.H.M. (2017) Heel-sway-yaw coupling hydrodynamic loads on a high speed vessel. To be published at: 11th Symposium on High Speed Marine Vehicles, Naples (Italy), 25-27 October.

Project leaders
A.P. van 't Veer, P. de Jong

Research theme
Complex dynamics of fluids

Participants
M. Bonci

Cooperations
-

Funded by
TTW, KNRM, DAMEN, MARIN, BUREAU VERITAS, LLOYD REGISTER

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
A.P. van 't Veer, J.J.W. van der Vegt
Research theme
Complex dynamics of fluids
Participants
G. Jacobi, F. Brink
Cooperations
TTW, KNRM, DAMEN, MARIN, BUREAU VERITAS, LLOYD REGISTER
Funded by
-
Funded %

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

Start of the project
2015
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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

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. A method for vibration correction and pressure reconstruction was developed and applied to reconstruct the flow field and the pressure distribution in front of an interceptor, mounted to the transom of a planing ship. In the second stage of the project, PIV measurements were performed in the bow region of a fast displacement vessel to reconstruct the pressure distribution on the ship hull. Tests were performed as well in calm water as with an oscillating model.

Dissertations

-

Scientific Publications

-

PROJECT AIM

Two-fluid flow phenomena arise in a variety of scientific and engineering applications. Many numerical methods designed for solving the underlying fluid ow equations can artificially create energy at the two-fluid interface. Even a small energy-inconsistency at the fluid surface can already lead to highly instable behaviour leading to inaccurate results. In this research we develop a numerical method which ensures correct energy behaviour, i.e. no more energy inconsistencies at the fluid surface. To that purpose we use stabilized finite elements methods in the isogeometric analysis framework. The two-fluid interface is described by the level set methodology. The resulting method is suitable for two-fluid computations with turbulence characteristics.

PROGRESS

We have developed a method that ensures correct energy behaviour:

- in the single fluid case with high Reynolds numbers
- in the two-fluid case with low Reynolds numbers

Currently we are working on the integration of both techniques. After that we aim to apply it to an industrial sloshing test case.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. I. Akkerman and M.F.P. ten Eikelder, Toward free-surface ow simulations with correct energy evolution: an isogeometric level-set approach with monolithic time-integration, arXiv preprint arXiv:1801.08759.
2. M.F.P. ten Eikelder, I. Akkerman and R. van ‘t Veer, Correct energy behaviour in two-fluid ow, Proceedings of the 20th Numerical Towing Tank Symposium - NuTTS’17, Wageningen, the Netherlands (October 2017).

PROJECT LEADERS

I. Akkerman

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

M.F.P. ten Eikelder, I. Akkerman

COOPERATIONS

-

FUNDED BY

-

FUNDED %

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

START OF THE PROJECT

2016

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.

Erosion of Sand at High Flow Velocities

Project Aim

The safety level of a dike is expressed in terms of risk. Risk is defined as the product of the probability of inundation of a polder (after failure of a dike) and the expected damage (casualties, economic damage and damage to the infrastructure) caused by inundation. The rate of inundation determines the amount of casualties and depends heavily on the flow velocity through the breach and breach development in time. The flow velocity in a breach can become larger than 5 m/s. Due to these large flow velocities, the application of conventional sediment pick-up functions in breach growth models, leads to a significant overestimation of the breach growth and thus the rate of inundation. In this study the sediment pick-up functions will be determined with novel experiments in the high speed erosion regime.

Progress

Finished.

Dissertations

1. F. Bisschop, Erosion of sand at high flow velocities, doctoral thesis Delft University of Technolgy.

Scientific Publications

-

Project leaders
C van Rhee, SA Miedema, PJ Visser

Research theme
Complex dynamics of fluids

Participants
F. Bisschop

Cooperations
Arcadis
Royal Boskalis Westminster
Van Oord
Royal IHC

Funded by
Arcadis
Royal Boskalis Westminster
Van Oord
Royal IHC

Funded %

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

Start of the project
2012

Information
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Project leaders
C van Rhee, SA Miedema, RLJ Helmons

Research theme
Complex dynamics of fluids

Participants
RLJ Helmons

Cooperations
Agentschap NL
Royal Dutch Shell
Royal Boskalis Westminster
Van Oord
Royal IHC

Funded by
Agentschap NL
Royal Dutch Shell
Royal Boskalis Westminster
Van Oord
Royal IHC

Funded %

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

Start of the project
2012

Information
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Project Aim

Excavation of rock-like materials in a marine environment are more complex than excavations in land-based operations. The aim of the project is to include the complexity of the rock being in a submerged environment by incorporating the effects of a pore fluid and a hydrostatic pressure to the cutting process. This will be modeled in a framework based on discrete elements for the rock counterpart and a pore pressure diffusion equation will be solved on top of that based on a smoothed particle approach.

Progress

Finished.

Dissertations

1. Helmons, R. L. J. Excavation of hard deposits and rocks: On the cutting of saturated rock. Doctoral thesis, Delft University of Technology. (cum laude).

Scientific Publications

-

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 create a numerical model which can be used to simulate unstable breaching.

Progress

We have created a model which incorporates all relevant processes for unstable breaching: Flow of granular media, quasistatic granular media, flow of sand water mixtures, pore-pressure feedback, and erosion by turbidity currents. With this model we are able to model the breaching process (see figures). Results are compared with flume test data. Thesis is expected in 2018.

Dissertations

-

Scientific Publications

-

Project leaders

C van Rhee, GH Keetels

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

D Weij

Cooperations

Deltares

Funded by

Stichting speurwerk baggertechniek
Rijkswaterstaat

Funded %

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

Start of the project

2013

Information

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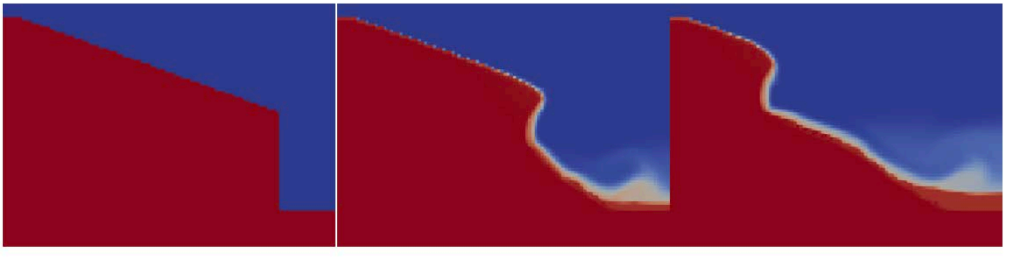

Project leaders
C. van Rhee, G.H. Keetels

Research theme
Complex dynamics of fluids

Participants
F. van Grunsven

Cooperations
NIOZ

Wageningen University/WUR

Funded by
STW, Royal IHC, Royal Boskalis Westminster, 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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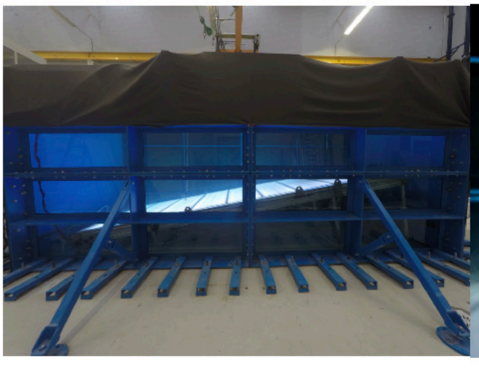
Project Aim
Develop a numerical model capable of predicting the three dimensional initial development of turbidity plumes which are expected during future deep-sea mining operations. The model will be validated by scientific literature and own experiments in the TU Delft dredging laboratory. Data gathered 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 advise for the industry.

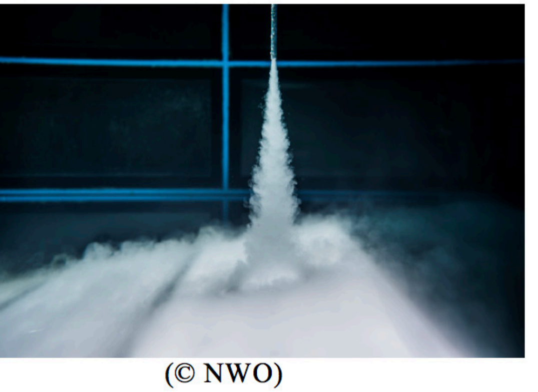
Progress
A set of measurements was performed in co-operation with a MSc student within a laboratory setup (25m3 tank) for the submerged discharge of turbidity plumes impinging on flat and sloped smooth surface. The goal is to quantify the dilution of the turbidity source and to measure the shear velocity of the turbidity current for various discharge scenarios for the validation of a numerical model.

Dissertations
-

Scientific Publications

1. Grunsven, F. van, Keetels, G.H. and Rhee, C. van. (2017). Simulating turbidity plumes with OpenFOAM. Proceeedins of the CEDA Dredging Days 2017: Sustainable Dredging – Continued Benefits, Rotterdam, The Netherlands.





(© NWO)

PROJECT AIM

In dredging engineering, underwater excavation process is one of the major procedures which involves complicated physics, no matter it is sand, clay or rock on the seabed. It is vitally important to reasonably estimate the cutting force needed on the excavator blade, which will be very helpful to improve the design and thus reduce the wear of the equipment and achieve higher working efficiency. However, it is widely acknowledged that the cutting force is greatly influenced by the local water pressure especially in deep water. The fluid flow will change the pore pressure distribution and meanwhile apply certain force to the solid particles. Since it is expensive to conduct experiments to measure the cutting force, a numerical model is then needed to describe the physics in it. This project will build up the numerical model of underwater excavation process for sand, clay and rock.

PROGRESS

The debugging work for parallel bond method is all finished. The model can now capture the behavior of normal force, shear force, moment due to shear force, bending moment and torque all in the calculation. Now I am busy generating results on tri-axial test and BTS tests. And these results will all be in my PhD thesis. Beside, writing the draft version of my PhD thesis.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Reduction of Energy Consumption When Using a Grab for Deep-Sea Mining Operations. Roel J. Kuiper, Xiuhan Chen, Jan C.L. Frumau, Sape A. Miedema Offshore Technology Conference, Houston, Texas, USA. 2–5 May 2016.

PROJECT LEADERS
C van Rhee, SA Miedema, Xiuhan Chen

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Xiuhan Chen

COOPERATIONS
STW, Seatools B.V.,
Tree-C Technology B.V.

FUNDED BY
STW

FUNDED %

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

START OF THE PROJECT
2012

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
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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
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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

Four way-coupled particle-fluid model is operational and several processes such as particle settling, particle-particle collision and particle-blade interaction are verified. Validation experiments have been executed. Experimental and numerical data has be compared. Dissertation is expected in 2018.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Modeling of turbulent hyper concentrated sediment transport in horizontal pipes

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. This PhD project is part of a collaboration with Dr. W.P. Breugem, Delft University of Technology.

Progress

Literature study and preliminary investigation to the applicability of two phase models in OpenFOAM for the prediction of sediment transport in the suspended regime. Apportioning the uncertainty in the computed concentration and velocity distribution in channel and pipe flow to uncertainties in the closures for the multiphase forces and numerical discretization. Design laboratory setup for validation of the model.

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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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 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 level.

Progress

Literature study and planning. Implementation of non-Newtonian fluids in ReFRESCO and solution verification. 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)

Dissertations

-

Scientific Publications

-

PROJECT AIM

In dredging engineering, underwater excavation process is one of the major procedures which involves complicated physics, no matter it is sand, clay or rock on the seabed. It is vitally important to reasonably estimate the cutting force needed on the excavator blade, which will be very helpful to improve the design and thus reduce the wear of the equipment and achieve higher working efficiency. However, it is widely acknowledged that the cutting force is greatly influenced by the local water pressure especially in deep water. The fluid flow will change the pore pressure distribution and meanwhile apply certain force to the solid particles. Since it is expensive to conduct experiments to measure the cutting force, a numerical model is then needed to describe the physics in it. This project will build up the numerical model of underwater excavation process for sand, clay and rock.

PROGRESS

The numerical model has been fully established, now capable of simulating the underwater sand, clay and rock cutting tests. Many scenarios are now running for building up a data base, for the material properties, and also for the cutting process.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Application of Parallel Bond Method in Rock Compression Simulation. Xiuhan Chen, Sape Miedema, Cees van Rhee, Proceedings of The 5th International Dredging Technology Development Conference of China, Beijing, China, 2017.
2. Preliminary results on the influence of large diameter pipeline for hydraulic transport in laboratory conditions. J.K. de Ridder, M.A. de Vreede, F. Wang, A.M. Talmon, X. Chen, Proceedings of The 5th International Dredging Technology Development Conference of China, Beijing, China, 2017.

PROJECT LEADERS

C van Rhee, SA Miedema, Xiuhan Chen

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Xiuhan Chen

COOPERATIONS

NWO, Seatools B.V., Tree-C Technology B.V.

FUNDED BY

NWO

FUNDED %

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

START OF THE PROJECT

2012

INFORMATION

Xiuhan Chen
015 278 4697
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www.tudelft.nl/en/3me/departments/maritime-and-transport-technology/research/dredging-engineering/phd-research/numerical-modelling-of-underwater-excavation-process/
http://www.h-haptics.nl/project.php?id=33

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

The project is aimed at studying the fundamentals of mass transfer in bubbly flows, inspired by industrial applications. 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, both at local bubble level and in a swarm of bubbles.

PROGRESS

During the first year of the PhD, focus has been placed on developing the experimental techniques for multiscale hydrodynamics investigations. Studies on a single rising bubble and an interacting bubble pair has been performed with high speed imaging and Particle image velocimetry (PIV). For a dense industrially relevant situation, initial X-ray particle tracking (XPTV) and gas fraction analysis were performed (figure below) in an airlift column. X-ray techniques will further be developed as an effective non-intrusive tool to compare with the two fluid CFD models. Simultaneously, first steps have been made towards mass transfer investigations in the wake of a single CO_2 bubble using planar laser induced fluorescence (PLIF). In combination with PIV, we aim to study simultaneously the flow structure and mixing around a pair of interacting bubbles.

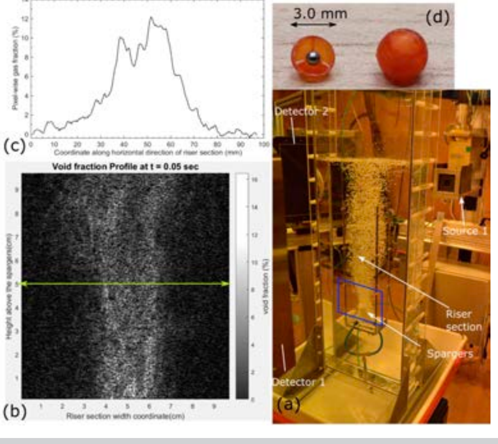
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

X-ray gas fraction measurement (a) Airlift column with two spargers (6L/min flow) (b) gas fraction contour of flow above the sparger (marked purple in (a)) (c) Gas fraction profile along at 5 cm above sparger (green line in (b)) (d) Neutrally buoyant particles with tungsten carbide insert, to be used for X-ray particle tracking velocimetry.



PROJECT LEADERS

Prof. Rob Mudde

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

FOM-IPP

FUNDED %

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

START OF THE PROJECT

2015

INFORMATION

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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)
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
Edoardo Cascioli
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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 fluids). These insights and models will make it possible to develop a reliable Computational Fluid Dynamics (CFD) tool for industrial use.

Progress

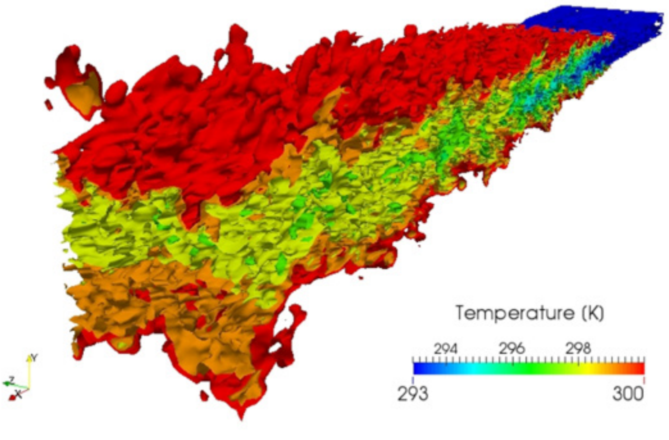
Single-effect cases are set up to get more insight on mixing phenomena and non-isothermal jets are recognized to be relevant to MYRRHA-like systems. Using OpenFOAM-2.4.0 CFD code, Large-Eddy Simulations (LES) of forced plane jet with heated co-flow have been performed at Pr = 0.71, 0.2, 0.025 and 0.006. This numerical database refers to and will be validated through an experimental campaign at The von Karman Institute of Fluid Dynamics (VKI). It is being used to compare, select and improve the currently available THT models which have not been developed to reliably predict thermal fields to low Prandtl unconfined flows.

Dissertations

-

Scientific Publications

1. Oral presentation: 4th SESAME/MYRTE Progress Meeting, Petten, Mar 2017 (WP3, D3.16).
2. Oral presentation: 5th SESAME/MYRTE Progress Meeting, Brasimone, Oct 2017 (WP3, D3.16).



Instantaneous temperature field from LES of a forced plane jet with heated co-flow at Pr = 0.2

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.

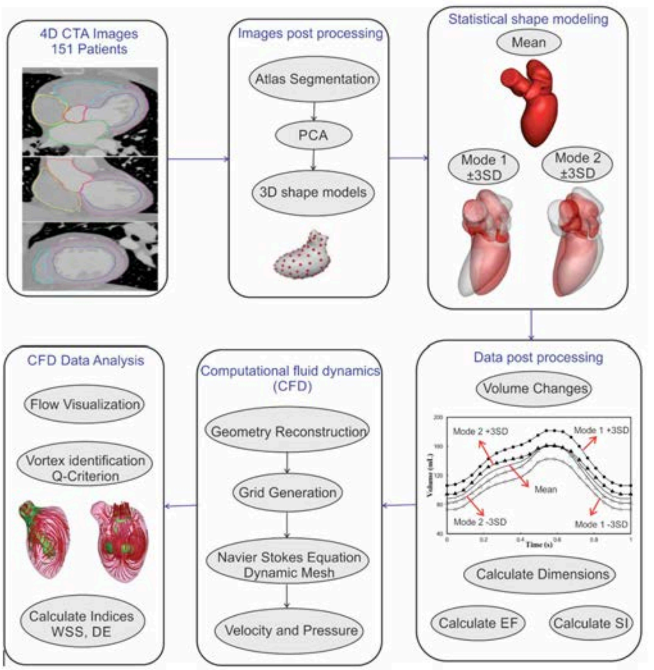
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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



PROJECT LEADERS

S.S.Khalafvand, 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	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2015

INFORMATION

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015 278 3649

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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http://cheme.nl/tp/people/perinajova.shtml

Project Aim

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

Progress

A proof of concept study has been performed on a complex, patient specific, geometry of a cerebrovascular system. The simulations were in a good agreement with the data obtained from Magnetic Resonance Imaging. Moreover, a complex model of oxygen mass transfer both in diluted form and bounded to the hemoglobin has been developed and studied. Results showed, that a patient specific simulations are crucial in order to obtain accurate results.

A comprehensive literature review has been performed in the first part of the study. The project and research questions have been formulated.

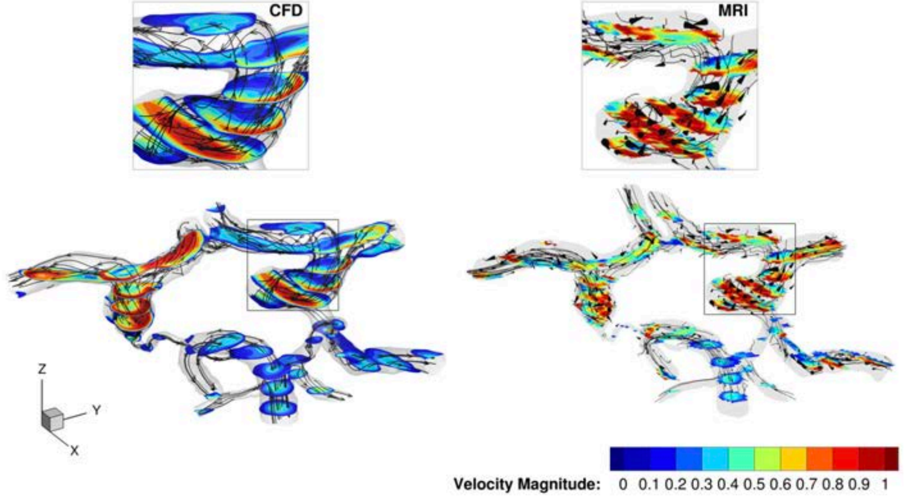
Dissertations

-

Scientific Publications

-

The streamtraces and contours of velocity magnitude for the Computational Fluid Dynamics model (left) compared to the results of Magnetic Resonance Imaging (right); as can be seen, the data are in a good agreement after applying the patient specific boundary conditions on all inlets and outlets



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 different ways.

1. The kinematics of the mechanical bi-leaflet is predefined from the experiments.

2. The dynamics of the bi-leaflet is represented as a result of the fluid-structure interactions (FSI) in which leaflets are considered as solid rotating objects with a limited degree of freedom.

We have applied various numerical approaches such as DNS, RANS and DES for the simulation.

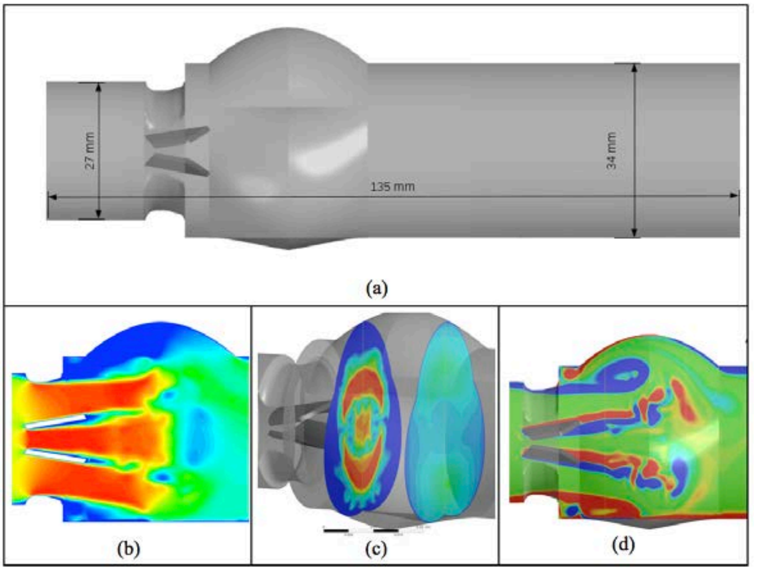
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

(a) The geometry of the simplified aortic root with bi-leaflet mechanical valve; (b) The stream-wise velocity contour on the central plane; (c) Stream-wise velocity contour on two chosen planes; (d) Vorticity contour on the central plane.



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
Fei Xu
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015 278 4387

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.

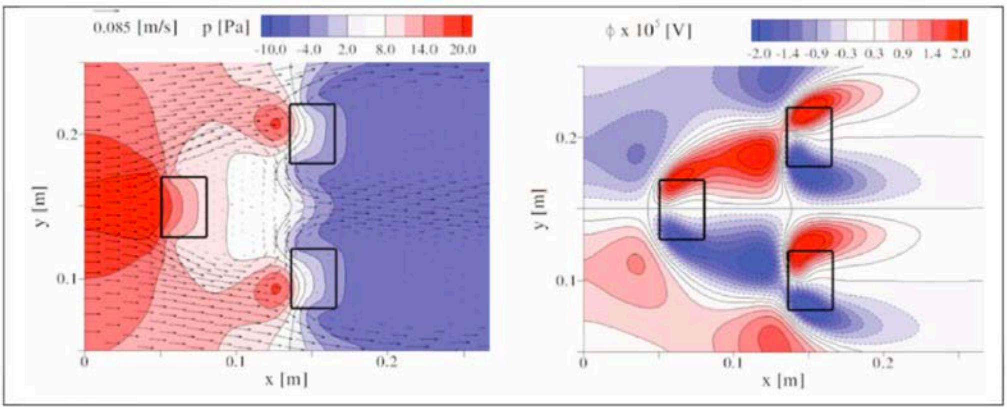
Dissertations

-

Scientific Publications

-

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 (2016).



Numerical Modeling, Simulations and Experiments of Blood and Air Flow with Magnetic Particles in Simplified and Realistic Patient Arterial and Airway Geometries: Towards Optimized Magnetic Drug Delivery

Project Aim

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

Progress

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

Dissertations

-

Scientific Publications

1. Kenjeres S. and Tjin J. L. (2017), "Numerical Simulations of Targeted Delivery of Magnetic Drug Aerosols in the Human Upper and Central Respiratory System: A Validation Study", Royal Society Open Science, Vol.4 (12), Art.No. 170873, pp.1-24 (DOI: 10.1098/rsos.170873).
2. Kenjeres S. and Tjin J. L. (2017), "Magnetically enhanced aerosol drug delivery in patient specific respiratory system", BME2017, The 6th Dutch Bio-Medical Engineering Conference, 26 and 27th January 2017, Egmond aan Zee, The Netherlands (oral presentation + extended abstract.
3. Voorneveld J., Hope T., Springeling G., Kenjeres S., Westenberg J., Gijsen F., de Jong N., Bosch J. (2017), "Multimodal left ventricular phantom for hemodynamic quantification studies", The 22nd European Symposium on Ultrasound Contrast Imaging, 19-20 January 2017, Rotterdam, The Netherlands.

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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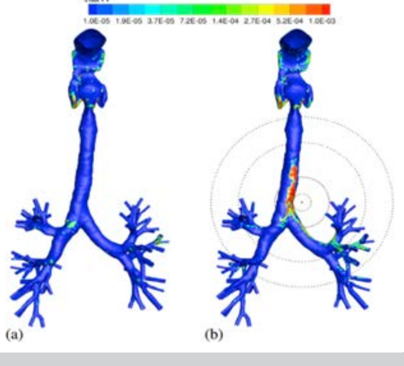

Contours of the local deposition efficiency (ζ) in the upper- and central-airways human respiratory system for the magnetic-core particles (dp = 3μm, St=4.3 × 10−2, Mnp=1.7 × 10−1) without (a) and with imposed magnetic field gradient (b), demonstrating potentials of the MDT, Kenjeres (2016)

Experimental and Numerical Investigations of Transitional and Turbulent Flows over Complex Surfaces with Heat Transfer and Emission of Passive Scalars

Project leaders
Dr. S. Kenjeres, Prof. P. Rudolf von Rohr
Research theme
Complex dynamics of fluids
Participants
A. Zenklusen, S. Kenjeres, P. Rudolf von Rohr
Cooperations
ETH Zurich, Switzerland
Funded by
ETH Zurich, HPC-Europa2, TU Delft
Funded %

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

Start of the project
2012
Information
S. Kenjeres
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Project Aim

This is a joint project between Transport Phenomena Section, Department of Chemical Engineering at the TU Delft and the Laboratory for Transport Processes and Reactions of Prof. P. Rudolf von Rohr at ETH Zurich. The project addresses the combined experimental and numerical study of turbulent flows over complex surfaces with heat transfer and distribution of passive scalars. The final goal is to perform in parallel state-of-the-art experiments (stereo PIV, LIF, TLC) and numerical simulations (LES, hybrid RANS/LES, DES, RANS) for different wall configurations over a range of Reynolds numbers and intensities of the wall heat flux and scalar emissions.

Progress

Experimental (PIV, LIF) and numerical studies (DNS and LES with dynamic Lagrangian SGS closure) performed for different flow regimes and different configurations of narrow channels with a porous medium. The turbulent mass transfer in good agreement with measurements.

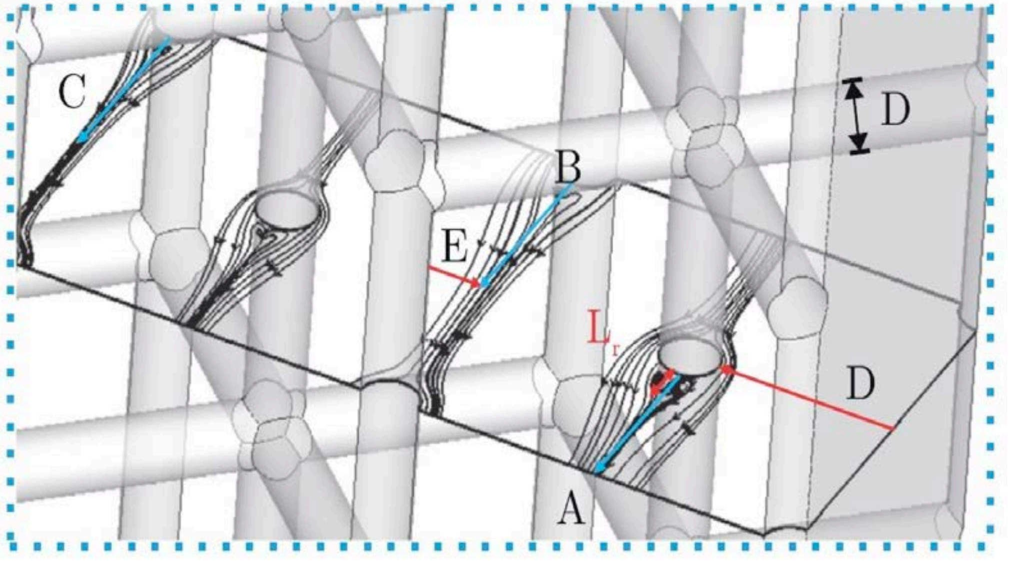
Dissertations

-

Scientific Publications

-

The wake structures and vortex shedding in dynamic LES simulation (performed at TU Delft) of the flow and mass transfer within a complex porous segment of a micro-reactor for which a detailed PIV and LIF measurements are performed at ETH.



PROJECT AIM

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

PROGRESS

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

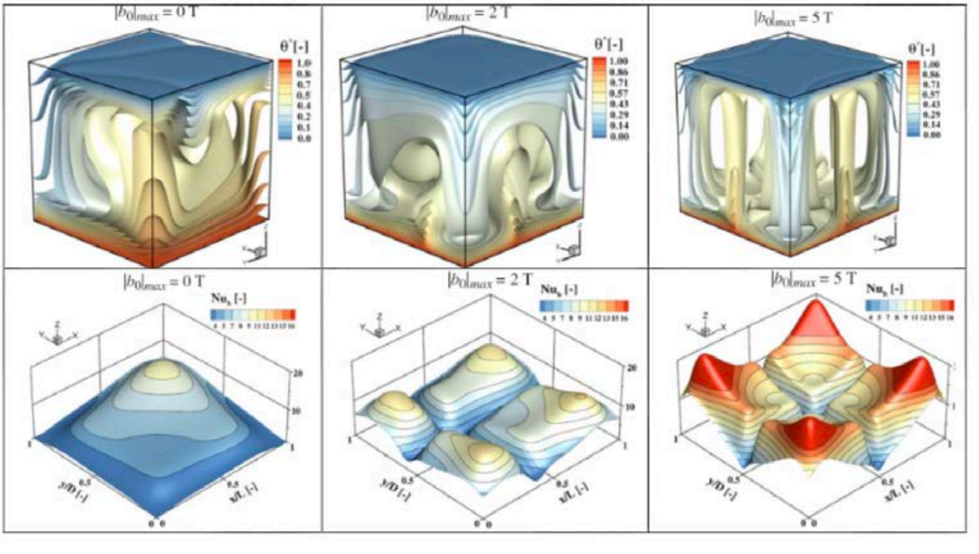
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Kenjeres S., Zinsmeester R., Pyrda L., Fornalik-Wajs E., Szmyd J.S. (2017), "Heat transfer control in thermo-magnetic convection of paramagnetic fluids in laminar, transient and turbulent regimes", Paper No. CHT-17-088, CHT-17 Advances in Computational Heat Transfer, 28 May – 1 June 2017, Napoli, Italy.

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



PROJECT LEADERS
Dr. S. Kenjeres

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Dr. S. Kenjeres, Prof. J. S. Szmyd, Dr. E. Fornalik-Wajs

COOPERATIONS
AGH University of Science and Technology, Krakow, Poland

FUNDED BY
EC Marie Curie, TU Delft, AGH Krakow

FUNDED %

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

START OF THE PROJECT
2010

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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.

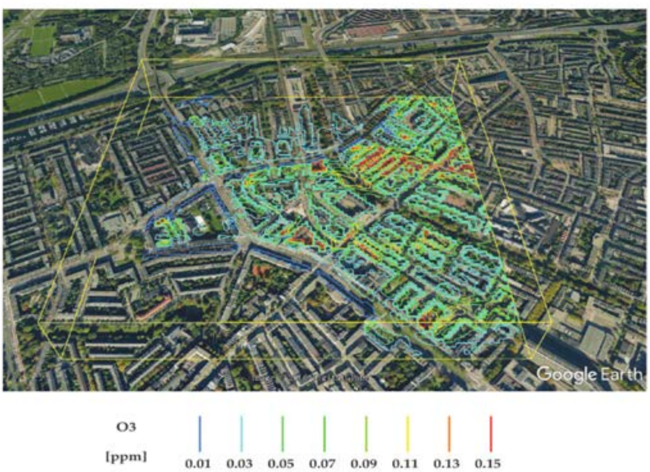
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Liu D., Kenjeres S. (2017), "Google-Earth Based Visualizations for Environmental Flows and Pollutant Dispersion in Urban Areas", Int. J. Environmental Research and Public Health, Vol.14 (3),247, pp.1-16 (doi: 10.3390/ijerph14030247).
2. Hennen J. and Kenjeres S. (2017), "Contribution to improved eddy-viscosity modeling of the wind turbine-to-wake interactions", Int. J. Heat and Fluid Flow, Vol.68, pp.319-336, (doi: 10.1016/j.ijheatfluidflow.2017.09.018).

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).



Experimental study of low and medium Prandtl number natural and mixed convection flows in coarse-grained porous media

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 will conduct 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. We will also perform X-ray particle tracking in a liquid metal to gain a better understanding of low-Prandtl number thermal convection flow in porous media.

Progress

Global heat transfer measurements were performed in a bottom-heated natural convection cubic cavity filled with various sphere conductivities, spheres sizes, and sphere packings for Rayleigh numbers between 107 and 109. Nu-numbers due to convection are obtained by subtracting the conduction terms from the measured Nu-numbers and plotted in figure 1. Two heat transfer regimes can be distinguished: (i) the decreased heat transfer regime at lower Ra numbers, where the Nu-number values depend on the porous media conductivity, packing structure and the grain size, and (ii) the asymptotic regime, at higher Ra numbers, where all data points coincide, and converge to the pure Rayleigh-Benard power-law curve.

Refractive index-matched fluid and solid spheres were used to perform Particle Image Velocimetry (PIV) and Liquid Crystal Thermography (LCT) measurements. Figure 2 shows that at Ra=8.5×107, in the decreased heat transfer regime, the flow velocities in the central region inside the pores are very small, and flow with high velocity is only observed in the wall regions. However, at Ra=7.3×108, in the asymptotic regime, high velocity occurs inside the pores as well as near the wall.

Dissertations

-

Scientific Publications

1. Ataei Dadavi, I., Kenjeres, S., Kleijn, C. R., & Tummers, M. J. (2017). Natural Convection Heat Transfer Measurements in Coarse-grained Porous Media. In Proceedings of the 9th World Conference on Experimental Heat Transfer, Fluid Mechanics and Thermodynamics.

Project leaders

Prof. dr. ir. C. R. Kleijn
Prof. dr. R. F. Mudde
Dr. ir. Mark Tummers
Dr. Sasa Kenjeres

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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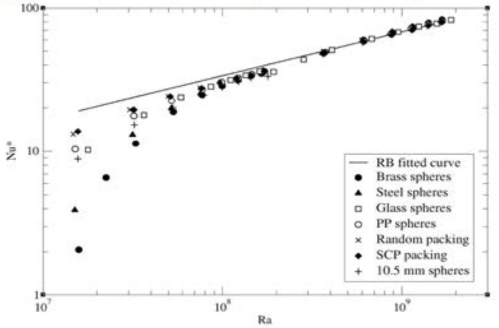
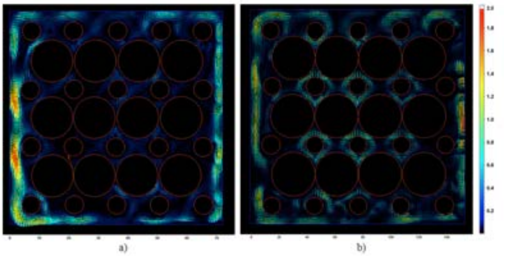
http://cheme.nl/tp/people/dadavi.shtml

Nu-Ra data curves for different sphere conductivities, packing types, and sphere sizes



Scaled mean velocity fields at a) Ra=8.5×10^7 and b) Ra=7.3×10^8



Numerical Study of Heat Transfer Enhancement due to Boiling in Rayleigh-Bénard Convection

Project leaders
Prof. dr. ir. C. R. Kleijn
Dr.ir. Saša Kenjereš

Research theme
Complex dynamics of fluids

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
The aim of the project is to provide a fundamental understanding of the influence of boiling on heat transfer in Rayleigh-Bénard Convection. This matter has only recently been studied by two independent groups. Lakkaraju et al. (2011-2014) have treated bubbles as point particles and neglected nucleate boiling. They have found a significant heat transfer enhancement due to bubbles, in addition to a reduced intermittency. Biferale et al. (2012) have performed Lattice-Boltzmann simulations and found a significantly lower heat transfer enhancement and the opposite effect on intermittency: an enhancement. We wish to address this conflict in literature.

Progress
The gross of the time of 2017 was spent on developing a library (code) for OpenFOAM, which can greatly reduce the spurious currents which appear when using the Volume-of-Fluid method to resolve a multiphase system. The essence of what this code does, is improving the calculation of the curvature for the surface tension force by making use of clever smoothing algorithms.

The next step is to implement the nucleation and phase-change model of Sato and Niceno (2017) within OpenFOAM. Afterwards, results may be produced.

Dissertations
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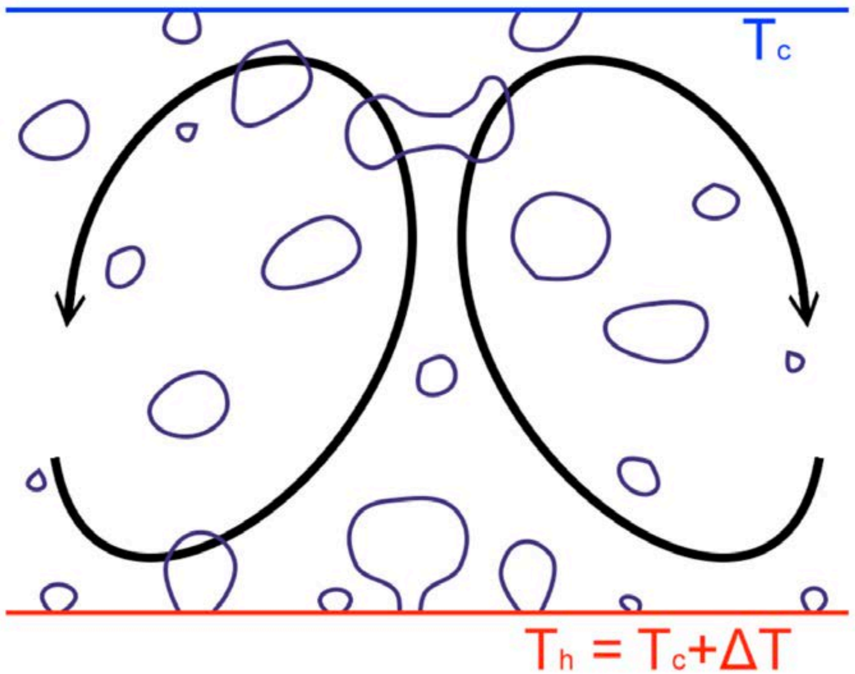
Scientific Publications
-



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 natural convection in a bottom heated cavity filled with coarse grained porous media is carried out using open source CFD solver, OpenFOAM. Coarse grained media of different thermal conductivity are analyzed at different Rayleigh number in a cavity filled with water (Figure 1). The heat transfer and flow in the cavity are compared with the results from an empty cavity. The results are validated with experimental results from the experimental project on the same topic in our group. Variation in heat transfer enhancement (Figure 2) and flow profile with conductivity of coarse grain media and change in Rayleigh number 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

Manu Chakkingal
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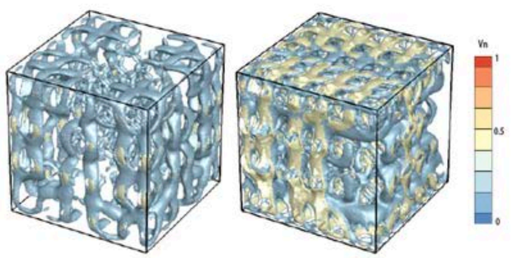
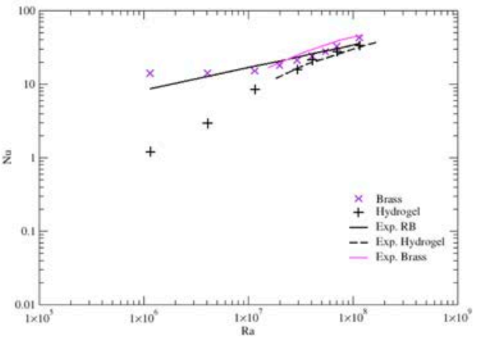
Instantaneous normalized velocity magnitude isosurface in a cavity filled with hydrogel beads at Ra (a) 107 (b)108 (colour code blue Vn=0.2, gold-Vn=0.5).



Change in heatransfer (Nu) with Rayleigh Number (Ra) in a bottom heated cavity filled with brass and hydrogel beads.



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 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

Recent progresses in numerical study of weld pool dynamic behaviour was reviewed to highlight the factors that can influence the process behaviour. A general multiphase model was developed to predict heat and fluid flow fields in fusion welding. Model verification was carried out with respect to data available in the literature. 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.

Dissertations

-

Scientific Publications

1. DSMC investigation of rarefied gas flow through diverging micro- and nanochannels, Amin Ebrahimi and E. Roohi. Microfluidics and Nanofluidics, vol. 21, no. 2, pp. 18, 2017, DOI: 10.1007/s10404-017-1855-1.
2. Laminar convective heat transfer of shear-thinning liquids in rectangular channels with longitudinal vortex generators, Amin Ebrahimi, B. Naranjani, S. Milani and F. D. Javan. Chemical Engineering Science, vol. 173, pp. 263-274, 2017, DOI: 10.1016/j.ces.2017.07.044.

PROJECT AIM

Coated nanoparticles have many potential applications, and we wish to produce large quantities of such particles by using Atomic Layer Deposition (ALD) in a fluidized bed reactor. However, due to the inter-particle cohesive forces, the nanoparticles form agglomerates in the fluidized bed, which influences the coating process. Our aim is to study the influence of the operating conditions and agglomerate structures on the overall coating time, and thus achieve guidelines for an efficient utilization of precursors and process optimization.

PROGRESS

Nanoparticle agglomerates are numerically constructed with up to 104 equally sized spherical nanoparticles for different fractal dimensions. Once generated, free molecular simulations are performed inside these agglomerates, including an ALD type of self-limiting reaction on the particle surfaces. Figure 1 shows surface coverage per particle for a partially coated agglomerate from such a simulation. We studied the overall coating time for agglomerates as a function of fractal dimension and agglomerate size. We developed a closed form theoretical model for predicting this time, which is validated by our molecular simulations. Furthermore, we came up with a regime map that teaches how the total coating time scales with the fractal dimension and the number of particles in an agglomerate.

DISSERTATIONS

1. Wenjie Jin, “modeling of atomic layer deposition on nanoparticle agglomerates” (29-11-2017).

SCIENTIFIC PUBLICATIONS

1. W. Jin, J. R. van Ommen, and C. R. Kleijn, A new cut-cell algorithm for \DSMC simulations of rarefied gas flows around immersed moving objects , Computer Physics Communications 2017, 212 , 146 – 151.
2. W. Jin, C. R. Kleijn, and J. R. van Ommen, Simulation of atomic layer deposition on nanoparticle agglomerates, Journal of Vacuum Science & Technology A, 2017, 35(1) , 01B116.

PROJECT LEADERS

Prof. Dr. Ir. C. R. Kleijn,
Prof. Dr. Ir. J. R. van Ommen

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Wenjie Jin

COOPERATIONS

-

FUNDED BY

NanoNextNL

FUNDED %

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

START OF THE PROJECT

2012

INFORMATION

Dr.ir. J.R. van Ommen
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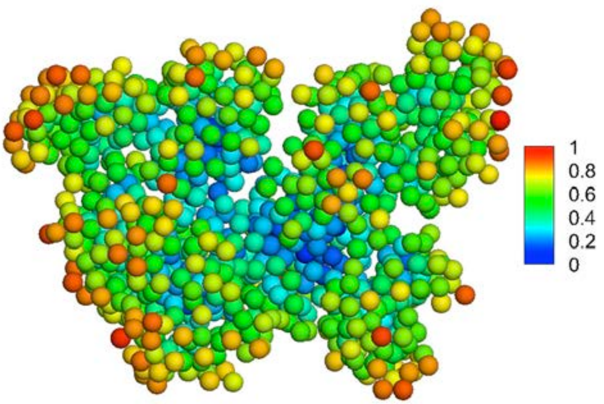
Surface coverage of each nanoparticle of an agglomerate



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
H.G. Pimpalgaonkar (PhD Student)

COOPERATIONS
FOM/Shell

FUNDED BY
FOM/Shell

FUNDED %

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

START OF THE PROJECT
2013

INFORMATION
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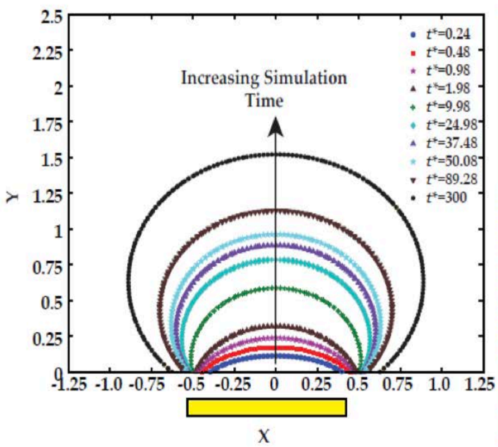
PROJECT AIM
This project aims at understanding the physics of oil-water separation and their escape from a nanoporous network in a Fischer-Tropsch catalyst. Study of the separation physics requires integration of the transport phenomena and a thermodynamic description of the phase behavior. The objective of this project is to develop a multicomponent multiphase fluid flow solver that captures the dynamics of reacting fluids inside nanopores. In this project, we wish to study the effect of surface wall heterogeneity of the nanopore, in terms of reaction activity and wetting, on the demixing inside the nanopores in Fischer-Tropsch processes. These insights will help us optimize the process catalyst, improve catalyst life, and increased catalyst selectivity.

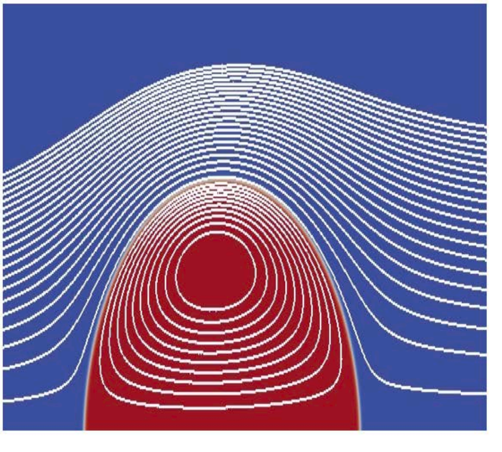
PROGRESS
We completed the development of the flow and reaction solver. The solver has been upgraded from an explicit method to a semi-implicit solver. We are currently applying this solver to a nanopore with significant convection to study the behavior of a droplet that forms at a hydrophilic catalytically active patch on the wall. In connection, we are also investigating the effect of various model parameters on the momentum transfer across the diffuse interface. In our simulations, we have observed that the momentum transfer across interface is significantly influenced by interface thickness, diffusivity and viscosity. We are currently developing a theory to explain the effect of model parameters on the effective surface tension.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-

Left figure shows the growth of the droplet with time in diffusion-reaction simulations1, figure on the right shows a streamline snapshot of a nanodroplet under shear (to be submitted)





Project Aim

Using stochastic simulations, we investigate the effect of thermal fluctuations at the interface of thin films between two foam bubbles. Thermal fluctuations have been shown to influence planar thin film dynamics, but their role in nonplanar films is largely unexplored. An important step forward from existing studies is to include the curvature, corresponding to the Plateau border, in the description of thin liquid films. The insights generated in this project will help us better understand the role of thermal fluctuations in the stability of emulsions and foams in food products.

Progress

We started this work by validating our code to study the dewetting dynamics of a thin, initially flat, film on a flat substrate with the literature. Figure 1 shows that the dewetting time decreases by a factor of 4 when thermal fluctuations are accounted for in the model, confirming earlier observations by Grun and co-authors [1]. Next, we studied the thin film drainage due to capillary suction and its subsequent rupture due to attractive van der Waals forces under the influence of thermal fluctuations. We find that the mean rupture times are insensitive to thermal fluctuations at high values of curvature, wherein the rupture time is predominantly determined by the time required to drain the liquid and follows the earlier reported scaling with curvature, Tr ~ □-10/7[2]. However, at low values of curvature, wherein rupture occurs due to the spontaneous growth of any fluctuations at the gas-liquid interface, noise intensities determine the rupture times, similar to what has been also observed in an initially flat film in dewetting studies.

Dissertations

-

Scientific Publications

1. Grün, G., Mecke, K., & Rauscher, M. (2006). Thin-Film Flow Influenced by Thermal Noise. Journal of Statistical Physics, 122(6), 1261–1291.
2. Kreutzer, M. T., Shah, M. S., Parthiban, P., & Khan, S. A. (2018). Evolution of nonconformal Landau-Levich-Bretherton films of partially wetting liquids. Physical Review Fluids, 3(1), 014203.

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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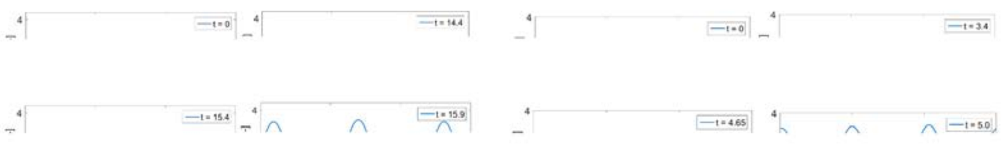
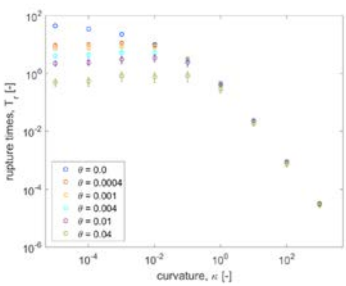


On the left, deterministic evolution of a nearly flat thin-film is shown. On the right, its stochastic evolution is shown

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 intensity ($kT/\gamma h0^2$)



Modeling of Vapor Flows for Design Optimization of a Novel Physical Vapor Deposition Apparatus

Project leaders
Prof. dr. ir. C. R. Kleijn
Dr.ir. Saša Kenjereš
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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http://cheme.nl/tp/people/elinvesper.shtml

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 Computational Fluid Dynamics (CFD) and 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

The literature review is finalized and the underlying solvers validated. The implementation of the hybrid solver is at an initial state and requires more fine tuning in the coming months. The main difficulties will be in the coupling of the solvers and the numerical instability of CFD. To obtain first results the DSMC method is used without coupling. A comparison of the obtained coating thickness with of experimental results from one nozzle is presented in the figure 3 (the height of the DSMC simulation is normalized to the maximum height of the experiments). Parallely the solver will be developed.

Dissertations

-

Scientific Publications

-

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 second year of the PhD, focus has been placed on studying hydrodynamics of dense recirculating bubbly flow in presence of dissolved electrolytes. X-ray imaging, high speed imaging and bubble imaging velocimetry (BIV) (figure below) were used to measure the local gas fractions, the bubble sizes and the liquid velocity respectively. In combination with concentration measurements, we aim to study mass transfer in dense flows. In parallel, a two month traineeship was undertaken at Akzo Nobel Pulp and Performance Chemicals (PPC), Sweden to understand bubbly flows relevant for electrolysis process and perform bubble rise and coalescence experiments at industrially relevant conditions.

Dissertations

-

Scientific Publications

-

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

FOM-IPP

Funded %

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

Start of the project

2015

Information

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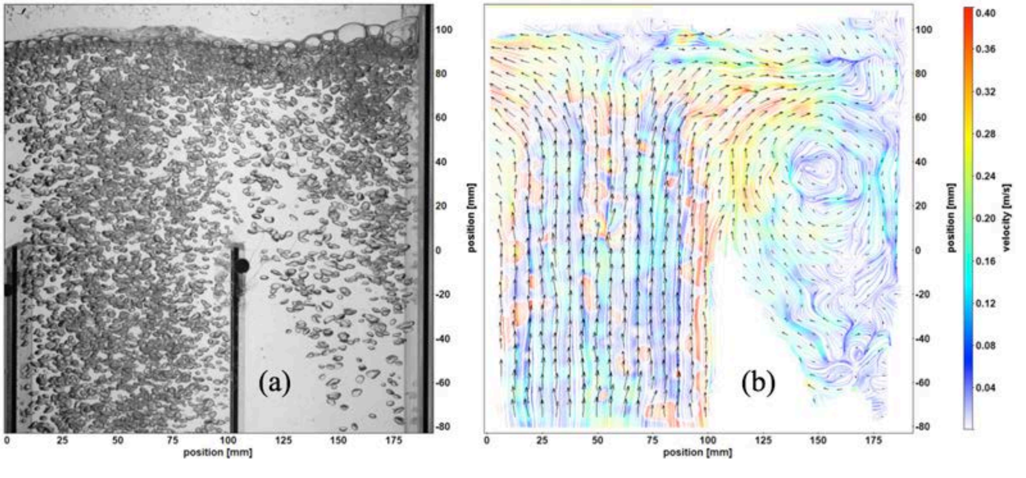
Recirculating dense bubbly flow in an airlift column (a) snapshot of recirculating zone (Q = 10l/min) (b) vector arrows and streamlines obtained from Bubble Imaging Velocimetry (BIV).



PROJECT LEADERS
Prof. Rob Mudde
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
Ir. Cees Haringa (PhD/TUD)
COOPERATIONS
ECUST Shanghai
DSM
Neil Tang MSc. (PhD/ECUST)
Prof. Henk J. Noorman (TUD, DSM)
Prof. Ju Chu (ECUST)
Dr. Jianye Xia (ECUST)
Prof. Joseph J. Heijnen (TUD)
Dr. Walter M. van Gulik (TUD)
Prof. Matthias Reuss (Univ. Stuttgart)
Dr. Wouter van Winden (DSM)
Dr. Amit T. Deshmukh (DSM)
FUNDED BY
NWO/MoST-Hé
DSM
FUNDED %

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

START OF THE PROJECT
2013
INFORMATION
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PROJECT AIM

The metabolic response of organisms in a fermentor depends on their environment, determined by the hydrodynamics, which may be spatially heterogeneous. The aim is to develop a computational fluid/reaction dynamics model that captures this heterogeneity. The results will serve as an input for laboratory experiments designed to study organisms in an industrially relevant environment; which is very relevant for the design of industrial fermentors.

PROGRESS

Euler-Lagrange CFD simulations to study how micro-organisms experience gradients in substrate concentration have been conducted, using 2 case studies (P. chrysogenum and S. cerevisiae). The cases were compared in terms of reaction vs. mixing timescales. Different analysis strategies have been explored to gather fluctuation statistics, which in turn are used as a basis for scale-down design. Different scale-down strategies have been theoretically explored. Metabolic model coupling to CFD simulations was explored. CFD simulations of 3l reactors revealed typically assumed ideal mixing does not hold for some lab fermentations. Further work was aimed at quantifying shortcomings in CFD simulations of multi-impeller mixing; a combination of LDA experiments and CFD simulations revealed poor turbulence predictions in the interaction region between the impellers.

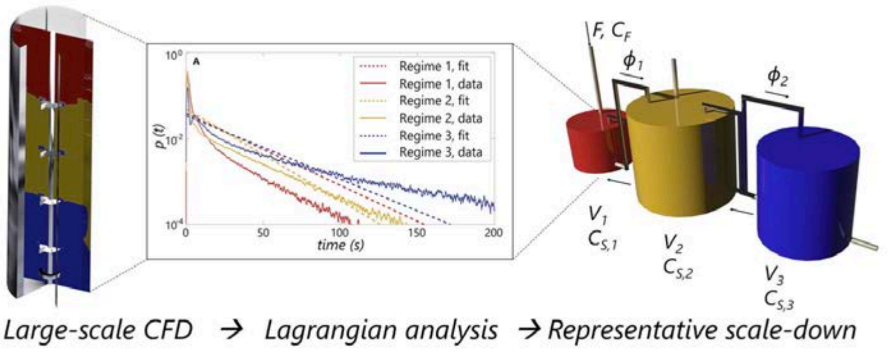
DISSERTATIONS

1. Haringa, C. "Through the Organism's Eyes" (11-12-2017).

SCIENTIFIC PUBLICATIONS

1. Haringa, C., et al., Chem. Eng. Sci, 157 p159-168 (2017).
2. Haringa, C., et al., Chem. Eng. Sci, 170, pp. 653-669 (2017).
3. Tang, W., et al., Biotechn. And Bioengng. 114(8), pp. 1733-1743 (2017).

Illustration of scale-down strategy. Left:Euler-Lagrange CFD analysis of industrial scale fermentor. Middle: residence time distribution in sections of the reactor with certain extra-cellular conditions (regimes). Right: 3-vessel lab scale (5l) reactor based on CFD analysis in order to replicate large-scale dynamics.



DNS of Emulsions: Mobile Interfaces and Adsorbed Surfactants

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

The new surfactant laden emulsion model in LB was tested over its parameter space, and extended to three dimensions. The model was used to simulate a pendent droplet formation problem, where the addition of the surfactant changes the droplet characteristics like the equilibrium diameter, path oscillation etc. (submitted to the AiChE journal). A turbulence forcing scheme was implemented in LB for single phase flow which is being tested and validated now – which will be combined with the model for simulating emulsions to study droplet dynamics in turbulence. The comparative assessment between VOF and LB was accepted for publication in IJHFF.

Dissertations

-

Scientific Publications

1. 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 (accepted).

Project leaders

Dr. Saša Kenjereš, Dipl-Ing
Prof. dr. ir. H.E.A Van den Akker
Prof. dr. Robert F. Mudde

Research theme

Mathematical and computational methods for fluid flow analysis

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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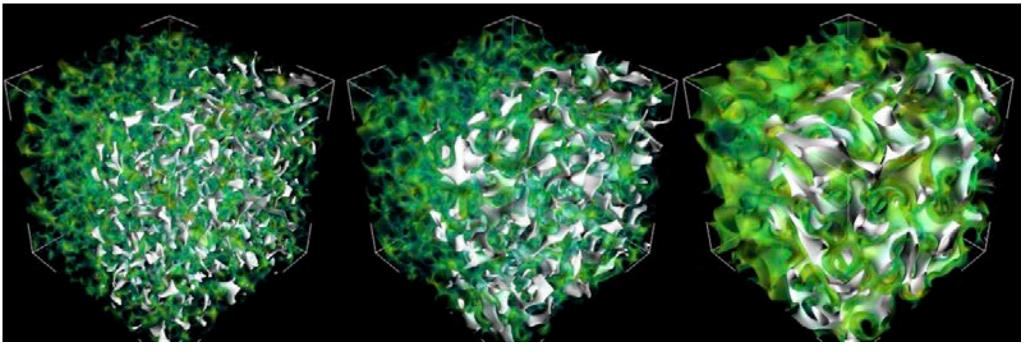
Snapshots of the normalized surfactant density fields (blue-green) shown for a spinodal decomposition simulation, which shows the coarsening of droplets by coalescence (left to right). The droplet contours are shown in white over half the domain



X-RAY TOMOGRAPHY AND SPECT IMAGING OF DYNAMIC STRUCTURES IN OPAQUE MULTIPHASE FLOW

PROJECT LEADERS
Prof. Rob Mudde
RESEARCH THEME
Complex Structures of Fluids
PARTICIPANTS
Ing, Evert Wagner (TUD)
COOPERATIONS
-
FUNDED BY
TU Delft
FUNDED %

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

START OF THE PROJECT
2007
INFORMATION
Evert Wagner
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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

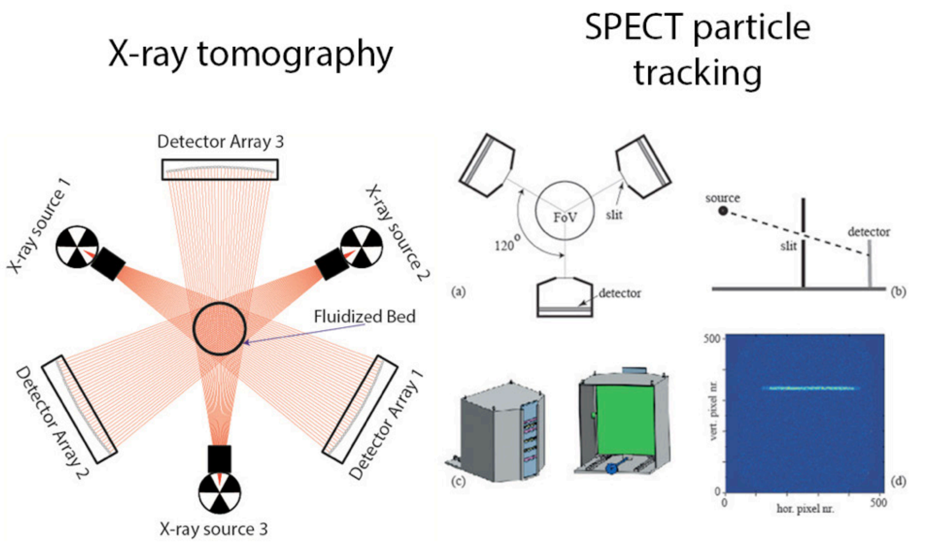
Both setups have been tested extensively in separate experiments. Currently, we have moved the equipment to a single lab, where they are combined to form a single measuring device. The first tests are expected in the spring of 2018.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Frank Schillinger, Simon Maurer, Evert C. Wagner, J. Ruud van Ommen, Robert F. Mudde, Tilman J. Schildhauer. Influence of vertical heat exchanger tubes, their arrangement and the column diameter on the hydrodynamics in a gas–solid bubbling fluidized bed. International Journal of Multiphase Flow 97 (2017) 46–59.
2. Helmi, A, E.C. Wagner, F. Galluccia, M. van Sint Annalanda, J.R. van Ommen, R.F. Mudde. On the hydrodynamics of membrane assisted fluidized bed reactors using Xray Analysis. Chemical Engineering & Processing: Process Intensification 122 (2017) 508–522.
3. Gomez-Hernandez, Jesus; Sanchez-Delgado, Sergio; Wagner, Evert; et al., “Characterization of TiO2 nanoparticles fluidization using X-ray imaging and pressure signals”, POWDER TECHNOLOGY, 316, 446-454 (2017).



Project Aim

Asphaltenes are heavy organic deposits that can be formed when the oil transport from subsurface reservoirs undergoes a sharp drop in pressure. Models are used for the prediction of asphaltene deposition and give important input to the design of deposition prevention and remediation methods. Models used so far in the oil and gas industry are highly empirical. The aim of the present project is to better understand the fundamentals of the influence of flow on the agglomeration and deposition process of asphaltenes. This will result into both new detailed flow models, as well as into improved models that can be used in the industry.

Progress

The Ph.D. thesis was defended in June 2016. The work was presented at the 9th International Conference on Multiphase Flow, held in Florence, Italy, in May 2016. In 2017, a paper was submitted to Journal of Fluid Mechanics and is currently under review.

Dissertations

-

Scientific Publications

-

Project leaders

R.A.W.M. Henkes
L.M. Portela
A. Twerda

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

K.C.J. Schutte (PhD student)

Cooperations

TNO, ENI (ISAPP2)

Funded by

ENI

Funded %

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

Start of the project

2011

Information

R.A.W.M. Henkes
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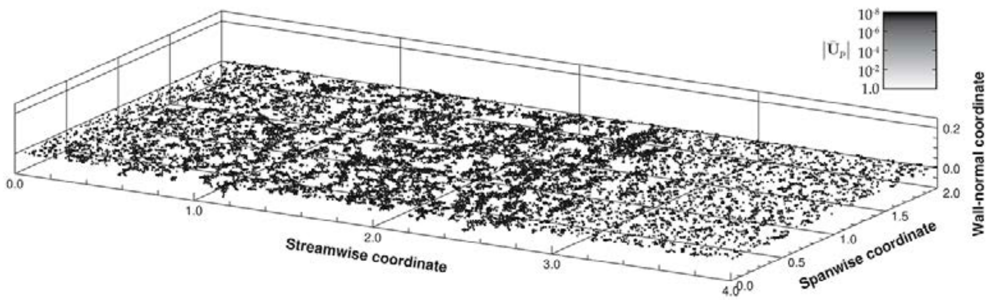
Snapshot of deposit layer formed in turbulent flow.



PROJECT LEADERS
R.A.W.M. Henkes, L.M. Portela
RESEARCH THEME
Complex structures of fluids
PARTICIPANTS
A.T. van Nimwegen
(PhD student and postdoc)
COOPERATIONS
NAM/Shell
FUNDED BY
NAM
FUNDED %

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

START OF THE PROJECT
2010
INFORMATION
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PROJECT AIM

This project is a combined experimental/modeling study on the performance of foamers for deliquification of gas wells as used in the gas and oil industry. The reduction of the reservoir pressure for maturing fields will cause that gas wells will start to accumulate liquid (water, condensate). The use of proper foamer chemicals will mix the liquid and gas into a foam, which decreases the hydrostatic head in the well and re-establishes the flow. The study includes flow experiments using a facility with pipe lengths of about 15 m and three diameters: 34, 50 and 80 mm.

PROGRESS

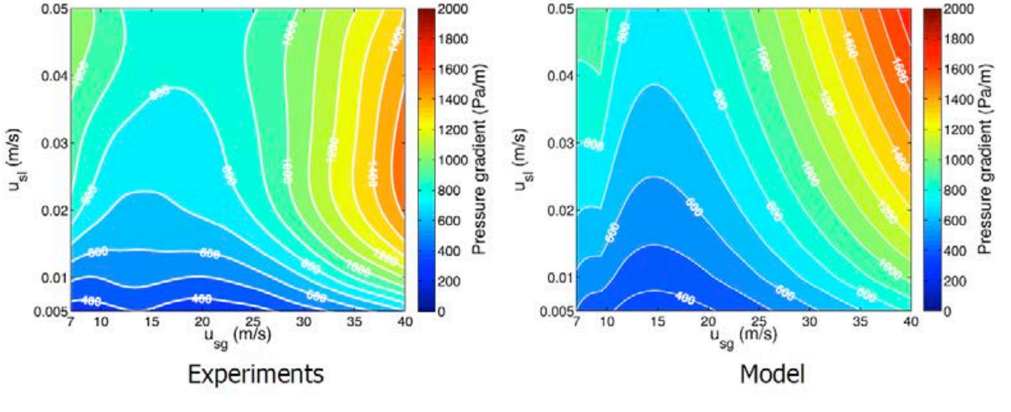
The experiments were concluded and A.T. van Nimwegen wrote his Ph.D. thesis and had his defense in June 2015. A. T. van Nimwegen continued working in the project as a postdoc, but his contract ended in 2016. The ideas for modeling resulted in a simple 1D model, which was successfully tested against the experimental data (see figure) and was implemented in the computer codes used by Shell/NAM. In 2017, a paper on this model was published in the International Journal of Multiphase Flow.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. A. T. van Nimwegen, L. M. Portela, and R. A.W. M. Henkes. The effect of the diameter on air-water annular and churn flow in vertical pipes with and without surfactants. International Journal of Multiphase Flow, vol. 88, pp. 179-190 (2017).
2. A. T. van Nimwegen, L. M. Portela, and R. A.W. M. Henkes. Modelling of upwards gas-liquid annular and churn flow with surfactants in vertical pipes. International Journal of Multiphase Flow, online, September 30, 2017.



PROJECT AIM

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

PROGRESS

A simple quasi-1D model that takes into account the main mechanisms associated with asphaltene agglomeration and breakup, and with the asphaltenes deposition at the wall was developed. In essence, the model is a simplified population-balance model: it considers only three classes of asphatenes and divides the cross-section of the pipe in a core region and a near-wall region. The model was incorporated into a simple quasi-1D turbulent pipe flow code and some preliminary simulations in long pipes were performed.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

L.M. Portela

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Marisa Bazzi

COOPERATIONS

Petrobras

FUNDED BY

-

FUNDED %

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

START OF THE PROJECT

2015

INFORMATION

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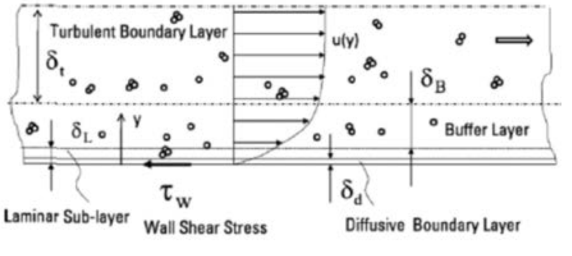

Project leaders
L.M. Portela
Research theme
Complex dynamics of fluids
Participants
Galileu Oliveira
(Petrobras engineer)
Cooperations
Petrobras
Funded by
Petrobras
Funded %

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

Start of the project
2015
Information
L.M. Portela
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Project Aim

Use advanced numerical simulation techniques, like DNS and LES, together with some modelling, to isolate the different mechanisms in gas-liquid annular flow, in order to get a better understanding of its dynamics,. Use this understanding to develop simple engineering models.

Progress

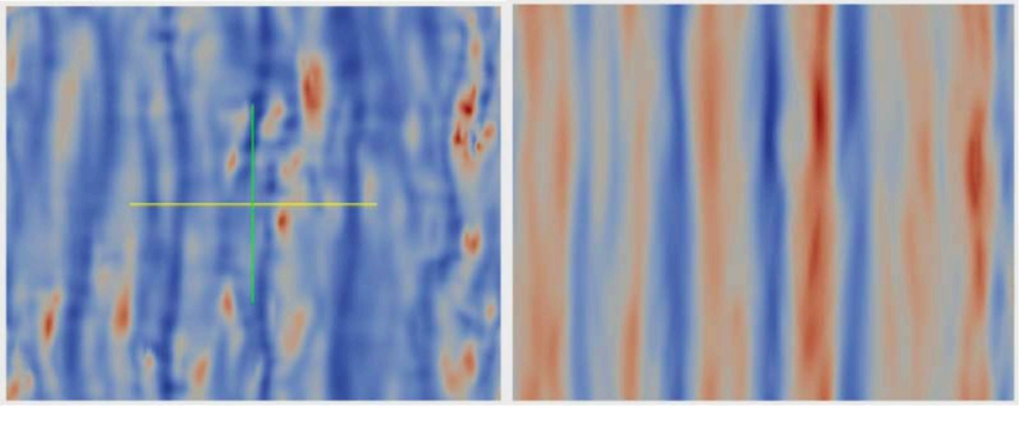
The project is a continuation of the Ph.D. work of Galileu Oliveira, who had to resume his activities as an engineer in Petrobras. He is now working part-time in the project. It was performed a DNS study of the flow with the suppression of the radial motion at the gas-liquid interface, in order to isolate this effect from the changes in the fluid properties at the interface.

Dissertations

-

Scientific Publications

-



Streamwise velocity patterns close to the interface, in the gas core (left) and in the liquid film (right), for vertical upward annular flow (blue: low velocity; red: high velocity)

Modeling and Simulation of Sediment Transport

Project Aim

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

Progress

The influence of different particle-force and resuspension models on the particle dynamics and particle patterns was evaluated using point-particle DNS. In particular, the use of a virtual resuspension wall was carefully evaluated. The results show that, except very close to the wall, the use of a resuspension wall does not affect significantly the particle dynamics; hence, it provides a simple way to model the resuspension of the particles. A paper, to be submitted to International Journal of Multiphase Flow, was prepared.

Dissertations

-

Scientific Publications

-

Project leaders

L.M. Portela
Christian Schaerer
Norberto Mangiavachi

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Hyun Shin (Ph.D. student)

Cooperations

State University of Rio de Janeiro
National University of Asuncion

Funded by

-

Funded %

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

Start of the project

2015

Information

L.M. Portela
06 20046078
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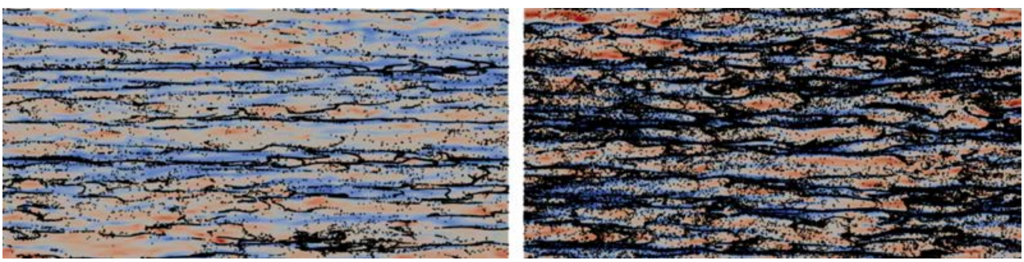

Snapshot of particle patterns close to the wall without (left) and with (right) a virtual wall

Simulating the meso-scale processes in two-phase chemical reactors

Project leaders
H.E.A. van den Akker
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
N. Looije, J.J.J. Gillissen
Cooperations
S. Sundaresan (Princeton uni.)
Funded by
Shell Global Solutions
ISPT
Funded %

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

Start of the project
2011
Information
Niels Looije
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Project Aim

The aim of the project is to provide a numerical framework for simulating multi-phase catalytic chemical reactors using the Lattice Boltzmann (LB) method. The mesoscopic nature of the LB method allows for an efficient implementation of many relevant phenomena such as phase separation, mass and heat transfer, and catalytic surface chemistry. A large part of the project will deal with combining these implementations and validating the resulting framework using canonical cases from literature. The final part of the project will be to use the framework to analyse an existing chemical reactor on relevant issues such as the occurrence of hot-spot formation.

Progress

The ongoing research has been on the LB implementation of a model which accounts for variable molecular masses in multi-component systems. A manuscript on the variation of the speed of sound in isothermal LBMs was not accepted by Phys. Rev. E and we are in the process of formatting the manuscript for submitting to Int. J. of Num. Methods. Several improvements have been made to the manuscript in terms of clarity and to the code in terms of accuracy of the validation cases based on the comments received from reviewers. Unfortunately, due to other personal and professional responsibilities elsewhere progress on this project has slowed down significantly.

An extension to this work applied to species with varying molecular weights in the simulation of a catalytic channel will be submitted to Chem. Eng. Sc.

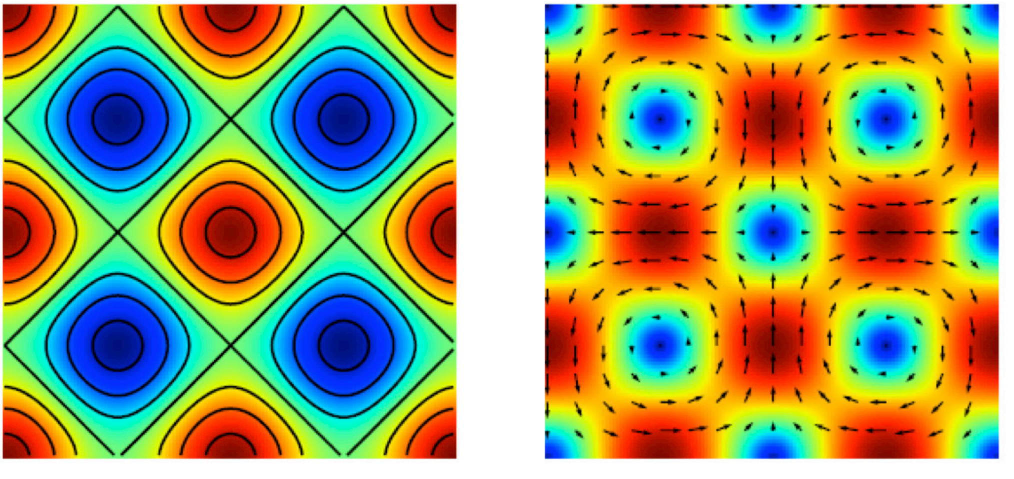
Dissertations

-

Scientific Publications

-

Initial conditions of a Taylor-Green Vortex: density (left), velocity (right).



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 behavior in spray drying processes, by studying collisions between a (1) partially-dried droplet and a solid wall, (2) a partially-dried droplet and a pre-formed agglomerate, and (3) two partially-dried droplets. Key for this understanding is to connect drying kinetics of single droplets to agglomeration behavior of colliding droplets and particles. Additionally the size of droplets will be reduced to 10-100 μm instead of the commonly used 1 mm diameter in order to better mimic the conditions in the spray dryer.

PROGRESS

In order to study spray drying collisions an experimental setup and method has to be developed. Controlled dispensing of <200 μm droplets has to be achieved before impacts can be realized. For this a PipeJet® and liquid-in-gas microfluidics (Fig. 1) are proposed. A free-falling single droplet dryer setup using the PipeJet® is in development. Chip designs from Tirandazi and Hidrovo (2017) will serve as a starting point for microdroplet dispensing of water and biopolymer-containing solutions. Optical Coherence Tomography and Particle Image Velocimetry are studied as tools to visualize particle morphology in-situ and post-drying.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

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

RESEARCH THEME

Complex structures of fluids

PARTICIPANTS

E.J.G. Sewalt (PhD candidate)

COOPERATIONS

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

FUNDED BY

STW, Nutricia Research, DSM, Tetra Pak.

FUNDED %

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

START OF THE PROJECT

2017

INFORMATION

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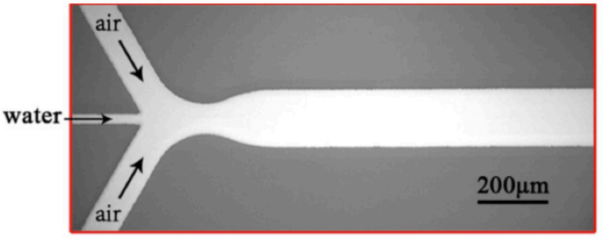

PROJECT LEADERS
Prof. Dr. Ir. C.R. Kleijn
Prof. Dr. Ir. M.T. Kreutzer
Dr. Ir. Volkert van Steijn

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 AIM

Using stochastic simulations, we investigate the effect of thermal fluctuations at the interface of thin films between two foam bubbles. Thermal fluctuations have been shown to influence planar thin film dynamics, but their role in nonplanar films is largely unexplored. An important step forward from existing studies is to include the curvature, corresponding to the Plateau border, in the description of thin liquid films. The insights generated in this project will help us better understand the role of thermal fluctuations in the stability of emulsions and foams in food products.

PROGRESS

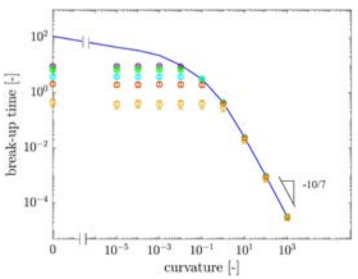
We started this work by validating our code to study the dewetting dynamics of a thin, initially flat, film on a flat substrate with the literature. Figure 1 shows that the dewetting time decreases by a factor of 4 when thermal fluctuations are accounted for in the model, confirming earlier observations by Grun and co-authors [1]. Next, we studied the thin film drainage due to capillary suction and its subsequent rupture due to attractive van der Waals forces under the influence of thermal fluctuations. We find that the mean rupture times are insensitive to thermal fluctuations at high values of curvature, wherein the rupture time is predominantly determined by the time required to drain the liquid and follows the earlier reported scaling with curvature, Tr ~ π-10/7[2]. However, at low values of curvature, wherein rupture occurs due to the spontaneous growth of any fluctuations at the gas-liquid interface, noise intensities determine the rupture times, similar to what has been also observed in an initially flat film in dewetting studies.

DISSERTATIONS

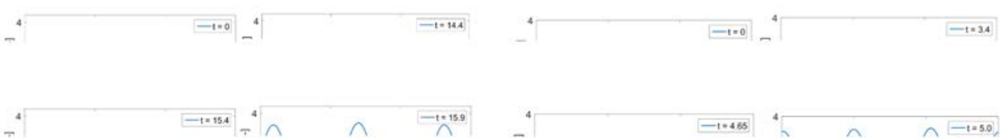
-

SCIENTIFIC PUBLICATIONS

1. Grün, G., Mecke, K., & Rauscher, M. (2006). Thin-Film Flow Influenced by Thermal Noise. Journal of Statistical Physics, 122(6), 1261–1291.
2. Kreutzer, M. T., Shah, M. S., Parthiban, P., & Khan, S. A. (2018). Evolution of nonconformal Landau-Levich-Bretherton films of partially wetting liquids. Physical Review Fluids, 3(1), 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 intensity ($kT/\gamma h0^2$)



On the left, deterministic evolution of a nearly flat thin-film is shown. On the right, its stochastic evolution is shown.

PROJECT AIM

This project aims at development of a droplet-based Lab on a Chip device for performing high throughput screening of microbes under industrially relevant conditions. In current biotechnology practice screening of microbes is done in batch mode, while most industrial reactors operate as a semi-continuous process. It is well established that the performance of microbes is significantly different under batch and semi-continuous conditions, explaining the limited success in microbe development. We address the lack of equipment to screen microbes in continuous conditions by developing a microfluidic device where microbes grow in droplets, which can be periodically fed with nutrients to establish semi-continuous conditions. By better matching the conditions in screening equipment and industrial environment, we expect that significant improvement in selection of newly developed microbes for industrial processes.

PROGRESS

After optimizing the microfluidic chip to minimize droplet shrinkage, we have been able to grow yeast cells for long term inside microfluidic devices. Fig. 1 shows the time lapse images of growth of Candida utilis over the period of 19 hours in aqueous droplets stored in a PDMS microfluidic device. Multiple growth experiments (16) can be performed on 1 single chip in parallel and growth rates can be analyzed and compared. Currently, fluidics are being developed to periodically generate nutrients droplets and coalescence them with cell-containing droplets to enable studying growth of microbes under semi-continuous process conditions.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

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

RESEARCH THEME

Complex structures of fluids

PARTICIPANTS

Kartik Arun Totlani (PhD Student)

COOPERATIONS

-

FUNDED BY

NWO

FUNDED %

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

START OF THE PROJECT

2016

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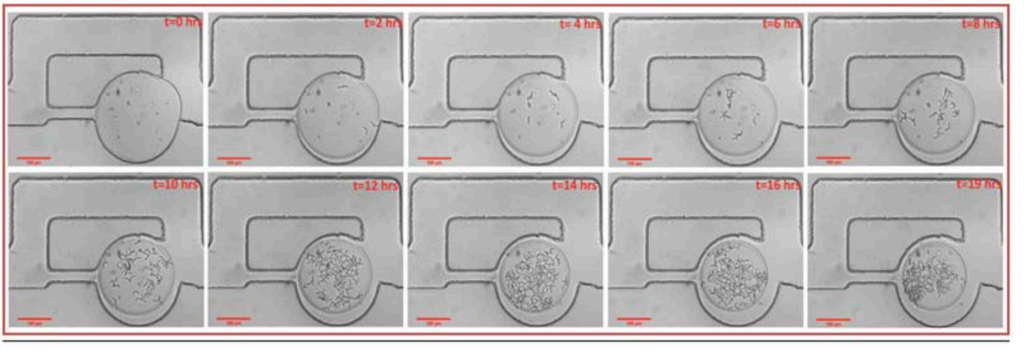
Time lapses experiment of 19 hours: Batch growth of Candida utilis inside droplets trapped and stored in PDMS microfluidic device



PROJECT LEADERS
Dr. Pouyan E. Boukany
Prof. dr. ir. Michiel T. Kreutzer
RESEARCH THEME
Complex structures of fluids
PARTICIPANTS
Aswin Muralidharan(PhD Student)
COOPERATIONS
-
FUNDED BY
ERC
FUNDED %

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

START OF THE PROJECT
2017
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PROJECT AIM

This project aims at studying the effect of electric fields typically used in electroporation on the interfacial tension of living cells using micropipette aspiration and membrane nanotube extraction. The effect of electroporation on the mechanical properties of a cell is unknown hindering the accurate development of theoretical knowledge. We address this lack of knowledge and aim to understand and explain (i) energy landscape of electropores, and (ii) dynamics of pore opening and closure in the presence and absence of cytoskeleton.

PROGRESS

To study the effect of electroporation on interfacial tension of living cells, an experimental setup involving membrane tether extraction and micropipette aspiration is utilized and a protocol for the same is developed. NIH 3T3 cell line was used as a model cell system. These techniques have been widely used to study mechanical properties of cells and model cell systems in the past. Preliminary visual inspection using confocal microscopy indicate that actin cytoskeleton is disrupted after an electric pulse used in electroporation. This effect is known to result in a variation of interfacial tension and bending rigidity of a membrane. In this study, we clearly identify that cytoskeleton play an active role on the mechanics of cell membrane during and after electroporation process.

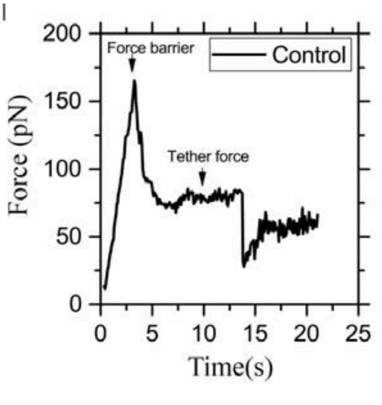
DISSERTATIONS

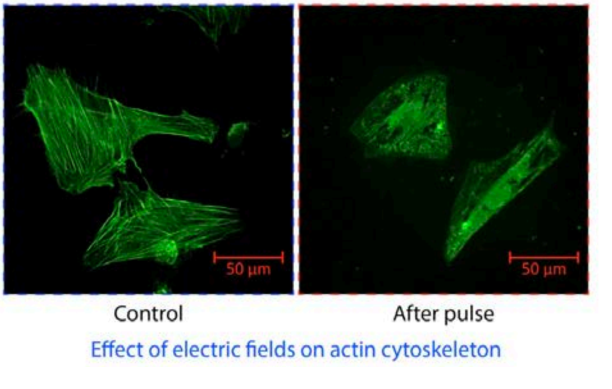
-

SCIENTIFIC PUBLICATIONS

-

(left)Typical force curve obtained during membrane nanotube extraction using optical tweezers.(right) Effect of electric field on the actin cytoskeleton(green).





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 PCs, GPUs and FPGAs. 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

1. M.H. Aissa, CFD Simulations for Turbomachinery Design Optimization, Prof.dr.ir. C. Vuik.

Scientific Publications

1. M. Moeller and C. Vuik. On the impact of quantum computing technology on future developments in high-performance scientific computing Ethics and Information Technology, 19, pp. 253-269, 2017.
2. M. de Jong and A. van der Ploeg and A. Ditzel and C. Vuik. Fine-grain parallel RRB-solver for 5-/9-point stencil problems suitable for GPU-type processors Electronic Transactions on Numerical Analysis, 46, pp. 375-393, 2017.
3. M.H. Aissa and T. Verstraete and C. Vuik. Toward a GPU-aware comparison of explicit and implicit CFD simulations on structured meshes Computers and Mathematics with Applications, 74, pp. 201-217, 2017.
4. M.H. Aissa and L. Muller and T. Verstraete and C. Vuik. Acceleration of Turbomachinery Steady Simulations on GPU European Conference on Parallel Processing Euro-Par 2016: Parallel Processing Workshops. Editors: F. Desprez and P.-F. Dutot and C. Kaklamanis and L. Marchal and K. Molitorisz and L. Ricci and V. Scarano and M.A. Vega-Rodriguez and A.L. Varbanescu and S. Hunold and S.L. Scott and S. Lankes and J. Weidendorfer. Lecture Notes in Computer Science book series (LNCS, volume 10104). Springer, Cham, pp. 814-825, 2017.

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

-

Scientific Publications

1. X. He and C. Vuik and C. Klaij. Block-preconditioners for the incompressible Navier-Stokes equations discretized by a finite volume method, Journal of Numerical Mathematics, 25, pp. 89-105, 2017. https://doi.org/10.1515/jnma-2015-0120.
2. C.M. Klaij and X. He and C. Vuik. On the design of block preconditioners for maritime engineering. Proceedings of the Seventh International Conference on Computational Methods in Marine Engineering MARINE. Editors: M. Visonneau and P. Queutey and D. Le Touze. May 15-17, Nantes, France, pp. 893-904, 2017.
3. H.A. van der Vorst and C. Vuik. Linear Algebraic Solvers and Eigenvalue Analysis. In: Encyclopedia of Computational Mechanics Second Edition Editors: Erwin Stein and Rene de Borst and Thomas J. R. Hughes John Wiley & Sons, Ltd, Chichester, pp. 1-28, 2017.

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. D. Lahaye and C. Vuik. How to Choose the Shift in the Shifted Laplace. Preconditioner for the Helmholtz Equation Combined with Deflation. Modern Solvers for Helmholtz Problems. Editors: D. Lahaye and J.M. Tang and C. Vuik Birkhauser, Basel, pp. 85-112, 2017.
2. D. Lahaye and J.M. Tang and C. Vuik. Modern Solvers for Helmholtz Problems Birkhauser, Geosystems Mathematics, Basel, 2017.

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

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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
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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

-

SCIENTIFIC PUBLICATIONS

1. J.S.B. van Zwieten and B. Sanderse and M.H.V. Hendrix and C. Vuik and R.A.W.M. Henkes. Efficient simulation of one-dimensional two-phase flow with a high-order h-adaptive space-time Discontinuous Galerkin method.
2. J. Chen and C. Vuik. Globalization technique for projected Newton-Krylov methods International Journal for Numerical Methods in Engineering, 110, pp. 661-674, 2017.
3. E. Wobbes and L. Beuth and C. Vuik and D. Stolle. Modeling of Liquefaction using Two-phase FEM with UBC3D-PLM model. Procedia Engineering, 175, pp. 349-356, 2017omputers and Fluids, 156, pp. 34-47, 2017.
4. M. Abbassi, D.J.P. Lahaye, and C. Vuik. Modelling turbulent combustion coupled with conjugate heat transfer in OpenFOAM. Proceedings of the Tenth Mediterranean Combustion Symposium 17 - 21 September 2017 Flegrea Area, Napoli, Italy. Editors: F. Beretta, N. Selcuk, M.S. Mansour, and A. D'Anna School of Polytechnic and Basic Sciences of University of Naples, pp. 1-15, 2017.
5. A. Lukyanov and C. Vuik. Meshless Multi-Point Flux Approximation. Meshfree Methods for Partial Differential Equations VIII. Editors: M. Griebel and M.A. Schweitzer. Lecture Notes in Computational Science and Engineering, volume 115. Springer, Berlin, pp. 67-84, 2017.

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. B. Hosseini, S. Turek, M. Möller, C. Palmes: Isogeometric Analysis of the Navier-Stokes-Cahn-Hilliard equations with application to incompressible two-phase flows, Journal of Computational Physics, 348, 171-194, https://doi.org/10.1016/j.jcp.2017.07.029, 2017.

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
Information
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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 his first year, the PhD-candidate has focused on efficient solvers for IgA discretisations of Poisson-type problems and particle-mesh projections. He has developed p-multigrid based solvers, which show complete independence of the iteration number on the mesh width 'h' and some dependence on the approximation order 'p'. A local Fourier analysis of the developed solvers is underway. It is planned to extend this approach to an hp-multigrid method, which will be designed to fully exploit the special, i.e. nested, structure of multivariate B-Spline spaces.

Dissertations

-

Scientific Publications

1. R. Tielen, E.D. Wobbes, M. Möller, and L. Beuth: A high order material point method. Proceedings of the 1st International Conference on the Material Point Method (MPM 2017), 10-13 January 2017, Delft, The Netherlands, 175 (2017), 265-272, DOI:10.1016/j.proeng.2017.01.022.

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 also implemented a prototypical volumetric generator that is currently being validated.

Dissertations

-

Scientific Publications

1. J. Hinz, M. Möller, C. Vuik: Elliptic Grid Generation Techniques in the Framework of Isogeo- metric Analysis Applications. Accepted for publication in Proceedings of GMP 2018.

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 release will 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 two fronts. The first is the modeling turbulent combustion including the lining of two simplified rotary kiln models. The second is the modeling of the iso-thermal flow in the real-life kiln. These developments relied on the use of the OpenFoam simulation software.

Dissertations

-

Scientific Publications

1. Modelling turbulent combustion coupled with conjugate heat transfer in OpenFOAM, Proceedings of the Tenth Mediterranean Combustion Symposium 17 - 21 September 2017.
2. Flegrea Area, Napoli, Italy, Editors: F. Beretta, N. Selcuk, M.S. Mansour, and A. D'Anna. School of Polytechnic and Basic Sciences of University of Naples, pp. 1-15, 2017.

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

-

Scientific Publications

1. P. Nakate, D. Lahaye, C. Vuik and M. Talice, Systematic Development and Mesh Sensitivity Analysis of a Mathematical Model for an Anode Baking Furnace, accepted for Fifth Joint US-European Fluids Engineering Division Conference (FEDSM2018), Montreal, July 15th-20th, 2018.

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

-

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

1. Daniel Koppenol. Biomedical implications from mathematical models for the simulation of dermal wound healing, June 15, 2017.

Scientific Publications

1. F.J. Vermolen and A. Gefen. Mathematical Modelling Tools and Software for BME Applications, In: Reference module in biomedical sciences (2017).
2. D.C. Koppenol, F.J. Vermolen. Biomedical implications from a morphoelastic continuum model for the simulation of contracture formation in skin grafts that cover excised burns. Biomech Modell Mechanobiol (2017) doi:10.1007/s10237-017-0881-y.
3. D.C. Koppenol, F.J. Vermolen, F.B. Niessen, P.P.M. van Zuijlen, C. Vuik. A biomechanical mathematical model for the collagen bundle distributiondependent contraction and subsequent retraction of healing dermal wounds. Biomech Modell Mechanobiol 16 (2017) 345-362.

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

-

Scientific Publications

-

State-of-the-art modeling of multiphase flow in large pipeline systems

Project Aim

The purpose of the project is to develop a robust, efficient and accurate algorithm for the simulation of multiphase flow in large (Length>>diameter) pipeline systems.

Progress

A major challenge in the modeling of multiphase pipe flow is handling states where one of the phases vanishes. In the final phase of the project focuses a discretization scheme is developed that is both robust and accurately momentum conserving.

Dissertations

-

Scientific Publications

1. J.S.B. van Zwieten and B. Sanderse and M.H.V. Hendrix and C. Vuik and R.A.W.M. Henkes. Efficient simulation of one-dimensional two-phase flow with a high-order h-adaptive space-time Discontinuous Galerkin method. Computers and Fluids, 156, pp. 34-47, 2017.

Project leaders

C.Vuik, D.R. van der Heul

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

J.S.B. van Zwieten

Cooperations

SHELL

Funded by

SHELL

Funded %

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

Start of the project

2010

Information

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Project leaders
DR van der Heul

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
G. Oud

Cooperations
-

Funded by
SHELL, Deltares, TNO

Funded %

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

Start of the project
2011

Information
DR van der Heul
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Project Aim

The purpose of the project is to obtain a better understanding of the transition from stable to unstable multiphase flow in pipeline systems through numerical simulations.

Progress

A number of large scale computations have been made using SURFsara's LISA cluster. These experiments show the implemented deflation preconditioning techniques lead to excellent scaling properties up to around 60 cores. On November 13 Guido Oud successfully defended his thesis.

Dissertations

1. G.T. Oud, A dual interface method in cylindrical coordinates for two-phase pipe flows, promotor: Prof.dr.ir. C. Vuik

Scientific Publications

-

Mathematical physics

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 using a Kalman filter. A serious problem with this approach is that the standard filter algorithm imposes a very large burden on the computer. In order to obtain a computationally efficient filter, simplifications have to be introduced. Model reduction is a corner stone in developing sub-optimal scheme's. In this project new sub optimal algorithms to solve large scale Kalman filtering problems are developed.

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. Furthermore we also studied observation sensitivity in order to identify the most relevant measurements for a given data assimilation problem. Other application areas are ecological coastal sea models and morphodynamic models.

Dissertations

1. Improving volcanic ash forecasts with ensemble-based data assimilation, G. Fu, TU Delft January 9, 2017.
2. Variational data assimilation of satellite observations to estimate volcanic ash emissions, S. Lu, TU Delft, March 1, 2017.

Scientific Publications

1. Curriculum vitae of the LOTOS-EUROS (v2.0) chemistry transport model, A.M.M. Manders, et al. Geoscientific Model Development, Volume 10, Issue 11, 16 November 2017, Pages 4145-4173.
2. Evaluation criteria on the design for assimilating remote sensing data using variational approaches, Lu, S, et al. Monthly Weather Review, Volume 145, Issue 6, 1 June 2017, Pages 2363-2374.
3. Accelerating volcanic ash data assimilation using a mask-state algorithm based on an ensemble Kalman filter: A case study with the LOTOS-EUROS model, Fu, G., et al., Geoscientific Model Development, Volume 10, Issue 4, 24 April 2017, Pages 1751-1766.
4. Data assimilation for volcanic ash plumes using a satellite observational operator: A case study on the 2010 Eyjafjallajökull volcanic eruption, Fu, G., et al. Atmospheric Chemistry and Physics, Volume 17, Issue 2, 25 January 2017, Pages 1187-1205.

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

Start of the project
2001

Information
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PERTURBATION METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS

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, T. Akkaya, N. Gaiko, M. Kumar, X. Wei, K. Xi, Y. Dijkstra, Jin Jianbing, Xiao Deng.
Cooperations
-
Funded by
-
Funded %

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

Start of the project
2003
Information
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Project Aim

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

Progress

In 2017 the applicability of different types of perturbation 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. A process--based, idealized study of salt and sediment dynamics in well-mixed estuaries, Wi, X. June 1, 2017, PhD thesis, promotor: A. Heemink, co-promotor: H.M. Schuttelaars.
2. Transversal waves and vibrations in axially moving continua, Nick V. Gaiko, March 20, 2017, PhD thesis, promotor: A.W. Heemink, co-promotor: W.T. van Horssen.

Scientific Publications

1. Fundamentals of Nonparametric Line Detection, Van Rossum, A.C., Lin, H.X., Dubbeldam, J.L.A., Van den Herik, H.J., Lecture Notes in Computer Science, Springer (2017).
2. Synchronization of cyclic power grids, Equilibria and stability of the synchronous state, Xi, K., Dubbeldam, J.L.A., Lin, H.X., Chaos 27 013109 (2017).
3. Kemeny's constant and the effective graph resistance, Wang, X., Dubbbeldam, J.L.A., Van Mieghem, P., Linear Algebra and Its Applications (2017), pp. 231-244.
4. On Parametric Stability of a Nonconstant Axially Moving String Near Resonances, Van Horssen, W.T., Malookani, R.A., Journal of Vibration and Acoustics (2017), pp. 1-12.
5. On constructing a Green's function for a semi-infinite beam with boundary damping, Akkaya, T., Van Horssen, W.T., Meccanica (2017) , pp. 2251-2263.
6. Oscillations of a string on an elastic foundation with space and time-varying rigidity, Abramian, A.K., Van Horssen, W.T., Vakulenko, S.A., Nonlinear Dynamics: an international journal of nonlinear dynamics and chaos in engineering systems (2017), pp. 567-580.
7. Unbounded boundaries and shifting baselines: Estuaries and coastal seas in a rapidly changing world (2017), Little S., Spencer, K.L., Schuttelaars, H.M., Millward, G.E., Elliott, M., Estuarine, Coastal and Shelf Science, 198, pp. 311-319.

8. The iFlow modelling framework v2.4: A modular idealized process-based model for flow and transport in estuaries (2017), Dijkstra, Y.M., Brouwer, R.L., Schuttelaars, H.M., Schramkowski, G.P., Geoscientific Model Development, 10 (7), pp. 2691-2713.
9. Three-dimensional salt dynamics in well-mixed estuaries: Influence of estuarine convergence, Coriolis, and bathymetry (2017) , Wei, X., Kumar, M., Schuttelaars, H.M., Journal of Physical Oceanography, 47 (7), pp. 1843-1871.
10. Generation of exchange flows in estuaries by tidal and gravitational eddy viscosity-shear covariance (ESCO) (2017), Dijkstra, Y.M., Schuttelaars, H.M., Burchard, H., Journal of Geophysical Research: Oceans, 122 (5), pp. 4217-4237.
11. Three-dimensional semi-idealized model for estuarine turbidity maxima in tidally dominated estuaries (2017), Kumar, M., Schuttelaars, H.M., Roos, P.C., Ocean Modelling, 113, pp. 1-21.
12. Symmetric solution of evolutionary partial differential equations, Bruell, G., Ehrnström, M., Geyer, A., Rei, L., Nonlinearity (2017) 30(10), pp. 3932-3950.
13. Spectral stability of periodic waves in the generalized reduced Ostrovsky equation, Geyer, A., Pelinovsky, D.E., Letters in Mathematicsl Physics (2017) 107(7), pp. 1293-1314.

Project leaders
A.W. Heemink, H.X. Lin
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
H.X. Lin, G.L. Fu, J.B. Jin, S. Lu
Cooperations
TNO, Tsinghua University, China, Reykjavik University, Iceland
Funded by
-
Funded %

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

Start of the project
2012
Information
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Project Aim

The research aims at modelling of the distribution of volcanic ash where measurements of satellite and aircraft are used to improve the forecast accuracy.

Progress

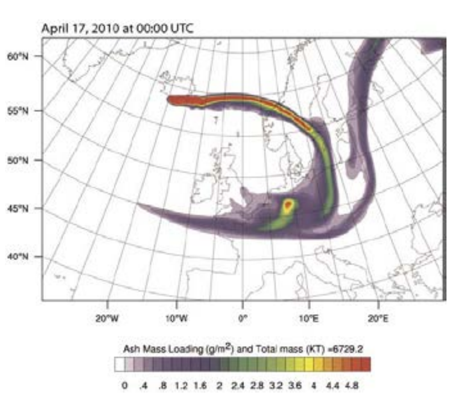
The research focuses on modelling the transport process of the volcanic ash. The performance and shortcomings of existing Ensemble Kalman filter techniques and 4D variational methods are studied given the constraints and limitations of exiting measurements. To overcome spurious correlations in typical data assimilation of vulcanic ash distribution process, a trajectory-based 4DVar method has been proposed to overcome the problem of spurious correlation caused by the insufficiency of data (lack of vertical resolution of satellite data), and an efficient back-trace localization scheme is designed to reduce the spurious correlations caused by finite ensemble size in EnKF.

Dissertations

1. G. Fu, Improving volcanic ash forecasts with ensemble-based data assimilation, 9 January 2017, TUD.
2. S. Lu, Varitaional data assimilation of satellite observations to estimate volcanic ash emissions, 1 March 2017, TUD.

Scientific Publications

1. S. Lu, A. Heemink, H.X. Lin, G. Fu, A Segers (2017), Evaluation criteria on the design for assimilating remote sensing data using variational approaches, Monthly Weather Review□145(6), pp.2165-2175.
2. K. Xi, J. L. A. Dubbeldam, H.X. Lin (2017) Synchronization of cyclic power grids: equilibria and stability of the synchronous state, Chaos, Vol.27(1) DOI:10.1063/1.4973770.
3. G. Fu, H.X. Lin, bA.W. Heemink, S. Lu, A. Segers, N. van Velzen, T.C. Lu, and S.M. Xu (2017), Accelerating volcanic ash data assimilation using a mask-state algorithm based on an ensemble Kalman filter: a case study with the LOTOS-EUROS model (version 1.10), Geoscientific Model Development, 10, pp.1751–1766.
4. G. Fu, F. Prata, H.X. Lin, A.W. Heemink, S. Lu, A.J. Segers (2017) Data assimilation for volcanic ash plumes using a Satellite Observational Operator: a case study on the 2010 Eyjafjallajokull volcanic eruption, Atmospheric Chemistry and Physics, Vol17(2), pp. 1187—1205, DOI: 10.5194/acp-17-1187-2017.



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

The experimental results obtained on the CAMEL test setup highlights the influence highlights that the large coherent structures detected in the flow are independent of the Reynolds number. FEP proves to be a suitable material for optical techniques also for optical measurements inside tight annuli (Publication available since January 2018 on Nuclear Engineering and Design).

Construction and installation of SEEDS1. Measurements of flow-induced vibrations and coherent structures are being done.

Dissertations

-

Scientific Publications

1. F. Bertocchi, M. Rohde, J. L. Kloosterman, "Experimental study of the onset conditions for cross-flow through the gap between two half-rods", Proc. 17th Int. Topl. Mtg. Nuclear Reactor Thermal Hydraulics (NURETH-17), Xi'an, China (2017).

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
M. Rohde, D. Lathouwers
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
-
Cooperations
-
Funded by
TU Delft
Funded %

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

Start of the project
2015
Information
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Project Aim

My project is connected to the European sCO2-HeRo project, which attempts to design a heat exchanger that is based on supercritical CO2. Heat transfer in supercritical fluids is difficult to calculate. The goal of my PhD is to develop a discontinuous Galerkin method for this, and to investigate it in connection to supercritical CO2. I will do calculations for the sCO2-HeRo heat exchanger.

Progress

We have developed a discontinuous Galerkin method for flows with variable material properties, including variable density. This means that we had to develop a time-splitting scheme for a compressible fluid. I also worked on various details of the numerical method, including new types of boundary conditions, and appropriate initial conditions.

Dissertations

-

Scientific Publications

-

Development of an accurate design correlation for supercritical heat transfer applications

Project Aim

This project aims to develop an accurate, physically sound design correlation for heat transfer in supercritical fluids. The correlation should prevent expensive oversizing of industrial equipment (required to avoid overheating) and stimulate the production of better products and more efficient processes.

Progress

Particle image velocimetry and background oriented schlieren measurements at supercritical conditions were done in a Rayleigh-Bénard cell. Three cases were investigated at supercritical pressure in the region around the pseudocritical point, where the specific heat transfer capacity at constant pressure reaches its peak and the density dependency on temperature is the highest. A strong asymmetry in the velocity fields was observed which can be related to the strong changes of the fluid properties at the studied experimental conditions. An heat transfer study at supercritical conditions in Rayleigh Bénard convection was done at the Max Planck Institute for dynamics and self organization of Goettingen in Germany for a EuHIT project. An increase of heat transfer in the supercritical region was found, while keeping constant the values of the global Rayleigh and Prandtl numbers of the experiments at different mean temperatures and pressures.

Dissertations

1. Rayleigh-Bénard convection of a supercritical fluid: PIV and heat transfer study.

Scientific Publications

1. Experimental part: V.Valori, G.E. Elsinga, M. Rohde, M. Tummers, J. Westerweel, T.H.J.J. van der Hagen. “Experimental velocity scaling of non-Boussinesq Rayleigh-Bénard convection”, Physical Review E, May 2017.

Project leaders

M. Rohde

Research theme

Complex dynamics of fluids

Participants

Experimetal part:
Valentina Valori
Martin Rohde
Gerrit Elsinga
Jerry Westerweel
Tim van der Hagen
Numerical part:
Jurriaan Peeters
Renè Pecnik
Bendix-Jan Boersma

Cooperations

Cooperation between the Nuclear Energy and Radiation Applications section of the Faculty of Applied Sciences and the Fluid Mechanics and the Energy Technology sections of the Faculty of Mechanical Engineering from TU Delft.

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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Three-dimensional, multi-physics simulation of a Molten Salt Fast Reactor

Project leaders
D. Lathouwers, 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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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. Advanced uncertainties quantification schemes (polynomial chaos expansion and fully coupled multi-physics adjoint sensitivity analysis) will be used to analyze the outcomes of simulations and investigate the influence of uncertainties.

Progress

Continuation of the development and testing of the in-house code which solves the Navier-Stokes equations based on Discontinuous Galerkin FEM discretization. Main achievements include:

- Implementation of low-Re Launder-Sharma k-epsilon turbulence model
- Implementation of positivity-preserving convection schemes for turbulent quantities
- Extension of the code to solve Conjugate Heat Transfer problems

The CFD code was used to simulate the flow behavior in the natural circulation loop DYNASTY, built at Politecnico di Milano, in presence of a distributed heat source. The code was therefore validated by comparison of the results obtained among SAMOFAR partners.

Continuation of the development of the in-house radiation transport code, based on Discontinuous Galerkin FEM discretization. Main achievements include:

- Implementation of delayed neutron precursors transport by convection and diffusion
- Realization of a code able to interpolate cross sections from discrete libraries at given temperatures

The CFD and the radiation transport codes were coupled and the multi-physics tool was benchmarked with a predefined multi-physics test-case (mimicking the behavior of a MSFR), by comparison of the results obtained among SAMOFAR partners.

Dissertations

-

Scientific Publications

-

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 have been characterized both in potential flows and in turbulent flows. A dedicated measurement system has been developed where the co-axial arrangement between cameras and light source enable unprecedented optical access. Furthermore, the compactness of such velocimeter makes it suitable for robotic manipulation via a collaborative robotic arm. Such system has been employed for the flow measurements all around a full-scale cyclist model. The light scattering properties of HFSB have been investigated experimentally and with a geometrical optics model.

Dissertations

1. J.F.G. Schneiders, Bridging PIV spatial and temporal resolution using governing equations and development of the coaxial volumetric velocimeter.

Scientific Publications

1. Caridi GCA, Sciacchitano A and Scarano F, Helium-filled soap bubbles for vortex velocimetry, Exp fluids 58:130.
2. Schneiders JFG and Sciacchitano A, Track benchmarking method for uncertainty quantification of particle tracking velocimetry interpolations, Meas Sci Technol 28 065302.

Project leaders

Dr. A. Sciacchitano
Prof. F. Scarano

Research theme

Complex structures of fluids

Participants

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

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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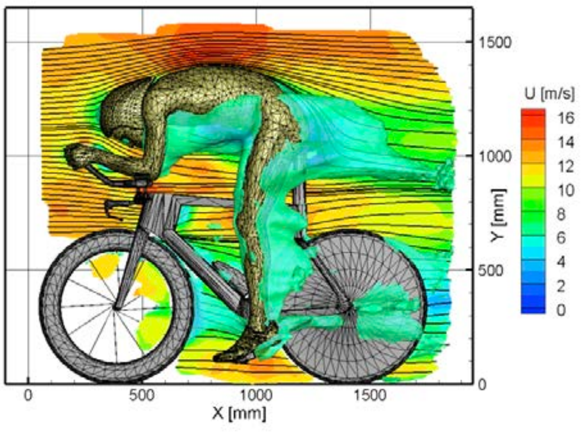
Velocity field around a full-scale cyclist model measured by large-scale PIV



Sport Aerodynamics Investigation by Quantitative Flow Visualization

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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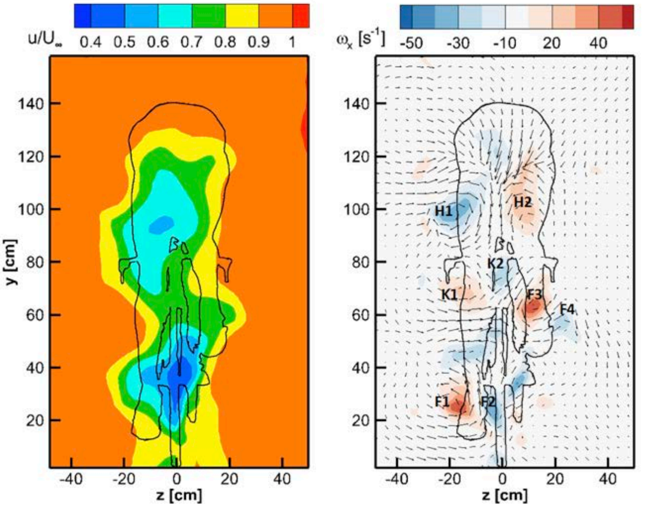
Project Aim
This project aims at investigating speed sports aerodynamics by quantitative flow visualization. Velocity measurements are conducted via large-scale Particle Image Velocimetry (PIV) both in wind tunnels and on-site during the athletes' training, using the innovative "ring of fire" concept. 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
Large-scale PIV measurements have been conducted in proximity and in the wake of a full-scale cyclist model. The comparison between PIV-based loads and aerodynamic forces measured by force balance showed very good agreement. A scaled model of the ring-of-fire system for aerodynamic investigation of transiting objects has been produced and assessed. Furthermore, a first prototype of ring-of-fire has been designed and built for on-site cycling aerodynamic measurements. Preliminary results show good agreement between the aerodynamic loads estimated with the ring-of-fire approach and those measured with conventional force balance in wind tunnels.

Dissertations
-

Scientific Publications
1. Terra W, Sciacchitano A and Scarano F, Aerodynamic drag of a transiting sphere by large-scale tomographic PIV, Exp Fluids (2017) 58:83.

Velocity and vorticity field in the wake of a full-scale cyclist model.



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. A wind tunnel study was directed towards the characterization of the DelFly in both hover and forward flight configurations, using multiple-plane stereo-PIV. Large-scale and free-flight visualization studies were performed using helium-filled soap bubbles.

Dissertations

-

Scientific Publications

1. S. Deng, M. Percin, B.W. van Oudheusden, H. Bijl, B. Remes, T. Xiao: Numerical simulation of a flexible X-wing flapping-wing micro air vehicle, AIAA Journal, Vol. 55, No. 7 (2017), pp. 2295-2306. doi.org/10.2514/1.J054816, 12 pp.
2. M. Percin, B. W. van Oudheusden, B. Remes: Flow structures around a flapping-wing micro air vehicle performing a clap-and-peel motion, AIAA Journal (2017), vol. 55, No.4, pp. 1251-1264. arc.aiaa.org/doi/10.2514/1.J055146, 14 pp.

Project leaders
BW van Oudheusden

Research theme
Complex dynamics of fluids

Participants
M Percin, S Deng

Cooperations
Nanjing University of Aeronautics and Astronautics, National University of Singapore

Funded by
STW

Funded %

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

Start of the project
2010

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PROJECT LEADERS
F.F.J. Schrijer, B.W. van Oudheusden
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
RHM Giepman, Q Ye, PL Blinde
COOPERATIONS
ESA, VKI, DLR, NLR, Airbus, ArianeGroup, TNO, ONERA, UNINA
FUNDED BY
EU (TFAST), ESA (TRAV2), CSC
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 and control, (compressible) roughness induced boundary layer transition and compressible baseflows.

PROGRESS

1) Investigation of flow control by means of micro-ramps of shock wave boundary layer interactions

2) Study and control of transitional shock-wave boundary layer interactions

3) Investigation of compressible and incompressible launcher base flows using (tomographic) PIV and PIV-based pressure integration

4) Experimental investigation of (hypersonic) boundary layer transition using tomographic particle image velocimetry

5) Application of IR thermography for quantitative heat transfer measurements in high speed turbulent boundary layers with roughness

5) Investigation of unsteady transonic airfoil aerodynamics (CleanSky2 project)

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. S. Nayak K, R.H.M. Giepman, F.F.J. Schrijer, B.W. van Oudheusden: Tomographic-PIV investigation of the 3D Separation behaviour of a micro-ramp controlled SWBLI, 52nd AAAF Symp. of Applied Aerodynamics, 27-29 March 2017, Lyon, France.
2. F.F.J. Schrijer, T. Horchler, S. Deck, P.L. van Gent: Comparison of high speed PIV experiments, unsteady pressure measurements and DES computations of a transonic Ariane 5 base-flow using POD: An experimental study, EUCASS 2017, 7th European Conference for Aeronautics and Space Sciences, 3-6 July, 2017, Milan, Italy.
3. S.S. Tambe, F.F.J. Schrijer, B.W. van Oudheusden: Effect of geometry on the downstream flow topology of a micro ramp in a supersonic turbulent boundary layer: an experimental study, EUCASS 2017, 7th European Conference for Aeronautics and Space Sciences, 3-6 July, 2017, Milan, Italy.
4. P.L. van Gent, Q. Payanda, S. Brust, B.W. van Oudheusden, F.F.J. Schrijer: Experimental study of the effects of exhaust plume and nozzle length on transonic and supersonic axisymmetric base flows, EUCASS 2017, 7th European Conference for Aeronautics and Space Sciences, 3-6 July, 2017, Milan, Italy.
5. Q. Ye, F.F.J. Schrijer, F. Scarano: Tomographic PIV Measurement of Hypersonic Boundary Layer Transition Past a Micro-ramp, 47th AIAA Fluid Dynamics Conference: 5-9 June 2017, Denver, Colorado.

PIV-based Non-Intrusive Determination of Pressure and Aerodynamic Loads

Project Aim

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

Progress

1) Extension of PIV-based determination of mean pressure in 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.

Dissertations

1. J.F.G. Schneiders, Bridging PIV spatial and temporal resolution using governing equations and development of the coaxial volumetric velocimeter, TU Delft, 24-12-2017.

Scientific Publications

1. P.L. van Gent, D. Michaelis, B.W. van Oudheusden, P.E. Weiss, R. de Kat, A. Laskari, Y.J. Jeon, L. David, D. Schanz, F. Huhn, S. Gesemann, M. Novarra, C. McPhaden, D. Rival, J.F.G. Schneiders, F.F.J. Schrijer: Comparative assessment of pressure field reconstructions from particle image velocimetry measurements and Lagrangian particle tracking, Experiments in Fluids (2017) 58:33.
2. D.E. Rival, B.W. van Oudheusden: Load-estimation techniques for unsteady incompressible flows, Experiments in Fluids (2017) 58:20.

Project leaders

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

Research theme

Complex dynamics of fluids

Participants

PL van Gent, JFG Schneiders

Cooperations

DNW, CNRS, DLR, Uni BW Munich, ONERA, LaVision GmbH

Funded by

-

Funded %

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

Start of the project

2006

Information

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PROJECT LEADERS
F Scarano, BW van Oudheusden, FFJ Schrijer
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
PL van Gent, V Gentile, M. Percin
COOPERATIONS
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 laucher 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. V. Gentile: Turbulent axisymmetric base flows: Symmetry and long-term behavior, TU Delft, 24-04-2017.

SCIENTIFIC PUBLICATIONS

1. V. Gentile, B.W. van Oudheusden, F.F.J. Schrijer, F. Scarano: Effect of angular misalignment on the wake dynamics of a slender axisymmetric body, JFM 813, R3 (2017).
2. M. Percin, M. Vanierschot, B.W. van Oudheusden: Analysis of the pressure fields in a swirling annular jet flow, Exp. Fluids 58:166 (2017).

PROJECT AIM

This project combines the efforts of seven separate PhD projects that involve numerical simulation of wind energy related problems: from large scale (wind farms) to mid scale (rotor/blade) to small scale (vortex generators, trailing edge serrations). The applications include aero-elasticity, aero-acoustics and fluid-structure-controller-interactions. The aim is to reduce computational time of high-fidelity modeling through energy conserving discretizations (wind farm wake modeling), acceleration by low-fidelity models using multi-fidelity optimization techniques, and parallel partitioned coupling techniques to enable massively parallel fluid-structure-acoustic interaction.

PROGRESS

Two of the seven PhD projects were already completed and in 2017 three more projects resulted in a dissertation, concluding the topics on the reduction of trailing edge noise by serrations, the validation of transition models for rotor blade simulations and high order computational methods for fluid-structure interaction. The FOAM-FSI library is published containing the algorithms to obtain high order accuracy in time for fluid-structure interaction simulations in OpenFOAM.

On the wind farm scale, a comparison is made between Partially Averaged Navier Stokes (PANS) and Reynolds Averaged (RANS) compared to Large Eddy Simulation (LES) results.

DISSERTATIONS

1. Blom, D.S. Efficient numerical methods for partitioned fluid-structure interaction simulations (2017) Delft University of Technology.
2. Van Der Velden, W.C.P., Computational aeroacoustic approaches for wind turbine blade noise prediction (2017) Delft University of Technology.
3. Zhang, Y. Wind turbine rotor aerodynamics – The IAE MEXICO rotor explained (2017) Delft University of Technology.

SCIENTIFIC PUBLICATIONS

1. Florentie, L., Van Zuijlen, A.H., Hulshoff, S.J., Bijl, H. Effectiveness of side force models for flow simulations downstream of vortex generators (2017) AIAA Journal, 55 (4), pp. 1373-1384.
2. Van Der Velden, W.C.P., Van Zuijlen, A.H., De Jong, A.T., Ragni, D. Flow and self-noise around bypass transition strips (2017) Noise Control Engineering Journal, 65 (5), pp. 434-445.
3. Van Der Velden, W.C.P., Van Zuijlen, A.H., De Jong, A.T., Bijl, H. Acoustic noncompactness of a beveled trailing edge using incompressible flow source data (2017) AIAA Journal, 55 (5), pp. 1757-1762.
4. Zhang, Y., Sun, Z., van Zuijlen, A., van Bussel, G. Numerical simulation of transitional flow on a wind turbine airfoil with RANS-based transition model (2017) Journal of Turbulence, 18 (9), pp. 879-898.
5. Zhang, Y., Gillebaart, T., van Zuijlen, A., van Bussel, G., Bijl, H. Experimental and numerical investigations of aerodynamic loads and 3D flow over non-rotating MEXICO blades (2017) Wind Energy, 20 (4), pp. 585-600.

PROJECT LEADERS
A.H. van Zuijlen, H. Bijl

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
David Blom, Liesbeth Florentie, Thijs Gillebaart, Shaafi Kaja Kamaludeen, Dhruv Mehta, Wouter van der Velden, Ye Zhang

COOPERATIONS
ECN, Siemens Wind Power, University of Stuttgart, Technical University München, University of Siegen, Technical University Darmstadt

FUNDED BY
Siemens Wind Power, German Research Foundation (DFG), EU, Shell, FOM, STW, CSC

FUNDED %

University	-
FOM	14 %
STW	14 %
NWO Other	-
Industry	28 %
TNO	-
GTI	-
EU	28 %
Scholarships	14 %

START OF THE PROJECT
2012

INFORMATION
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Efficient Adjoint Approach to Automatic Mesh Optimization for Predictive Large Eddy Simulation

Project leaders
Stefan Hickel, 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

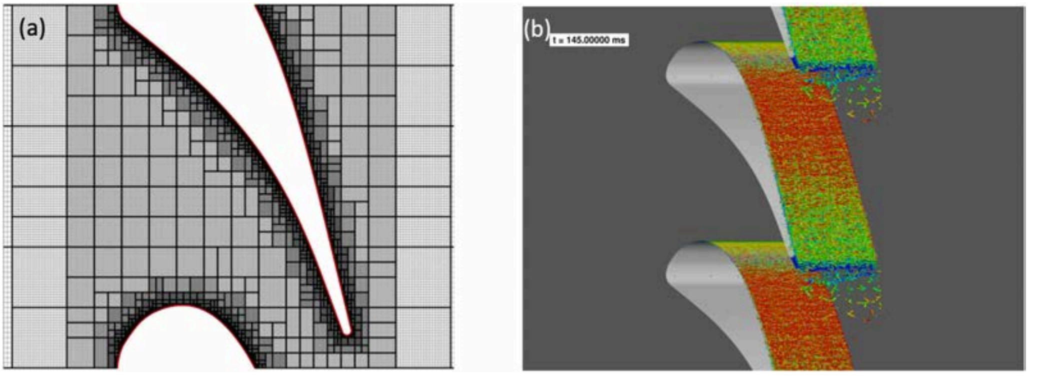
The students performed a literature research and got familiar with the numerical methods and models that are readily available or need to be implemented. The dual solution procedure has been formulated and implemented for different representations of the primal solution and objective functions.

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

So far, 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, 2017). The next step is to combine this model with our finite-rate chemistry solver (Diegelmann et al, 2017), which can accurately predict ignition and the transition between deflagration and detonation. During 2018 we will develop dynamic multi-level parallelization for scalable high-performance multi-physics simulations.

DISSERTATIONS

1. Jan Matheis: Numerical Simulation of Fuel Injection and Turbulent Mixing Under High-Pressure Conditions. Felix Diegelmann: Ignition and Mixing in a Reacting Shock-Bubble Interaction.

SCIENTIFIC PUBLICATIONS

1. Diegelmann, F., Hickel, S., Adams, N.A. (2017) Three-dimensional reacting shock-bubble interaction. Combustion and Flame 181: 1339-1351. doi: 10.1016/j.combustflame.2017.03.026.
2. Matheis, J., Hickel, S. (2017) 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

Stefan Hickel

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Mohamad Fathi

COOPERATIONS

Universität der Bundeswehr München

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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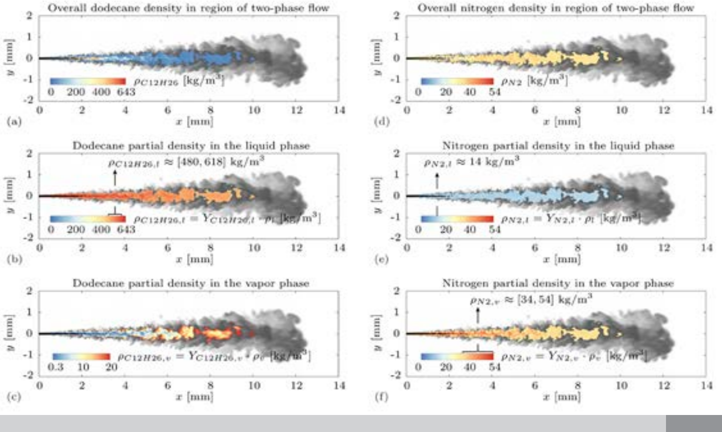
Full phase information for VLE-LES of transcritical n-dodecane jet at 60bar. Left and right column show contours of dodecane and nitrogen partial densities, respectively, from blue to red shades. All cells with 0.1% > vapor volume fraction > 99.9% are blanked out and the background contour shows the temperature field from dark to light shades (Matheis & Hickel, 2017)



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

In Matheis & Hickel (2015), e.g., we 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 and numerical analysis shock-shock interactions and are currently preparing a corresponding experimental campaign. 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.

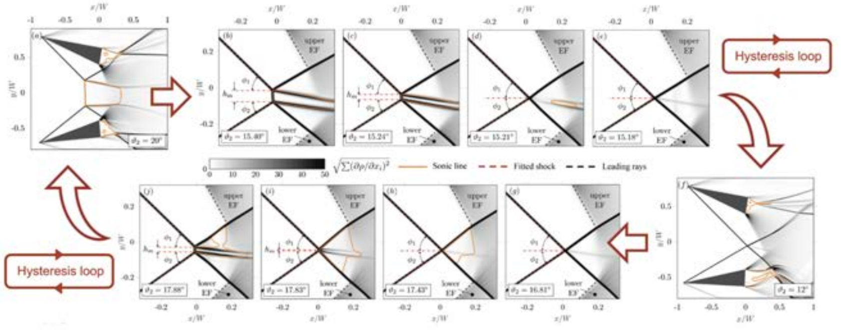
Dissertations

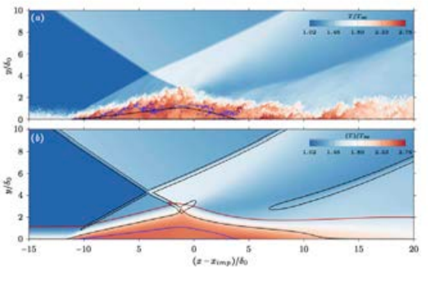
-

Scientific Publications

1. Pasquariello, V., Hickel, S., Adams, N.A. (2017) Unsteady effects of strong shock-wave/boundary-layer interaction at high Reynolds number. Journal of Fluid Mechanics 828: 617-657. doi: 10.1017/jfm.2017.308.

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

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 fundamental flow 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

We performed DNS of forced rotating turbulence varying the ratio between the domain size and the integral length scale from R=6.4 up to 640 for several Rossby numbers Ro. We observed a linear growth of columnar eddies, which are artificially confined if the domain size is too small. A steady-state free of confinement effects is achieved only if R is large enough; for weak rotation, Ro=O(1), we find that R≈20 is required, whereas for strong rotation with Ro=0.027 not even R≈100 is enough. We found that confinements effects lead to mispredictions of important aspects of rotating turbulence, such as scaling laws for the energy spectrum and skewness of the vorticity.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Pestana, T., Hickel, S. (2017) Confinement Effects on the Inverse Energy Cascade in Forced Homogeneous Rotating Turbulence. Direct and Large Eddy Simulation 11.

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
Stefan Hickel
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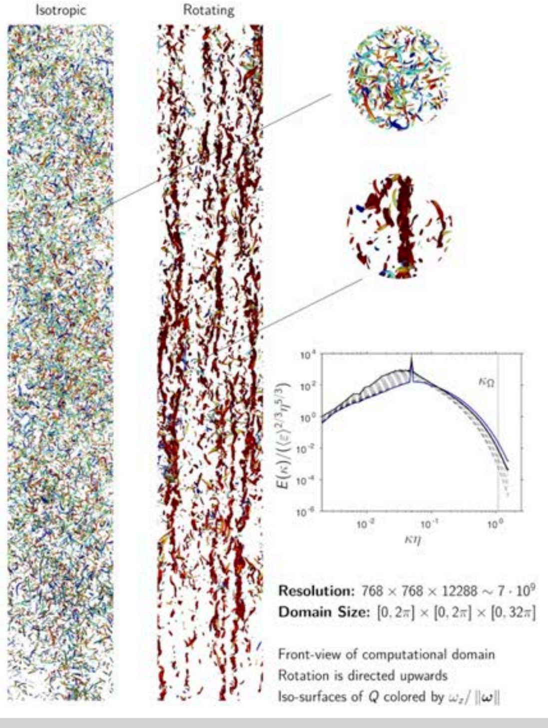
http://tudelft.nl/lr/aerodynamics



Prof.dr.ir. AJHM Reniers

Prof.dr. JD Pietrzak

Prof.dr.ir. WSJ Uijttewaal

The Environmental Fluid Mechanics Group performs fundamental, process-oriented research on fluid flow problems of practical relevance in water management, environmental engineering, hydraulic engineering river and coastal engineering. To enhance the potential of practical applications, the section not only aims at writing publications, as far as scientific output is concerned, but also at the production of software that is available via internet. Examples of software packages are 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 coming years. Within this philosophy the research program encompasses the following main items:

- Free surface waves in coastal zones with topics such as: Generation and prediction of (hurricane) storm impacts, harbour seiches, dynamics of surf beat and the wave models SWAN and SWASH.
- Elementary Fluid Mechanics and Turbulence in the context of rivers, coastal areas and open ocean with the following topics: turbulence and flow structures in rivers and its flood planes, stability and transport under waves and currents of rock elements in cover layers consisting of loose, granular material, transport and dispersion of the freshwater and SPM, the response of high-latitude climate change to mesoscale ocean eddies.
- Transport of suspended particulate matter with topics such as: advanced, experimental and numerical work concerning particle-turbulence interaction as well as flocculation and sedimentation processes
- Numerical model development with topics such as: development of the non-hydrostatic models for the investigation of dam breaks including inundations, short wave problems, near field plume discharges, stratified flows, and local scour near dams, unstructured grids via finite volume methods and finite element methods and development of large scale integrated 1d/2d rainstorm drainage/flooding model applicable to rural and urban areas.

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 eddies, ocean convection and downwelling of dense water masses in the Labrador Sea. The model output demonstrates a good agreement with observations with regard to the eddy field and convection characteristics as well as a basin mean net downwelling of 2.8 Sv. The sensitivity of the characteristics of the deep convection and the downwelling of the dense waters with respect to surface and lateral buoyancy fluxes is examined. The presence of eddies in this model determines the mixed layer depth and dense water volume and also affects the magnitude and the preferred location of the downwelling. This analysis confirms that the downwelling occurs near the boundaries of the domain and that the eddies spawned from the boundary current play a major role in controlling its dynamics. The temporal variability of the downwelling in areas with high eddy activity is well correlated to the time evolution of the eddy field. This study shows that the characteristics of the downwelling in a marginal sea like the Labrador Sea depend crucially on the properties of the eddy field, and hence it is crucial to resolve the eddies to properly represent the downwelling and overturning in the North Atlantic Ocean and its response to changing environmental conditions.

Dissertations

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Scientific Publications

1. Georgiou, S., van der Boog, C.G., Brüggemann, N., Pietrzak, J.D., and Katsman, C.A., (2017). The interplay between eddies, deep convection and sinking of dense water in an idealized model study of the Labrador Sea. Poster presentation, European Geophysical Union General Assembly, Vienna, Austria.

Project leaders

Dr. C.A. Katsman

Research theme

Complex dynamics of fluids

Participants

Prof. J.D. Pietrzak
Dr. N. Brüggemann (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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Stability of Caribbean coastal Ecosystems uNder future Extreme Sea level changes (SCENES), Sub-project B: Biogeomorphic modelling of complex Caribbean bays and inlets

Project leaders
JD Pietrzak, M Zijlema

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
AS Candy, JD Pietrzak, M Zijlema

Cooperations
University of Notre Dame, IMAU (UU), NIOZ (Yerseke), University of Texas, University of North Carolina, North Carolina State University, Ohio State University

Funded by
NWO (Caribbean Research Programme)

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 in this project focuses on modelling of the regional circulation in the geometrically complex Caribbean bays and lagoons, which are dominated by multi-scale flows. It explicitly aims to link our interdisciplinary research; from large scale climate change to the small scale biogeomorphology of the coastal bays and lagoons under study. To achieve this we use proven technology but uniquely couple the effect of long term climate change trends including short term extreme events on calcifying macro algae. The modelling systems applied in this project simulate tidal, wind and wave driven flows, wind waves from ocean basin to inlets scales using one integrated model domain and mesh, and a local biogeomorphology model. In particular, hydrodynamic features such as eddies, high flow gradients and wave transformation zones that form within and outside the bay and lagoon systems will be dynamically resolved at very high levels of localized mesh resolution. Parallel scalable model design will ensure that very high resolution grids can be efficiently simulated on high performance computers. Among the models and approaches being applied are the tightly coupled, unstructured mesh, parallel, SWAN+ADCIRC wave-current model developed by the University of Notre Dame, Delft University of Technology, the University of Texas at Austin, and the University of North Carolina at Chapel Hill together with Delft3D for biogeomorphology and POP for large-scale global dynamics of future climate scenarios.

Progress

The challenge of generation and initialization of the integrated domains required to model the large range of scales demanded by the project is being tackled first. New methods and approaches are under development to produce unstructured mesh domains of the Caribbean region spanning the thousand kilometre basin scales of the Atlantic down to the small metre-scales of the geometrically-complex bays and lagoons. Initial models of the whole region in the integrated domains have been setup and run in massively-parallel simulations on the Dutch supercomputing resource Cartesius. Furthermore, new approaches to efficiently analyse and interpret model output are under development which are key when data spans such large spatial scales in this new integrated model.

Dissertations

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Scientific Publications

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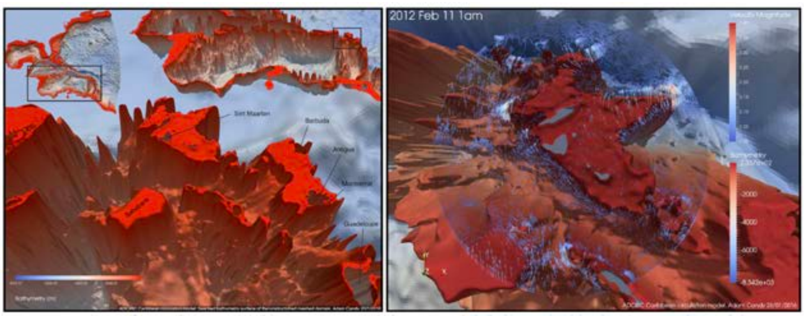
ADCIRC finite element Caribbean ocean circulation model (left) sea bed bathymetry surface of the unstructured meshed domain (right) instantaneous flow vectors around Sint Maarten and Sababank in the Dutch Antillies.



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

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Scientific Publications

1. Flores, R., Rijnsburger, S., Horner-Devine, A., Souza, A., & Pietrzak, J. (2017). The impact of storms and stratification on sediment transport in the Rhine region of freshwater influence. Journal of Geophysical Research.
2. Horner-Devine, A. R., Pietrzak, J. D., Souza, A. J., McKeon, M. A., Henriquez, M., Flores, R. P., et al. (2017). Cross-shore transport of nearshore sediment by river plume frontal pumping. Geophysical research letters.

Project leaders

J.D. Pietrzak, 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
A Blom, WSJ Uijttewaal
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
ECMM Arkesteijn
COOPERATIONS
RWS, Twente University
FUNDED BY
STW
FUNDED %

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

START OF THE PROJECT
2014
INFORMATION
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PROJECT AIM

The main objective of this project is to assess and improve numerical techniques to predict the large scale channel response to sediment augmentation measures. Large scale morphodynamic changes take place on the long-term (i.e. 100-1000 years). Performing numerical simulations on these scales requires rather large computation times. Techniques such as the application of reduced flow models (e.g. assumption of steady or normal flow), or a morphodynamic factor are frequently applied to overcome this. In this project we will assess the existing techniques, focus on improving them, and study the effects of nourishment projects in the Rhine by application of a new or improved tool.

PROGRESS

In the past year we have focused on the equilibrium state and slow morphodynamic changes in a river. Over time rivers tend to an equilibrium state in which the morphodynamic state is dynamic (varies around a mean state). The prediction of a long-term trend using a numerical model can only be accurate if the system tends to the correct equilibrium state. We have studied the equilibrium state and assessed the role of variable and (non-) uniform flow conditions. Meanwhile we have developed a fast algorithm to numerically approximate the dynamic equilibrium state under variable steady flow conditions, and worked on a model to compute long-term trends in river morphodynamic behavior more efficiently by directly starting from the flow statistics rather than a time-series hydrograph.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Blom, A., L. Arkesteijn, V. Chavarrías, and E. Viparelli (2017), The equilibrium alluvial river under variable flow and its channel-forming discharge, J. Geophys. Res. Earth Surf., 122 1-25.
2. Arkesteijn, L., R. J. Labeur, and A. Blom (2017), A space-marching model to assess the morphodynamic equilibrium behaviour in a river’s backwater dominated reaches. Poster presented at the 10th Symposium on River, Coastal and Estuarine Morphodynamics, 15-22 September, Trento-Padova, Italy.

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 are working on generalizing the model proposed by Smit and Janssen (2015) for the evolution of the complete second-order statistics. The aim is to make the model applicable for wave-current interaction problems. The outcome of this research step is a generalized RTE model for the wave action, that predicts the generation and evolution of cross-correlations over varying bathymetry and shear currents. Such a generalization would allow for the development of wave interference patterns generated due to the correlation between wave component which travel in different directions. The figure below demonstrates the effect of cross-correlations on the resulting wave statistics for the case of wave propagation over a vortex-ring.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

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PROJECT LEADERS

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

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

PhD student: Ir. Akrish, G.

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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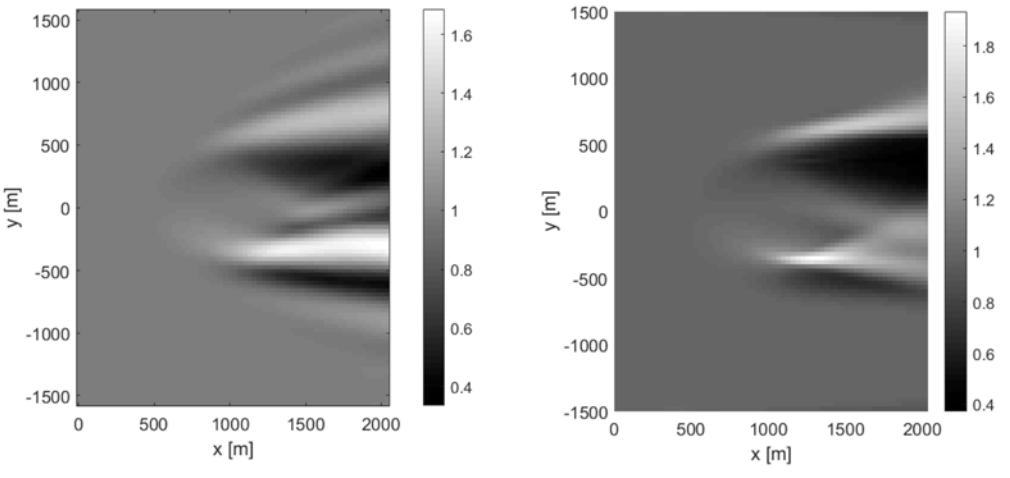

Planar view of the variations in wave height over the vortex-ring, for an almost unidirectional, monochromatic incoming wave field. Results as predicted by: Present model (left), and SWAN (right).

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, K.P. Hilgersom, 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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http://swash.sf.net

Project Aim

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

Progress

A new numerical algorithm has been developed in SWASH that accounts for the presence of a non-moving floating body to resolve the wave impact on a restrained ship that is moored in coastal waters. This model aims to be applicable at the scale of a harbour or coastal region, while accounting for the key physical processes that determine the hydrodynamic loads on the ship. An online, one-way coupling procedure between the SWAN and the SWASH models has been developed, with the aim of modelling the wave evolution from generation to runup and land inundation. SWASH can be downloaded from http://swash.sf.net. There were about 2,500 downloads over 100 countries by the end of 2017 since the launch of SWASH at the website (as of February 9, 2011).

Dissertations

-

Scientific Publications

1. Tomohiro Suzuki, Corrado Altomare, William Veale, Toon Verwaest, Koen Trouw, Peter Troch and Marcel Zijlema. Efficient and robust wave overtopping estimation for impermeable coastal structures in shallow foreshores using SWASH, Coastal Engeering, 122, 108-123.
2. D.P. Rijnsdorp, P.B. Smit, M. Zijlema, A.J.H.M. Reniers. Efficient non-hydrostatic modelling of 3D wave-induced currents using a subgrid approach Ocean Modelling 116, 118-133.

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

Project Aim

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

Progress

An high resolution, idealized model configuration of the MITgcm is developed that reproduces the main characteristics of the Nordic Seas, including a warm cyclonic boundary current, a strong eddy field in the east and the hydrographic asymmetry between east and west. Multiple studies have been performed to better understand the sensitivity of the system to changes in the heat flux. Furthermore, to better understand the circulation in the Nordic Seas, a Lagrangian study is performed using particles tracing the warm Atlantic Water inflow through Denmark Strait.

Dissertations

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Scientific Publications

1. Ypma, S.L., N. Brüggemann, J. Pietrzak, C. Katsman, 2017: A changing heat flux over the Nordic Seas: asymmetry in an idealized model study, EGU general assembly 2017, Vienna.

Project leaders

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

Research theme

Complex dynamics of fluids

Participants

S.L. 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 LEADERS
C.A. Katsman, J.D. Pietrzak,
H.A. Dijkstra

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Carine van der Boog (PhD)

COOPERATIONS
Institute of Marine and Atmospheric Research Utrecht, Utrecht University

FUNDED BY
Delft University of Technology

FUNDED %

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

START OF THE PROJECT
2016

INFORMATION
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PROJECT AIM

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

PROGRESS

The project started in December 2016, and the model is in the development phase. The first results indicate a significant role of the wind stress on the eddy variability.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

BioManCO: Bio-morphodynamic modeling of mangrove-mud coasts

Project Aim

A bio-morphodynamic model for mangrove-mud coasts will be developed, with input from field work, carried out at the extremely eroding Demak coastline, Java, Indonesia. This model 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. Finally, the model will be used for developing generic design rules for coastal restoration.

Progress

2017 was the first full year for the three PhDs. A first field campaign in Indonesia took place in July and August and was very successful, both with respect to collected data as well as gained experience. Furthermore, the research proposal was worked out in detail and the first steps were made. In this first phase of the research, Alejandra focuses on the permeable structures, Celine investigates the natural (and artificial) establishment of mangrove vegetation as well as the effects of subsidence, and Silke focuses on the wave transformation.

Dissertations

-

Scientific Publications

-

Project leaders

JC Winterwerp, WSJ Uijttewaal

Research theme

Complex dynamics of fluids

Participants

A Gijón Mancheño, SAJ Tas, C van Bijsterveldt

Cooperations

TU Delft, NIOZ, Diponegoro University (Indonesia)

Funded by

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

Funded %

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

Start of the project

2016

Information

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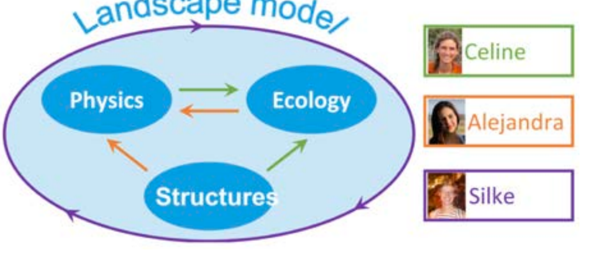
www.biomanco.org

Installing a wave logger in front of mangrove vegetation during the first field campaign (July 2017) © Silke Tas

Organisation structure of BioManCO project



SEAWAD

Project leaders
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
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www.citg.tudelft.nl/en/research/stories-of-science/hydraulic-engineering/seawad/

Project Aim

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

Progress

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.

Dissertations

-

Scientific Publications

-

Project Aim

The project aims at constructing a numerical wave flume for the design and assessment of coastal structures. 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 focused on an important and long-standing issue in particle-mesh methods on reconciling accuracy and exact conservation. A PDE-constrained optimization problem was formulated, which enables an accurate and conservative reconstruction of mesh fields from scattered particle data. Results of the approach are promising in that it allows to solve transport problems without any numerical diffusion. Two peer-reviewed papers were published, and another paper is in preparation for publication in a scientific journal.

Dissertations

-

Scientific Publications

1. 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.
2. J.M. Maljaars, R.J. Labeur, M. Möller, W.S.J. Uijttewaal, Development of a hybrid particle-mesh method for simulating free-surface flows, Journal of Hydrodynamics, Ser. B 29 (3) (2017) 413-422. https://doi.org/10.1016/S1001-6058(16)60751-5 .

Project leaders

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

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PROJECT LEADERS
A Blom, WSJ Uijttewaal
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
V 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 AIM

We need to account for the mixed character of sediment to be able to model important physical processes that occur in rivers. This 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. In order to gain insight into the physical processes that occur when the model is ill-posed we have run a set of laboratory experiments. This data set has been used to develop a strategy to recover the well-posedness of the model.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Blom, A., V. Chavarrias , R. I. Ferguson, and E. Viparelli (2017), Advance, Retreat, and Halt of Abrupt Gravel-Sand Transitions in Alluvial Rivers, Geophys. Res. Lett., 44, 1-10.
2. Blom, A., L. Arkesteijn, V. Chavarrías, and E. Viparelli (2017), The equilibrium alluvial river under variable flow and its channel-forming discharge, J. Geophys. Res. Earth Surf., 122 1-25.

PROJECT AIM

The upper Dutch Rhine is degrading at a rate of 1 to 2 cm per year (e.g. Figure 1). This poses problems to navigation and water management. Our objective is to improve our understanding of the relative contribution of the causes of long-term bed degradation in the Rhine River and other degrading rivers. In particular, the research is intended (1) to quantify past channel adjustment processes (mainly bed degradation and bed surface coarsening) over time and space, (2) to identify and assess the possible causes of bed degradation and their relative roles, and (3) to predict future trends in bed elevation and bed surface texture. The project will combine literature survey, analysis of measured field data, and numerical modelling.

PROGRESS

- A literature survey has been conducted focusing on the effects of the sediment supply and its grain size distribution in laboratory and field cases
- Causes of bed degradation in mixed-size sediment channels and related adjustment time scales have been assessed using a 1D numerical research code.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Siele, M., A. Blom, R. Frings, E. Viparelli (2017), Causes of long-term bed degradation in rivers: Setup of research. Abstract NCR Days 1-3 Feb. 2017.

PROJECT LEADERS

A Blom, WSJ Uijttewaal

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Meles Siele

COOPERATIONS

RWTH Aachen U., South Carolina U., Deltares, RWS-ON, BfG, BAW, Consultants

FUNDED BY

NWO

FUNDED %

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

START OF THE PROJECT

2016

INFORMATION

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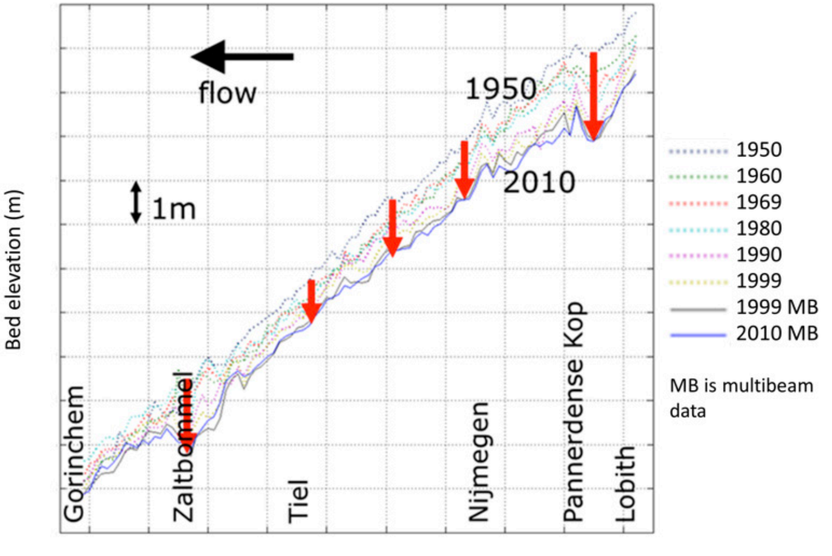
Bed level in the Bovenrijn-Waal in the last 60 years (Blom 2016, data courtesy Rijkswaterstaat)



A seasonal assessment of the net sinking of waters in the North Atlantic Ocean and its connection with AMOC variability

Project leaders
Dr. C.A. Katsman
Research theme
Complex dynamics of fluids
Participants
S. Georgiou (PhD student)
S.L. Ypma (PhD student)
Cooperations
-
Funded by
NWO
Funded %

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

Start of the project
2015
Information
Dr. Juan Manuel Sayol
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Project Aim

The aim of this Postdoc is to analyze the spatio-temporal variability of the net sinking of waters in the North Atlantic Ocean at seasonal scales (from days to few years), and to give some light about how this sinking is linked with the Atlantic Meridional Overturning Circulation (AMOC).

Progress

Available observations and model-based 3D fields of ocean currents, temperature, salinity, mixed layer depth and potential density are assessed in order to analyze the physical mechanisms of this variability. This large-scale overview links with the more theoretical work previously performed by Dr. Nils Bruggemann (2015-2017), and the more regionally focused studies of PhD students S. Georgiou and S.L. Ypma. Currently we are combining information from different realistic ocean models to quantify downwelling in coastal boundaries and/or nearby mesoscale eddies. By working with more than one simulation it is possible to provide a range of uncertainty. The relative importance of each marginal North Atlantic Sea to this net sinking is being presently evaluated.

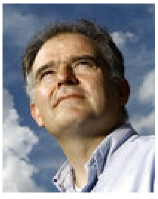
Dissertations

-

Scientific Publications

-

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.

PROJECT AIM

This project aims to predict the cessation of continuous turbulence in the atmospheric evening boundary layer. The interaction between the lower atmosphere and the surface is studied in detail, as this plays a crucial role in the dynamics. Present generation forecasting models are incapable to predict whether or not turbulence will survive or collapse under cold conditions.
In nature, both situations frequently occur and lead to completely different temperature signatures. As such, significant forecast errors are made, particularly in arctic regions and winter conditions. Therefore, prediction of turbulence collapse is highly relevant for weather and climate prediction.

PROGRESS

Different approaches where made to model moderately and very stable boundary layers occurring at Dome C, Antarctica, using both high resolution turbulence resolving models (LES/DNS) as well as more applied models (RANS) in weather forecasting modus. Implications for frost and fog predictions at mid-lattides, where assessed by dedicated observational analysis using new observational technologies. Finally, we investigated the effect of daytime 'history of turbulence' on the evolution of the nocturnal boundary layer. As domain-size and scale separation are typically very different between day and night, so-called Adaptive Mesh Refinedmet (AMR) approaches are used in order to resolve turbulence.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Van Hooft et al., (2017) "Towards Adaptive Grids for Atmospheric Boundary Layer Simulations", Bound. Layer Meteor., 167. 421-443.
2. Van de Wiel et al. (2017) Regime transition in near-surface temperature inversions: a conceptual model. J. Atm. Sci.,74, 1057-1073.
3. Van der Linden et al. (2017) Local Characteristics of the Nocturnal Boundary Layer in Response to External Pressure Forcing, J. Applied Meteor. Clim., 56, 3035–3047.
4. Baas et al., (2017) From Near-Neutral to Strongly Stratified: Adequately Modelling the Clear-Sky Nocturnal Boundary Layer at Cabauw. Bound. Layer Meteor., 166, 217-238.
5. Van Hooijdonk et al. (2017) Temperature inversion growth rate during the onset of the stable boundary layer, J. Atmos. Sci., 74, 3433–3449.
6. Vignon et al. (2017) Clear-sky summertime Atmospheric Boundary Layer at Dome C, Antarctica, in the LMDZ General Circulation Model, J. Geophys. Res., 122, 6818–6843.
7. Vignon et al. (2017) Stable Boundary Layer regimes at Dome C, Antarctica. Quart. J. Roy. Meteor. Soc., DOI: 10.1002/qj.2998, 143: 1241-1253.

PROJECT LEADERS

BJH van de Wiel

RESEARCH THEME

-

PARTICIPANTS

Antoon van Hooft (Phd Students)
Steven van der Linden
Jonathan Izett
Peter Baas (Postdoc)

COOPERATIONS

Delft University of Technology
Eindhoven University of Technology
Wageningen University
Royal Netherlands Institute for Meteorology
Grenoble University, France
University of Victoria, Canada

FUNDED BY

NWO, ERC

FUNDED %

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

START OF THE PROJECT

2013 (NWO), 2016 (ERC)

INFORMATION

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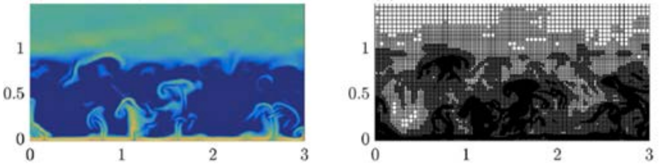

Vertical slices of the buoyancy field and the corresponding grid, for a case with decaying (afternoon) convection, using Direct Numerical Simulation (Van Hooft et al.,2017)

CloudBrake: How nature's smallest clouds slow down large-scale circulations critical for climate

Project leaders
Dr. Louise Nuijens
Research theme
-
Participants
Kevin Helfer
Beatrice Saggiorato
Mariska Koning
Cooperations
Max-Planck Institute for Meteorology
German Aerospace Center (DLR)
European Center for Medium-Range Weather Forecasting (ECMWF)
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

CloudBrake tests the hypothesis that shallow clouds slow down the large-scale Hadley circulation by vertical transport of momentum. It connects observations of clouds and winds to expose the causality of their relationship, using ground-based and airborne measurements and high resolution modeling (Large Eddy Simulation). Different models of momentum transport used in global (climate) models and their impact on global circulations are evaluated. CloudBrake strives to increase the predictability of low-level winds, which are important to many disciplines, including climate studies, numerical weather prediction and wind-energy research.

Progress

The first phase has focused on training three PhD students in atmospheric dynamics and answering the question: How does wind shear influence shallow cloud and their momentum transport? And vice versa? High-resolution simulations with the Dutch Atmospheric Large-Eddy Simulation (DALES) model have been set-up for two atmospheric regimes (subtropical convection and midlatitude cold air outbreak), revealing distinct wind variability on scales of tens of kilometers underneath cloudy areas. These may have a large impact on wind energy generation and air-sea fluxes, which in turn is critical for subsequent cloud formation and dynamics of ocean surface layers.

Dissertations

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Scientific Publications

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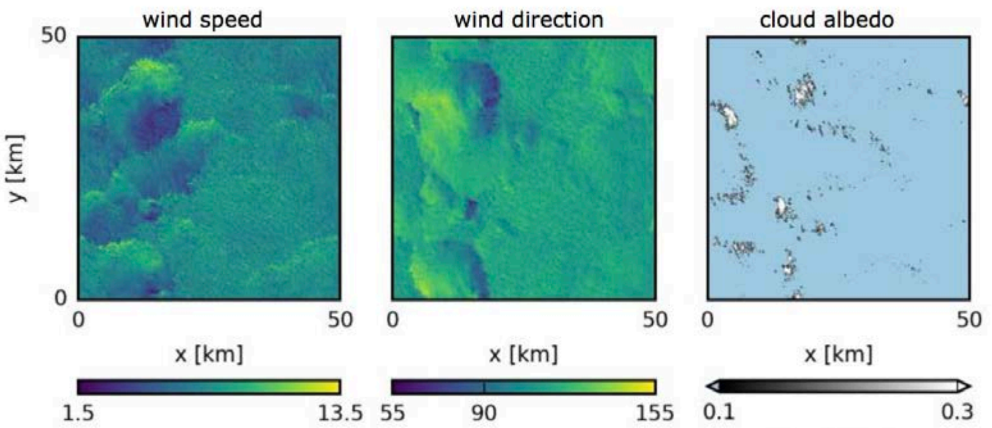
Horizontal cross sections of (left to right) wind speed at 10m, wind direction at 10m and cloud albedo from large-eddy simulation of convection reaching up to 3 km.



PROJECT AIM

In recent years evidence has grown that extreme precipitation intensity during short periods (hourly) is increasing at a rate (10-14% per degree warming), much larger than expected from purely thermodynamical considerations. This project will analyse observed trends and scale dependencies of the spatio-temporal behaviour of strong precipitation. It will utilize high-resolution mesoscale models (resolution 2km) and large-eddy simulations to explore the added role of atmospheric dynamics on the size, intensity and frequency of strong precipitation for present day and future atmospheric conditions. This knowledge will be applied in the long term management and planning of water boards, main road systems and urban sewer systems.

PROGRESS

Observations show that subdaily precipitation extremes increase with dew point temperature at a rate exceeding the Clausius-Clapeyron (CC) relation. Here the size and intensity of rain cells are investigated by using a tracking of rainfall events in high-resolution radar data. Small rain cells follow CC scaling, larger cells display super CC behavior. Even more, for dew point exceeding 15 oC, the rain cell size has to increase in order to sustain super CC scaling and a remarked increase in rain cell area is found. Our results imply that the source area of moisture, the cloud size, and the degree of mesoscale organization play key roles in the context of a warming climate.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. K. Lochbihler, G. Lenderink and A.P. Siebesma., (2017) “The spatial extent of rainfall events and its relation to precipitation scaling”, Geophysical research Letters., 44. 8629-8636.

PROJECT LEADERS

Dr. ir. Geert Lenderink
Prof .dr. A.P. Siebesma

RESEARCH THEME

-

PARTICIPANTS

Kai Lochbihler

COOPERATIONS

Royal Meteorological Netherlands Institute (KNMI), Rioned, Waterboard Rijnland, RWS, STOWA

FUNDED BY

NWO

FUNDED %

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

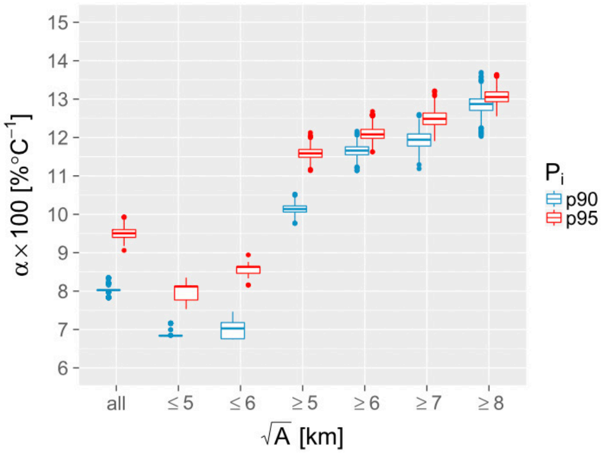
START OF THE PROJECT

2017

INFORMATION

A.P. Siebesma
06 10487084
a.p.siebesma@tudelft.nl

The scaling parameter a for the 90% and 95% percentiles of the most extreme precipitation events for different area constrained subsamples showing that for smaller events the precipitation intensity increases with 7% per degree warming while larger events can increase their intensity by as much as 13% per degree warming.



Project leaders
Prof. dr. D Crommelin
Prof .dr. A.P. Siebesma
Research theme
-
Participants
Gijs van den Oord (E-science center)
Fredrik Jansson (CWI)
Cooperations
CWI, KNMI, E-science Center
Funded by
NWO
Funded %

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

Start of the project
2017
Information
A.P. Siebesma
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a.p.siebesma@tudelft.nl

Project Aim

Clouds and convection processes are important for the climate system, yet they are not explicitly resolved in global climate models due to computational limitations. We will pursue a new 3d-super-parameterization (3d-SP) approach to overcome this conundrum. We will nest 3-dimensional Large Eddy Simulation (LES) models into the grid columns of a Global Circulation Model. This way, the parameterized descriptions of clouds, convection and turbulence with all their shortcomings will be replaced by a realistic 3-dimensional simulation technique for these processes.

Progress

The technical design for a replacement of the convection parameterization scheme of the climate model EC-Earth atmosphere model by the convection-resolving, fully 3D, Large Eddy Simulation (LES) model DALES has been established. The model coupling consists of bidirectional data exchange between the global model and the high-resolution LES-models embedded within the columns of the global model, commonly re- ferred to as super-parameterization. The setup allows for selective superparameterization, i.e. for applying superparameterization in local regions selected by the user, whilst keeping the standard parameterization of OpenIFS in- tact outside this region.

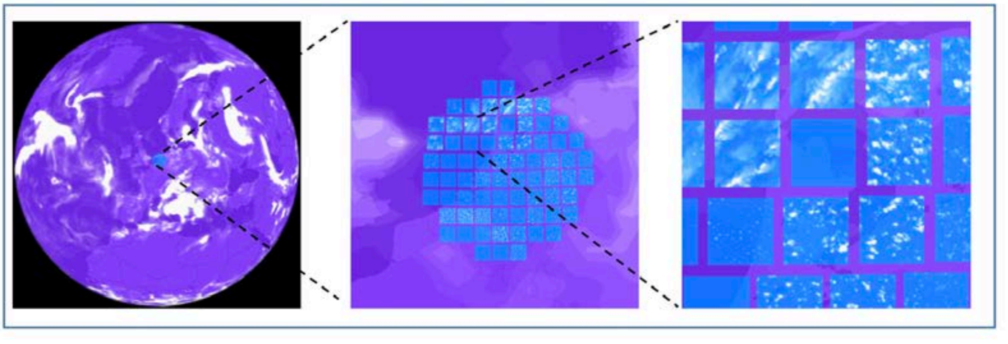
Dissertations

-

Scientific Publications

-

Visualisation of the concept of the superparameterisation. Left panel: Cloud fields from the global model. Middle panel: Zoom in on a superparameterised region covering the Netherlands. Right panel: Further zoom in on a few superparameterized gridboxes over part of the Netherlands



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)

Vortex dynamics and turbulence

Prof.dr. HJH Clercx

Prof.dr.ir. GJF van Heijst

Prof.dr. F Toschi

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

The range of control parameters of rotating thermal convection to be investigated have been discussed and defined in order to explore regime transitions. Production runs have been carried out at low Prandtl number Pr = 0.1 (relevant for Earth's liquid-metal outer core), where post-processing and analysis of the output data have been done in terms of heat transfer, boundary layers thicknesses and distribution of dissipation of energy. We have been able to distinguish two different scaling regimes of the heat transfer as a function of the rotation rate. We have identified the transition likely to occur at Ek=9.5x10-7. The lower-Ek regime have been identified as the Geostrophic Turbulent regime where Nu approximately scales as Ek1.2. Forthermore, we have conducted runs at higher Pr = 5 for comparison with experimental results, showing very nice agreement.

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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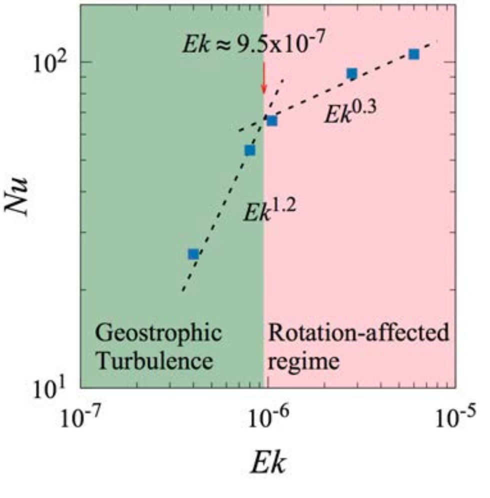

Convective heat transfer (Nu) as a function of Ek (inverse rotation rate). The simulations have been performed at Pr-0.1 and Ra=1x1010 in a horizontally periodic domain with no-slip boundaries at top/bottom

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
-
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 will be implemented in the Rayleigh-Bénard system 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 such that they 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). In particular, we find that both the number of particles at the plate and the time particles spend inside the thermal boundary layers is increasing with increasing τT and increasing thermal expansion coefficient of the particles.

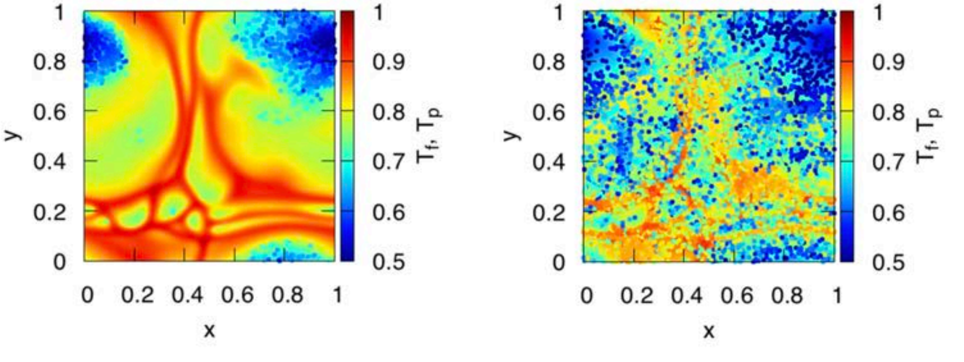
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Alards, K.M.J., Rajaei, H., Del Castello, L., Kunnen, R.P.J., Clercx, H.J.H. & Toschi, F. (2017). Geometry of tracer trajectories in rotating turbulent flows. Physical Review Fluids, 2(4):044601.

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.



Lagrangian mixing analysis of heat transfer: a new way for thermal optimisation

Project Aim

The objective is in-depth analysis of the Kenics static mixer by Lagrangian mixing analysis of heat transfer. The study is divided into two subprojects: Topological mixing analysis of heat transfer in the Kenics mixer (E. Demissie; Wbt) and Experimental heat-transfer and mixing analysis of the Kenics mixer (O. Baskan, Applied Phys.). The latter subproject focuses on experimental characterization of Lagrangian mixing properties in case studies by measurement of 3D fluid trajectories and evolution of 3D scalar fields using advanced optical measurement techniques. Benchmarking of numerical thermal mixing analyses and testing of the prototype thermal-analysis tools for advanced data processing.

Progress

This project has been finished with the thesis of O. Baskan (2015).

Dissertations

1. Baskan, Ö., Rajaei, H., Speetjens, M.F.M. & Clercx, H.J.H. (2017). Scalar transport in inline mixers with spatially periodic flows. Physics of Fluids, 29(1):013601.

Scientific Publications

-

Project leaders

HJH Clercx

Research theme

Complex dynamics of fluids

Participants

O Baskan, HJH Clercx

Cooperations

MFM Speetjens (TU/e-Wtb),
EA Demissie (TU/e-Wtb),
G Metcalfe (CSIRO, Australia)

Funded by

STW

Funded %

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

Start of the project

2010

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

Main: Completed construction and made various design improvements to the experimental rotating convection setup. Data in the smallest tank (height 0.8 m) has been collected: heat transfer results showing marked agreement with previous studies and with numerical simulations (see figure 1). Exploring a novel method for characterizing flow regimes via temperature profiles. We have installed the 2.0 m tank, and are currently collecting nonrotating data for calibration.

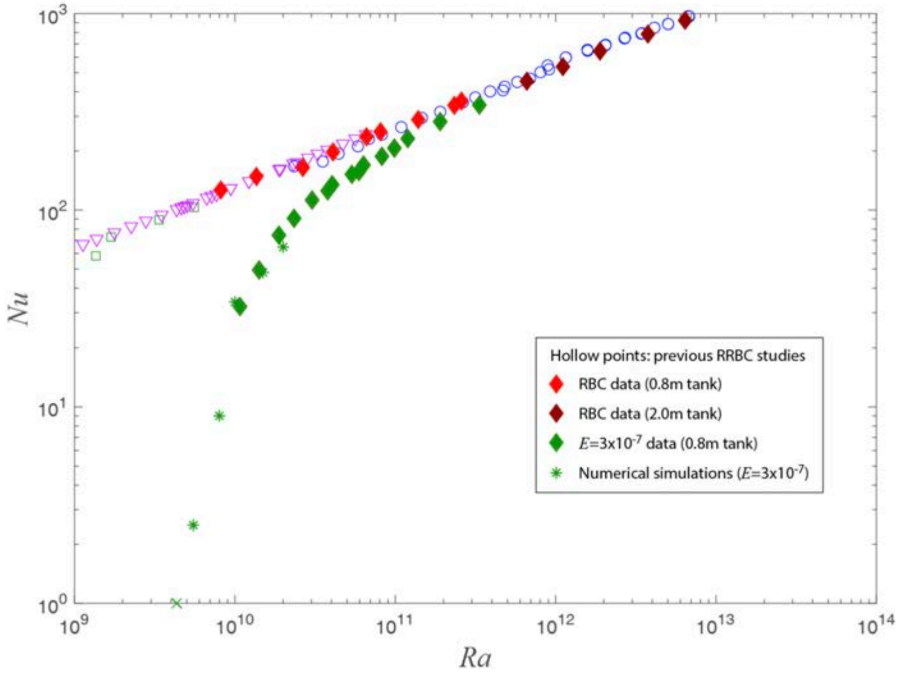
Secondary: Conducted numerical rotating convection simulations with varying centrifugal forcing. Currently analyzing results and exploring literature for physical interpretation ideas.

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 second year of the project included both pedestrian dynamics modeling and measurements. A novel quantitative model for fluctuations and rare events in diluted pedestrian flows, based on a bi-stable Langevin equation, has been proposed. On the experimental side, techniques based on computer vision and deep neural networks have been developed to increase accuracy of real-life pedestrian measurements. Finally, the issue of crowd steering has been considered. In particular, we investigated the capability of illumination of swaying individual routing decision (cf. figures: uneven illumination steers the crowd on one side of an obstacle along the 2017 Glow festival route).

Dissertations

-

Scientific Publications

1. Corbetta, A., Lee, C.-M., Benzi, R., Muntean, A. & Toschi, F. (2017). Fluctuations around mean walking behaviors in diluted pedestrian flows. Physical Review E, 95(3):032316.
2. Corbetta, A., Lee, C.-M., Muntean, A. & Toschi, F. (2017). Frame vs. trajectory analyses of pedestrian dynamics asymmetries in a staircase landing. Collective Dynamics, 1(A10), 1-26.
3. Bruno, L. & Corbetta, A. (2017). Uncertainties in crowd dynamic loading of footbridges : a novel multi-scale model of pedestrian traffic. Engineering Structures, 147, 545-566.

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

Funded by

NWO

Funded %

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

Start of the project

2016

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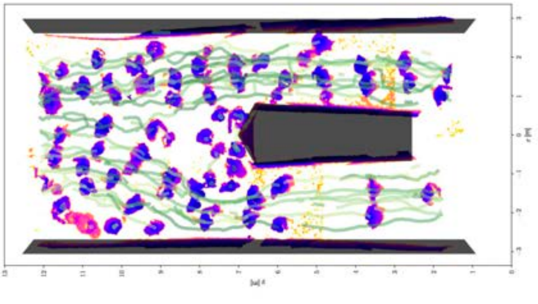


4. Venuti, Fiammetta, Racic, Vitomir & Corbetta, Alessandro (2017). Modelling framework of pedestrian-footbridge interaction in vertical direction. Procedia Engineering, 199, 2901-2906.
5. Benzi, R., Biferale, L., Bonaccorso, F., Clercx, H. J.H., Corbetta, A., Mobius, W., Toschi, F., Salvadore, F., Cacciari, C. & Erbacci, G. (2017). TurBase: a software platform for research in experimental and numerical fluid dynamics. Proceedings - 2017 International Conference on High Performance Computing and Simulation, HPCS 2017 (pp. 51-57). Piscataway: Institute of Electrical and Electronics Engineers (IEEE).
6. Corbetta, A., Menkovski, V. & Toschi, F. (2017). Weakly supervised training of deep convolutional neural networks for overhead pedestrian localization in depth fields. 2017 14th IEEE International Conference on Advanced Video and Signal Based Surveillance (AVSS), 29 August - 1 September 2017, Lecce, Italy (pp. 1-6). Piscataway: Institute of Electrical and Electronics Engineers (IEEE).
7. A. Corbetta, F. Toschi. Overhead pedestrian tracking for large scale real-life crowd dynamics analyses. to appear, invited panelist contribution at “New approaches to evacuation modelling” (as part of the 12th International Symposium on Fire Safety Science), 2017.

PROJECT AIM

Main aim is the development of numerical tools to characterize transport of particle debris under combined effects of fluid dynamics and plasma physics. Our aim is 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.

PROGRESS

The new 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. The very good results both in terms of accuracy and reduction of computational cost have been. The main result is the drastic reduction of computational time (a 4x speed-up with respect to a full DSMC simulation is achieved) while maintaining an accurate solution. The import of CAD files within the code has also been implemented, drastically enlarging the possible applications for the method.

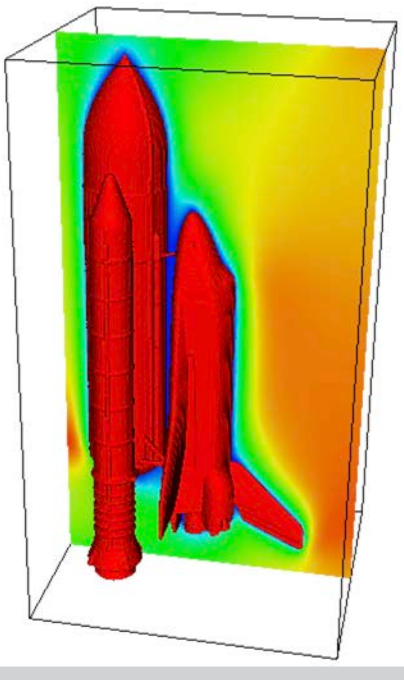
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Example of import of a CAD file into the hybrid code: Mach number field



PROJECT LEADERS

HJH Clercx, F Toschi

RESEARCH THEME

Complex dynamics of fluids

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	-

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RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
M Duran Matute, GJF van Heijst
COOPERATIONS
Wim-Paul Breugem (TUD)
FUNDED BY
NWO
FUNDED %

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

START OF THE PROJECT
2014
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PROJECT AIM

In environmental flows (e.g. in rivers or at the coast), vortices can play an important role in shaping the sediment bed underneath. The main aim of the project is to provide a complete and coherent theory behind sediment transport by barotropic vortices in such environmental water systems. Through a combination of laboratory experiments and numerical simulations, the full cycle of erosion, transport, and deposition of sediment by the vortices will be systematically studied.

PROGRESS

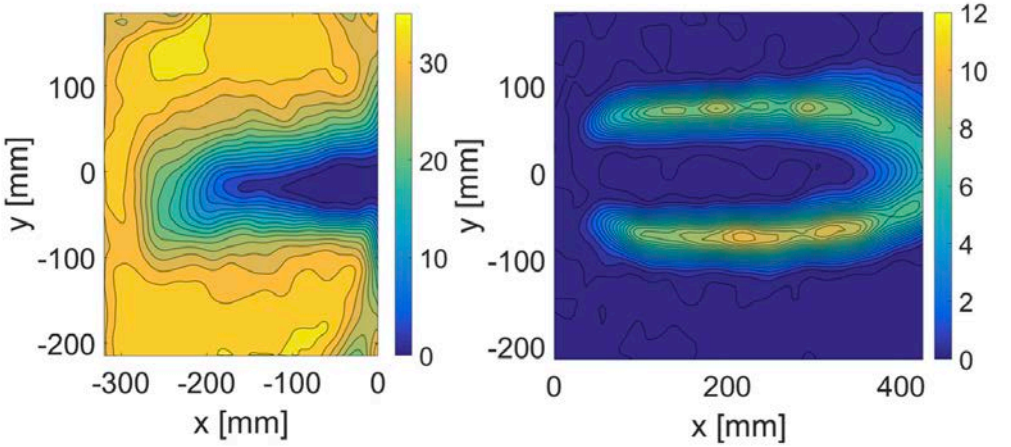
In the first stage of this project, two research lines have been undertaken: 1) the study of particle trajectories in the boundary layers below a swirling flow and 2) the morphodynamics and ripple formation under an oscillating swirling flow. In a second stage, we have been studying the transport of sediment and the related morphodynamics around a tidal inlet. Laboratory experiments have been carried out where an oscillating flow is forced through a narrow opening. Initially, sediment is present on one side of the opening, and part of it is then transported by the flow to the other side. The flow velocity, the changes in the bed morphology, and the net amount of sediment are measured relating the flow characteristics to the changes in the sediment bed.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Gerkema, T. & Duran Matute, M. (2017). Interannual variability of mean sea level and its sensitivity to wind climate in an inter-tidal basin. Earth System Dynamics, 8(4), 1223-1235.
2. Nauw, J.J., Philippart, C.J.M., Duran Matute, M. & Gerkema, T. (2017). Estimates of exposure times in the Wadden Sea: A comparison of methods. Journal of Sea Research, 127, 12-25.



The effects of barotropic vortices on sediment transport: an experimental and numerical study

Project Aim

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

Progress

The experiments on sediment transport under a spin-down flow were concluded. We are currently studying the effect of a translating monopolar vortex on a sediment bed. Surface flow velocity fields and the regions of high sediment suspension are simultaneously obtained, together with the net changes in morphology. This allows us to link the characteristics of the flow to the overall sediment transport. Experiments on the sediment transport asymmetry between cyclonic/anticyclonic vortices are underway.

Dissertations

-

Scientific Publications

-

Project leaders

GJF van Heijst, M Duran Matute

Research theme

Complex dynamics of fluids

Participants

AS Gonzalez Vera, M Duran Matute

Cooperations

R Verzicco (UT)

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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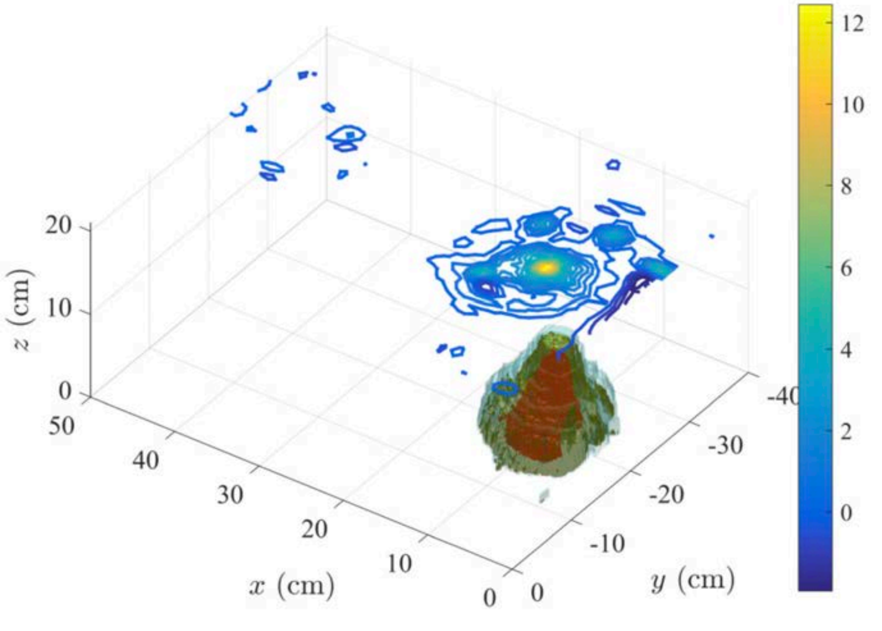

Study of non-isothermal rarefied gas flows with hybrid DSMC-LBM simulations

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

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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

A Lattice Boltzmann code has been developed and verified for different problems: Couette flow, Poiseuille flow, Kolmogorov flow, and sound wave. Validation has been done via different comparisons between numerical and analytical results, e.g. measurement of slip velocity, or study of LBM behavior through different Knudsen numbers with measuring the viscosity change.

Dissertations

-

Scientific Publications

-

High-efficiency organic solar cells by controlling microstructure through processing

Project Aim

The aim is to study the basic fluid dynamics physics of multi-component phase separation and solidification of suspensions under steady evaporation. This will contribute to a better understanding on the dynamics of the morphology formed during the processing of organic solar cells and may contribute in increasing the power conversion efficiency.

Progress

The literature on the problem and the necessary physics were studied during the first year of the PhD (Sept 2016-Sept 2017). This included statistical physics of phase ordering, Lattice-Boltzmann Method (LBM) and learning about existing computer codes. Additionally, the Free Energy LBM was implemented and validated by comparisons with analytical predictions and previous studies reported in the literature. Also, the study of the effect of substrate wetting on the phase separation is initiated to characterize the growth dynamics near the substrate in thin films.

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

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PROJECT LEADERS
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RESEARCH THEME
Complex Dynamics of Fluids
PARTICIPANTS
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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
2013
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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

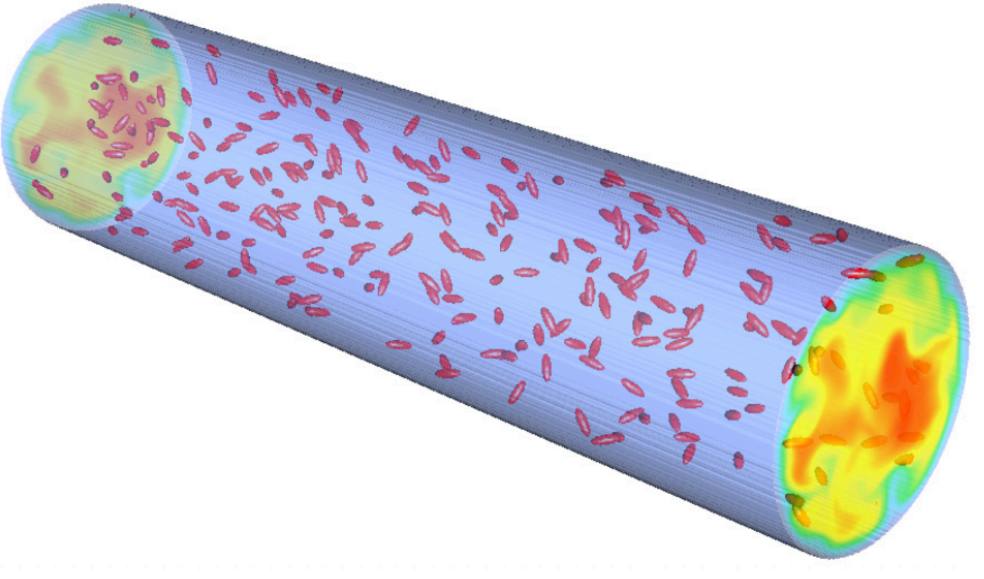
DNS of turbulent pipe flows with finite-size prolate spheroids embedded in it is performed using the lattice Boltzmann method (LBM). We studied the effect of different particle shapes on flow modulation, particle dynamics and orientation. Consequently, these particle laden turbulent simulations are employed to compute irradiance, light-dark cycle, average mutual shading and fragmentation rate in photo-bioreactors. We show how these fully-resolved numerical simulations with particles can be used to understand and compute several relevant quantities that can be used for optimizing these systems. With the incorporation of these works, the PhD thesis is finalized.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Project Aim

The goal is to address the basic phenomenology of droplets under realistic situations, the focus being on large-scale behavior. In this study the focus will be on the effects of gravity and of shear on droplet transport and collision rates.

Progress

This project has been finished with the thesis of M.A.T. van Hinsberg (2016).

Dissertations

-

Scientific Publications

1. van Hinsberg, M.A.T., Clercx, H.J.H. & Toschi, F. (2017). Enhanced settling of nonheavy inertial particles in homogeneous isotropic turbulence: The role of the pressure gradient and the Basset history force. Physical Review E, 95(2):023106.

Project leaders

F Toschi, HJH Clercx, GJF van Heijst

Research theme

Complex dynamics of fluids

Participants

MAT van Hinsberg, HJH Clercx, F Toschi

Cooperations

L Biferale (Rome, Italy), P Perlekar (TIFR, Hyderabad, India),
J ten Thije Boonkkamp (W&I-TU/e)
Chung-Min Lee (California, USA)

Funded by

FOM

Funded %

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

Start of the project

2011

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PROJECT LEADERS
HJH Clercx, BJH van de Wiel
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
IGS van Hooijdonk, HJH Clercx, BJH van de Wiel, AF Moene
COOPERATIONS
A. Monahan (Univ. Victoria, Canada), M. Scheffer (WUR)
FUNDED BY
NWO-ALW
FUNDED %

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

START OF THE PROJECT
2013
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PROJECT AIM

A well-known phenomenon in the atmospheric boundary layer is the sudden decrease in turbulence intensity. This generally occurs in the case of weak winds (shear production) strong cooling at the surface (buoyant destruction). Data analysis of atmospheric data (Cabauw weather tower), theoretical analysis and direct numerical simulation are used to investigate this phenomenon. Though originally the research is motivated by meteorological application, we also aim to obtain fundamental insight in the laminarisation of turbulence near a cooled surface.

PROGRESS

This project has been finished with the thesis of I.G.S. van Hooijdonk (2017).

DISSERTATIONS

1. van Hooijdonk, I.G.S. (2017). Plane couette flow as model for the nocturnal boundary layer. Eindhoven: Technische Universiteit Eindhoven. ((Co-)promot.: Herman Clercx, Bas van de Wiel & A.F. Moene).

SCIENTIFIC PUBLICATIONS

1. van Hooijdonk, I.G.S., Moene, A.F., Scheffer, M., Clercx, H.J.H. & van de Wiel, B.J.H. (2017). Early warning signals for regime transition in the stable boundary layer: a model study. Boundary-Layer Meteorology, 162(2), 283-306.
2. Vignon, E., van de Wiel, B.J.H., van Hooijdonk, I.G.S., Genthon, C., van der Linden, S.J.A., van Hooft, J.A., Baas, P., Maurel, W., Traullé, O. & Casasanta, G. (2017). Stable boundary-layer regimes at dome C, Antarctica : observation and analysis. Quarterly Journal of the Royal Meteorological Society, 143(704):143.
3. van de Wiel, B.J.H., Vignon, E., Baas, P., Bosveld, F.C., de Roode, S.R., Moene, A.F., Genthon, C., van der Linden, Steven J.A., van Hooft, J. Antoon & van Hooijdonk, I.G.S. (2017). Regime transitions in near-surface temperature inversions : a conceptual model. Journal of the Atmospheric Sciences, 74(4), 1057-1073.
4. van der Linden, S.J.A., Baas, P., van Hooft, J.A., van Hooijdonk, I.G.S., Bosveld, F.C. & van de Wiel, B.J.H. (2017). Local characteristics of the nocturnal boundary layer in response to external pressure forcing. Journal of Applied Meteorology and climatology, 56(11), 3035-3047.
5. van Hooijdonk, I.G.S., Clercx, H.J.H., Abraham, C., Holdsworth, A.M., Monahan, A.H., Vignon, E., Moene, A.F., Baas, P. & van de Wiel, B.J.H. (2017). Near-surface temperature inversion growth rate during the onset of the stable boundary layer. Journal of the Atmospheric Sciences, 74(10), 3433-3449.

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

-

Dissertations

-

Scientific Publications

1. Van Houwelingen, Josje, Roerdink, Melvyn, Huibers, Alja V., Evers, Lotte L.W. & Beek, Peter J. (2017). Pacing the phasing of leg and arm movements in breaststroke swimming to minimize intra-cyclic velocity fluctuations. PLoS ONE, 12(10):e0186160.
2. van Houwelingen, J., Willemsen, D.H.J., Kunnen, R.P.J., van Heijst, G.J.F., Grift, E.J., Breugem, W.P., Delfos, R., Westerweel, J., Clercx, H.J.H. & van de Water, W. (2017). The effect of finger spreading on drag of the hand in human swimming. Journal of Biomechanics, 63, 67-73.
3. van Houwelingen, J., Schreven, S., Smeets, J.J.B., Clercx, H.J.H. & Beek, P.J. (2017). Effective propulsion in swimming: grasping the hydrodynamics of hand and arm movements. Journal of Applied Biomechanics, 33(1), 87-100.

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

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PROJECT LEADERS
HJH Clercx, F Toschi
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
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COOPERATIONS
G Ahlers (UCSB), B Geurts (UT), D Lohse (UT), R Verzicco (Roma)
FUNDED BY
FOM
FUNDED %

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

START OF THE PROJECT
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PROJECT AIM

Rayleigh-Bénard convection (RBC) is the laboratory realization of buoyancy-driven convection, which is relevant to many natural phenomena and industrial applications. Since these processes are often coupled with system rotation, its effect on RBC is also of interest. In general, depending on the system parameters, the Rayleigh-Bénard system can exist in multiple turbulent states with different heat transfer characteristics. The aim of this project is to explore the possibility of tuning the transitions between various turbulent regimes, and/or controlling the heat transfer, in rotating RBC by adding particles to the fluid or changing boundary conditions.

PROGRESS

Project concluded.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Joshi, P.R., Rajaei, H., Kunnen, R.P.J. & Clercx, H.J.H. (2017). Heat transfer in rotating Rayleigh-Bénard convection with rough plates. Journal of Fluid Mechanics, 830.

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 the fourth year of the PhD, the influence of the water depth on the oscillating boundary layer has been investigated. It has been found that oscillating flows with small water depths are characterized by (i) a phase shift of the velocity profile and (ii) an increase of the wall shear stress. The model for the density driven flow has been extended to handle highly unsteady flows. Preliminary simulations for simulations with combined oscillating flow and density driven flow have been performed.

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

STW

Funded %

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

Start of the project

2014

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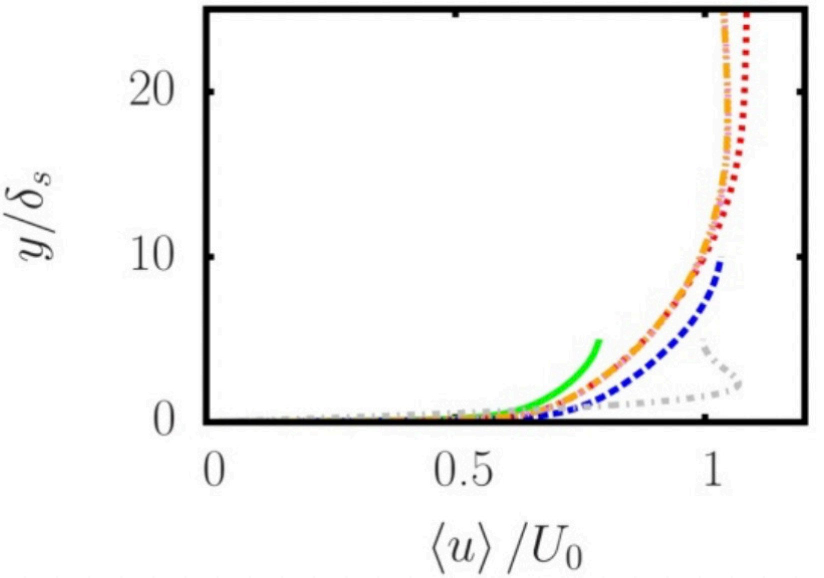

Sensing and controlling resin-layer thickness in additive manufacturing processes

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

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

Start of the project
2017
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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

The recoating process in ceramics additive manufacturing was investigated by means of CFD modeling. Based on the numerical simulation results, the relation between recoating parameters and the resin layer thickness was derived for the flat substrate geometry. First results were obtained for the rectangular cavity configuration. A few sensing techniques were compared to measure the topography of the liquid surface with reasonable accuracy. The confocal chromatic sensor showed suitable performances and was chosen as a main candidate.

Dissertations

-

Scientific Publications

-

Free surface deformation of the resin when the recoater passes through a step-shaped cavity (CFD simulation). Red colour represents the resin; blue is the air; the white rectangular is the recoater. Recoater moves from the left to the right.

Earthquake dynamics: understanding their physics from modeling soft-glassy materials

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. This earthquake model will then be fine-tuned using inversion of surface seismic recordings.

Progress

- Confirmation of inter-event waiting time distribution for avalanches obtained from simulations in soft matter with experiments by 2 groups.
- Finding the numerical method to suppress plastic events in a soft glass, which enables for the 1st time the ability prove causality between sets of 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 (UU)

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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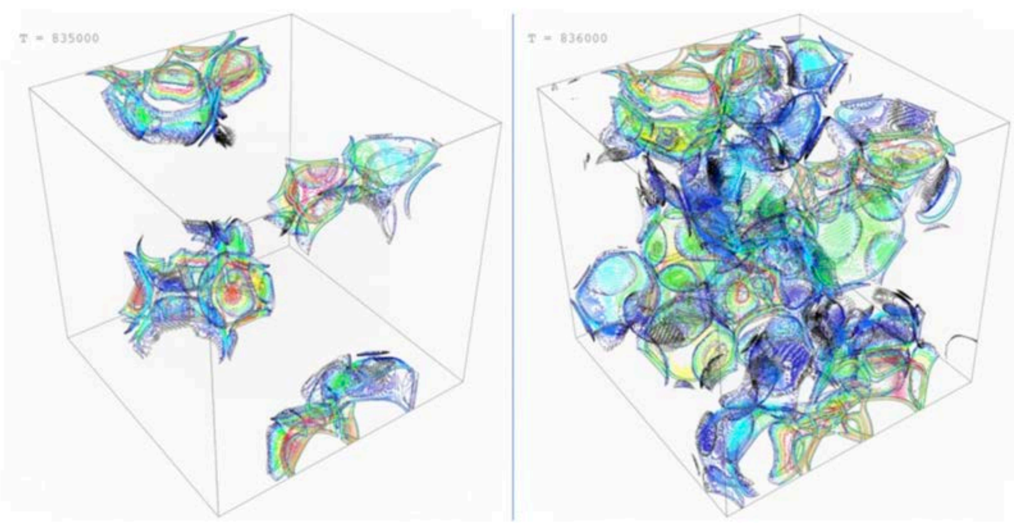
Shown above is the displacement field extracted from the continuum density field during a plastic event in 3D. The strong intermittency in space and time are noteworthy



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 CO2 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 CO2 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 simple reactive fluid model was set up with LBM method, and the result showed good agreement with analytical solution.

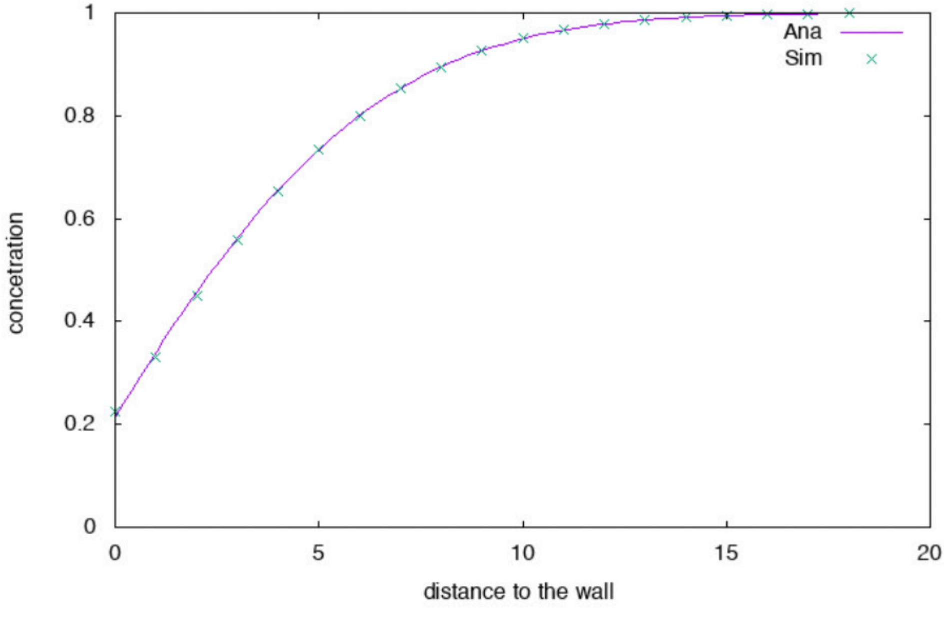
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Concentration distribution of species A: comparison of the numerical solution vs. the analytical solution for a simple 1d geometry. Reaction takes place at the wall boundary.



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

Starting focus on literature review and discussions on rotating convection. Finalization and final tuning of the experimental setup, with non-rotating runs in order to validate the setup. Collection of the first rotating data with the smallest tank size (0.8 m), calculating the heat transfer at different regimes and analysis of the bulk temperature gradient. Upgrade of the setup into a taller tank (2.0 m). Discussion on the outcome of the experiment and comparison of the transitions predicted in the literature with the data. First insights on the optical measurements.

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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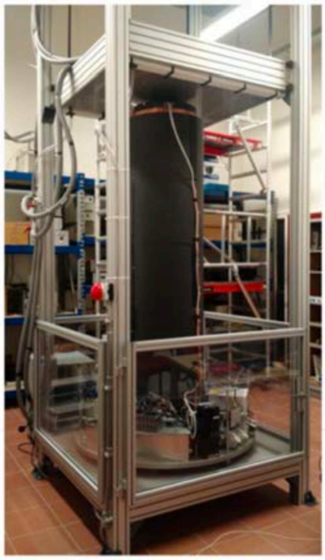
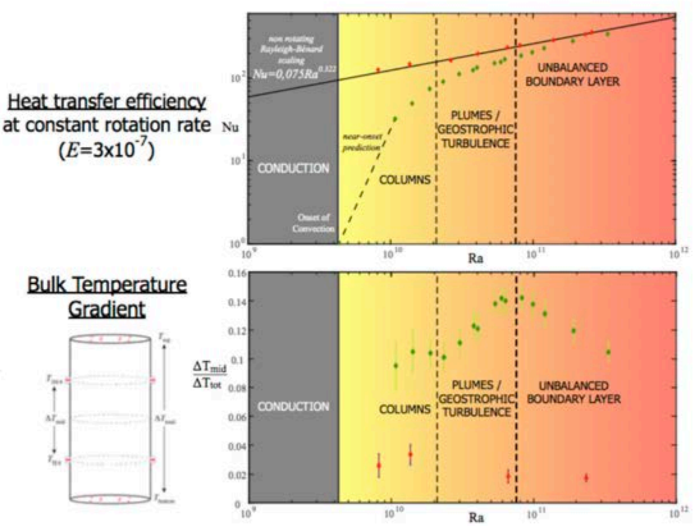


Current size of the tank (2 m)



Algorithms for Eulerian-Lagrangian approaches in Turbulence, micro- and nano-fluidics

Project leaders
F Toschi

Research theme
Complex dynamics of fluids

Participants
FMN Milan, L Biferale (Rome), M Sbragaglia (Rome), F. Toschi

Cooperations
University of Rome, Tor Vergata, HPC-LEAP Program, Univ. of Wuppertal (Germany)

Funded by
HPC-LEAP (Marie Curie Fellowship)
Horizon 2020

Funded %

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

Start of the project
2015

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Project Aim

Developing new algorithms to describe finite-size particles (with internal dynamics) in turbulent flows.

Progress

The progress includes the following steps:

- Benchmark of LBM boundary conditions for a time-dependent simple shear flow
- Analysis of dynamics of a droplet in a time-dependent simple shear flow
- Study of the time-dependent droplet break up in an oscillating simple shear flow
- Implementation of the boundary conditions for a 3D elongational flow

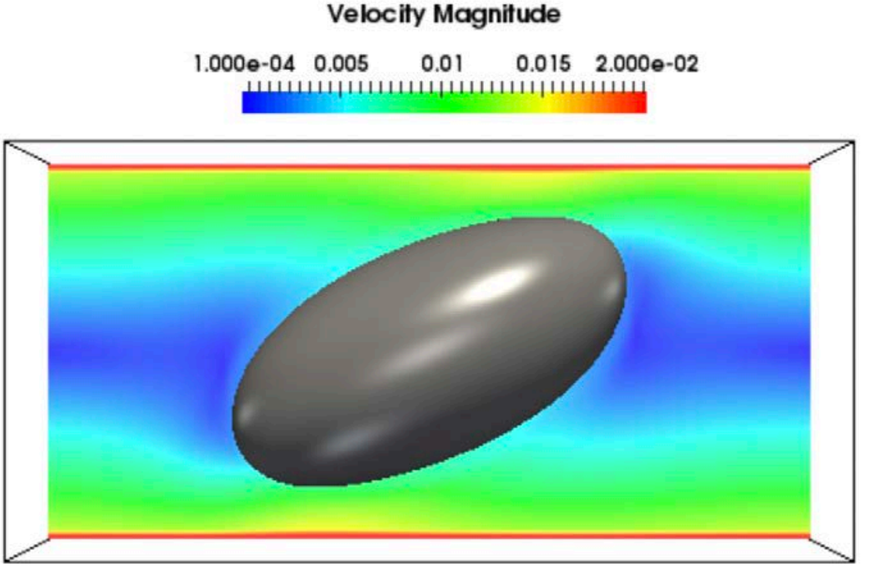
Dissertations

-

Scientific Publications

-

Ellipsoidally deformed droplet in an oscillatory shear flow with confinement



Project Aim

The aim of this project is to realize laboratory and numerical setups to perform a fundamental investigation on the flow transition from one state to the others in rotating convection and provide insight into the driving forces behind these transitions.

Progress

This project has been finished with the thesis of H. Rajaei (2017).

Dissertations

1. Rajaei, H. (2017). Rotating Rayleigh-Bénard convection. Eindhoven: Technische Universiteit Eindhoven. ((Co-)promot.: Herman Clercx, Federico Toschi & Rudie Kunnen).

Scientific Publications

1. Alards, K.M.J., Rajaei, H., Del Castello, L., Kunnen, R.P.J., Clercx, H.J.H. & Toschi, F. (2017). Geometry of tracer trajectories in rotating turbulent flows. Physical Review Fluids, 2(4):044601.
2. Baskan, Ö., Rajaei, H., Speetjens, M.F.M. & Clercx, H.J.H. (2017). Scalar transport in inline mixers with spatially periodic flows. Physics of Fluids, 29(1):013601.
3. Joshi, P.R., Rajaei, H., Kunnen, R.P.J. & Clercx, H.J.H. (2017). Heat transfer in rotating Rayleigh-Bénard convection with rough plates. Journal of Fluid Mechanics, 830:R3.
4. Rajaei, H., Kunnen, R.P.J. & Clercx, H.J.H. (2017). Exploring the geostrophic regime of rapidly rotating convection with experiments. Physics of Fluids, 29(4):045105.

Project leaders
HJH Clercx, F Toschi

Research theme
Complex dynamics of fluids

Participants
H Rajaei, HJH Clercx, RPJ Kunnen, F Toschi, KMJ Alards, PR Joshi

Cooperations
-

Funded by
FOM

Funded %

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

Start of the project
2013

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PROJECT LEADERS
MFM Speetjens, F Toschi
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
S Varghese
MFM Speetjens
RR Trieling
F Toschi
COOPERATIONS
-
FUNDED BY
FOM (CSER programme)
FUNDED %

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

START OF THE PROJECT
2014
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PROJECT AIM

Traditional approaches for underground gas and heat recovery suffer from incomplete throughflow of the production fluid due to “short-circuiting” via large fractures and relatively low diffusion towards fractures. The project adopts a radically different approach based on chaos theory which can significantly boost performance by (i) distributing production fluids throughout the entire reservoir and (ii) promoting diffusion of gas or heat towards fractures by inducing large gradients. Principal aim is development of a computational strategy that enables a new way of reservoir analysis. Key to this is definition of closure models by lattice Boltzmann simulations.

PROGRESS

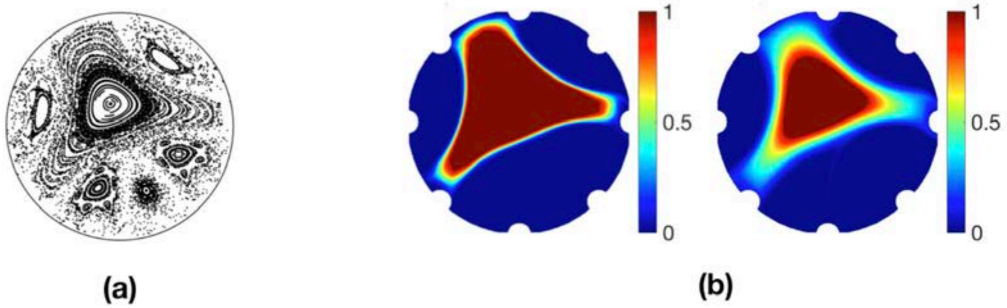
The primary focus of the current year was to supplement the Lagrangian analysis of distribution of production fluid in reoriented injector-extractor well systems (RPM flows), with thermal transport analysis using local thermal equilibrium model. Dynamic mode decomposition was used to extract spatially coherent structures called DMD modes (Fig. b) from the temperature field, which together with transport operator factorization helps establish the link between thermal transport characteristics and Lagrangian dynamics captured by Poincaré sections (Fig. a) for different system parameters. We are further investigating thermal transport in RPM flows using local thermal non-equilibrium model.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Lagrangian Transport and Chaotic Advection in Two-Dimensional Anisotropic Systems. Varghese, S., Speetjens, M.F.M. & Trieling, R.R. (2017). Transport in Porous Media, 119(1), 225-246.



Comparison of a) Poincaré section obtained from Lagrangian analysis with b) dominant DMD mode extracted from temperature field evolution for Pe = 106 (left), 104 (right) employing an 8-well pair RPM configuration

Experimental study of the dynamics of droplets in turbulent sprays and clouds

Project Aim

The main aims are 1) to experimentally investigate the breakup of turbulent jets and sprays by means of phosphorescence, 2) to study the behavior of individual droplets in turbulent sprays and in zero-mean homogeneous isotropic turbulence by Lagrangian measurements, and 3) to explore droplet dispersion in these systems.

Progress

This project has been finished with the thesis of D.D. van der Voort (2017).

Dissertations

1. van der Voort, D.D. (2017). The breakup and dispersion of glowing sprays. Eindhoven: Technische Universiteit Eindhoven. ((Co-)promot.: Herman Clercx, Willem van de Water & Nico Dam).

Scientific Publications

1. van der Voort, D.D., Dam, N.J., Kunnen, R.P.J., van Heijst, G.J.F. & Clercx, H.J.H. (2017). Effect of microbubble-induced capillary voids on the dispersion of sprays. Physical Review Fluids, 2(3):033601.

Project leaders

HJH Clercx, GJF van Heijst

Research theme

Complex dynamics of fluids

Participants

DD van der Voort, HJH Clercx, NJ Dam (TU/e-Wtb), GJF van Heijst, W van de Water

Cooperations

N Maes (TU/e-Wtb)

Funded by

FOM

Funded %

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

Start of the project

2013

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

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

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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. Exploration of the coupling with finite size particles (with and/or without internal dynamics).

PROGRESS

1. Study the thermal fluctuating effect on nano-ligament break up with fluctuating multicomponent ligament.
2. Implement wettability for the wetted finite-size particle settling at the non-fluctuating interface
3. Optimized finite-size particle in turbulence simulations and it about twenty times faster than non-optimized one.

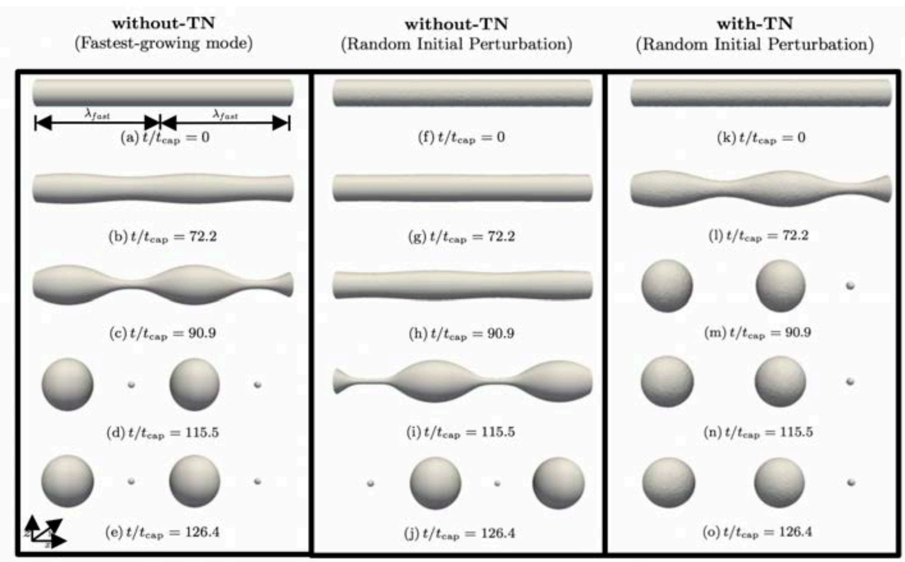
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Influence of the thermal noise (TN) on the speed-up of the ligament break-up process. On the left panel, ligament breaks up under Plateau-Rayleigh instability via the dominance of the fastest growing mode. After the break-up, we observe that the volumes of the two large droplets are equal to each other, the same happens for the satellite droplets. Middle panel ("without-TN" protocol): random initial condition followed by Lattice Boltzmann (LB) deterministic evolution. Droplets start to disperse under initial random disturbance. Right panel ("with-TN" protocol): random initial condition followed by evolution with fluctuating hydrodynamics evolution with thermal noise. In the latter case the ligament breaks up even faster than the fastest growing mode and droplets become even more disperse.



Mesoscopic transport phenomena

Prof.dr.ir. AA Darhuber

Research in the area of micro- and nano-fluidics comprises both fundamental and application-inspired topics ranging from fluid physics at nano-scales to manufacturing processes of optoelectronic devices. Current and commencing projects concern dip- and die-coating of chemically patterned substrates, flows driven by temperature and concentration gradients, dewetting, laser-induced flows, as well as flows involving phase changes.

Additional research activities concern the fluid physics and technology of vortex tubes as well as flow laminarization and particle interactions in magnetic density separation.

PROJECT AIM

The aim of the project is to understand and control the absorption and imbibition of suspensions (example: inkjet ink) in porous media, such as paper. For this, we will develop a realistic mesoscale model base on the lattice Boltzmann method.

PROGRESS

At first, we investigated the dynamics of an evaporating suspension droplet sitting on a chemically patterned substrate. We reproduced the so-called “coffee stain effect”. At second, we studied the adsorption of liquid in a capillary and reproduced the standard Washburn prediction. Currently, we investigate the impact of suspended particles on the imbibition.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

J Harting, AA Darhuber, S Luding

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

G Venditti, J Harting, AA Darhuber, S Luding

COOPERATIONS

Océ

FUNDED BY

NWO/STW

FUNDED %

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

START OF THE PROJECT

2016

INFORMATION

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True Solvent Free: Towards the next generation waterborne coatings

Project leaders
J. Harting
Research theme
Complex dynamics of fluids
Participants
M.P.J. Wouters, Jens Harting, H.P. Huinink, S.J.F. Erich, O.C.G. Adan, P. Venema, J. Keddie, B. Voogt
Cooperations
-
Funded by
DSM Coating Resins, AkzoNobel, Océ, Drywood, TNO, NVVT, SHR
Funded %

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

Start of the project
2014
Information
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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 currently being parallelized. This will allow us to reach timescales relevant for the formation of polymer films during solvent evaporation. Furthermore, simulations have been performed on dense suspensions (up to 70% volume fraction) of soft capsules under shear to study the dependency of the bulk viscosity for different parameters such as the packing fraction and the stiffness of the capsule membrane.

Dissertations

-

Scientific Publications

-

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. Currently a small scale windtunnel has been designed and built. Measurements are started up since Jamuary 2018 using Laser Doppler Anemometry (LDA) to study the decay of turbulence behind honeycombs. This information is relevant for the operation of MDS machines.

Dissertations

-

Scientific Publications

-

Project leaders

J.C.H. Zeegers, J.G.M. Kuerten, A.A. Darhuber

Research theme

Complex dynamics of fluids

Participants

R. Dellaert, S. Tajfirooz, J. van der Veen and Project leaders

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 LEADERS
J.C.H. Zeegers, J.G.M. Kuerten, A.A. Darhuber
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
R. Dellaert, S. Tajfirooz, J. van der Veen and Project leaders
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) 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. Currently a master student is professionalizing the measurement method. Furthermore he has started to measure detailed particle tracking with spheres and use numerical methods to validate the experiments.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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 in the presence or absence of electrolytes.

Also the possible presence of trapped bubbles and the possible occurrence of stable liquid bridges that resist removal will be considered.

Progress

Experiments concerning dewetting of thin liquid films sandwiched between a soft substrate and a patterned soft substrate have been performed in collaboration with INM. Dynamical features of dewetting of thin liquid films between unpatterned soft substrates have been studied systematically.

Dissertations

-

Scientific Publications

-

Project leaders
Prof. Dr. A.A. Darhuber
Prof. Dr. Jacco Snoeijer

Research theme
Complex dynamics of fluids

Participants
Maciej Chudak, Jacco Snoeijer, Anton 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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Spreading and imbibition of water-based printing inks in porous media -- experiments

Project leaders
Prof. Dr. A.A. Darhuber,
Dr. J.C.H. Zeegers

Research theme
Complex dynamics of fluids

Participants
Vignesh Murali, A.A. Darhuber,
J.C.H. Zeegers

Cooperations
Dr. N. Tomozeiu (Océ)
Prof. Dr. H. Wijshoff (Océ)
Prof. Dr. J. Harting
Prof. Dr. 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 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

A setup for measuring the water imbibition dynamics with 2D resolution has been designed and constructed. First measurements were promising. A literature study of the dynamics of imbibition, evaporation and heat transfer in paper has been conducted.

Dissertations

-

Scientific Publications

-

Active control of solution processing of organic electronic devices

Project Aim

This project aims at generating insight into and implementing control of evaporative deposition processes in the context of organic electronics manufacturing. Quantitative experiments and computer simulation will be combined to develop a validated process simulation tool. This tool will be used to develop and test strategies for the active control of the deposition process and the elimination of layer non-uniformities. Control strategies include for instance laser induced non-uniform temperature distributions.

Progress

Both PhD students finalized publications as well as prepared and defended their PhD theses.

Dissertations

1. H. M. J. M. Wedershoven, Active control of solution deposition processes, PhD thesis, defended on 6 December 2017 at the Eindhoven University of Technology.
2. Q. Xie, Active control of colloidal assembly and patterning at interfaces, PhD thesis, defended on 14 December 2017 at the Eindhoven University of Technology.

Scientific Publications

1. B.J. Brasjen, H.M.J.M. Wedershoven, A.W. van Cuijk, and A.A. Darhuber, Dip- and die-coating of hydrophilic squares on flat, hydrophobic substrates, Chem. Eng. Sci. 158, 340-348 (2017).
2. H. M. J. M. Wedershoven, K. R. M. Deuss, C. Fantin, J. C. H. Zeegers, and A. A. Darhuber, Active control of evaporative solution deposition by means of modulated gas phase convection, Int. J. Heat Mass Transfer 117, 303-312 (2018).
3. J. Muller, H. M. J. M. Wedershoven, and A. A. Darhuber, Monitoring Photochemical Reactions Using Marangoni Flows, Langmuir 33, 3647-3658 (2017).
4. D. Hessling, Q. Xie and J. Harting, Diffusion dominated evaporation in multicomponent lattice Boltzmann simulations, J. Chem. Phys. 146, 054111 (2017).

Project leaders

Prof. Dr. A. A. Darhuber
Prof. Dr. Jens Harting
Dr. J.C.H.Zeegers

Research theme

Complex dynamics of fluids

Participants

Qingguang Xie, Ber Wedershoven, Jos Zeegers, Jens Harting, Anton Darhuber

Cooperations

Holst Centre/TNO

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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Active control of solution processing of organic electronic devices

Project leaders
J Harting, AA Darhuber, JCH Zeegers
Research theme
Complex dynamics of fluids
Participants
Q Xie, B Wedershoven, J Zeegers, AA Darhuber, J Harting
Cooperations
-
Funded by
NWO/STW
Funded %

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

Start of the project
2014
Information
Qingguang Xie
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Project Aim

This project aims at the development of a validated process simulation tool. This tool will be used to develop and test strategies for the active control of the deposition process and the elimination of layer non-uniformities.

Progress

1. Studied the effect of friction between the particles and substrate on the deposition in drying colloidal suspension droplets. We observed a transition from a dot-like to a ring-like deposit with increasing friction force. We proposed a theoretical model for the effective radius of the deposit as a function of the friction force and found a good agreement with the simulation results.

2. Finalized the PhD thesis.

Dissertations

1. Qingguang Xie. Active control of colloidal assembly and patterning at interfaces. Eindhoven: Technische Universiteit Eindhoven. Promotor/ Co-Promotor.: Jens Harting / Anton Darhuber) (2017).

Scientific Publications

1. Dennis Hessling. Qingguang Xie & Jens Harting. Diffusion dominated evaporation in multicomponent lattice Boltzmann simulations. Journal of Chemical Physics, 146:054111 (2017).
2. Qingguang Xie, Gary B. Davies & Jens Harting. Direct Assembly of Magnetic Janus Particles at a Droplet Interface. ACS Nano, 11, 11232-11239 (2017).

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 stabilisation of inorganic crystal hydrates in order to:

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

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

Progress

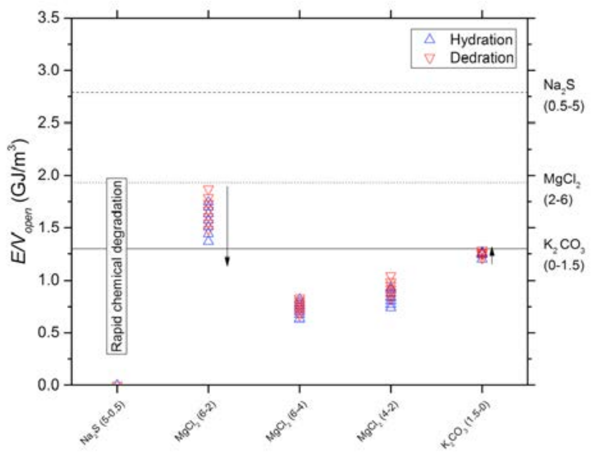
In-depth characterisation and study of chemical stability of thermochemical materials: K2CO3, MgCl2 and Na2S, this was published subsequently in Applied Energy, 215, 159-173 (2018).

Dissertations

-

Scientific Publications

1. Donkers, P.A.J., Sögütoglu, L.C., Huinink, H.P., Fischer, H. & Adan, O.C.G. (2017). A review of salt hydrates for seasonal heat storage in domestic applications. Applied Energy, 199(C), 45-68. In Scopus Cited 8 times.



Project leaders

H.P Huinink

Research theme

Complex dynamics of fluids

Participants

-

Cooperations

TNO, DOW, CALDIC

Funded by

-

Funded %

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

Start of the project

-

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Project leaders
H.P. Huinink, O.C.G. Adan
Research theme
Complex dynamics of fluids
Participants
C.J. Kuijpers
Cooperations
M2i, Océ Technologies BV
Funded by
M2i
Funded %

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

Start of the project
2013
Information
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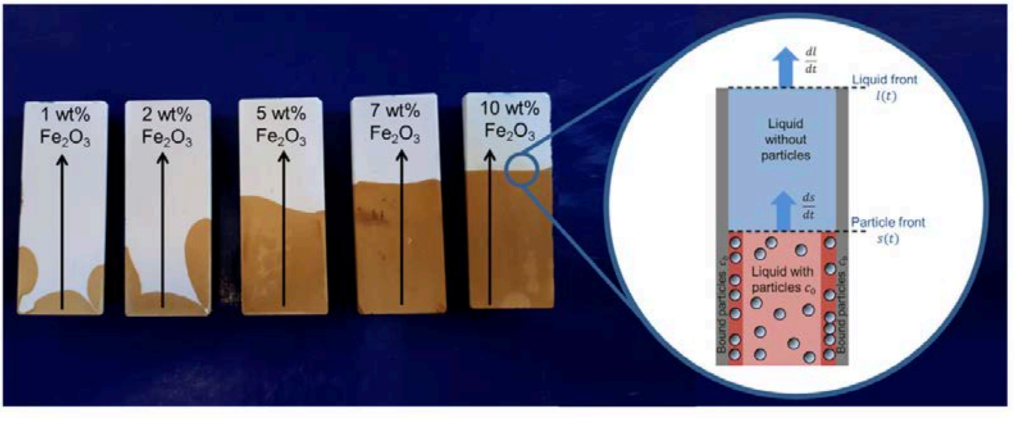
Project Aim
With current health and safety regulations, the reduction of the volatile components in printer ink is an ongoing challenge. Water based inks are therefore increasingly used. These inks contain, amongst other things, water, co-solvent and pigment. The pigment, which results in the visual image, is minimized to reduce costs and obtain a more eco-friendly ink. The project aim is to develop a mathematical model that quantitatively describes particle penetration into paper. We aim to predict the penetration depth of the pigment, and find the determining parameters. Ink can then be optimized in order to contain a lower pigment concentration.

Progress
We have studied the movement of nano-particles during liquid penetration in porous Al2IO3. The average particle size (62nm) is similar to pigment particles in a inkjet ink and as a result can serve as a model for the pigment particles. We have found a dependency on the pore size of the porous material as well as a dependency on the initial concentration of the penetrating liquid. A theoretical model is described to predict the particle retention and predicted limiting cases are verified experimentally. Furthermore, we have verified the scaling of Darcy's law on length and time scales relevant to the printing industry using ASA measurements and found good agreement.

Dissertations
-

Scientific Publications
1. C.J. Kuijpers, H.P. Huinink, N. Tomozeiu, S.J.F. Erich, O.C.G. Adan, Sorption of water-glycerol mixtures in porous Al2O3 studied with NMR imaging, Chem. Eng. Sci., Vol. 193, pp. 218-229, 2017.



Project Aim

To understand the transport mechanism of liquid moisture/vapor in monolithic refractories during first heat up (up to 400^{o}C). It is in this range of temperatures that steam pressure can build up and cause the material to spall (i.e. explode). The target materials of interest are: conventional castables (CC), low-cement castables (LCC) and other materials with a low (or zero) cement content. Experiments that simultaneously measure the temperature and moisture content are carried out and used to validate the conceptual model.

Progress

The high-temperature Nuclear Magnetic Resonance (NMR) experimental setup is functioning and results have been generated (and in continuation) for the first-heating up of CCs and LCCs. These results have been achieved for heating rates around 3^{o}C/min., with a sample surface temperature of 350^{o}C and thermal gradient in the range of 100+^{o}C across the whole sample. The experiments have been carried out for samples with different curing times: (1) 24 hours and (2) 48-72 hours. What can be concluded so far is that the drying behavior is very sensitive to the curing time. Currently we are experimenting with LCCs, which so far display long drying timess (factor of 2-3) compared with CCs, as well as containing a lot more free water in the pores.

Dissertations

-

Scientific Publications

1. “Direct Observation of the Moisture Distribution in Drying Refractory Concretes, by NMR”, A. Barakat, L. Pel, O.C.G. Adan, 5th International Workshop on Concrete Spalling due to Fire Exposure, October 12-13, 2017 (published in proceedings).
2. “Direct Insight into Drying of Low-Cement Castables, by NMR”, A. Barakat, L. Pel, O.C.G. Adan, 60th International Colloquium on Refractories, October 18-19, 2017 (published in proceedings).

Project leaders
L. Pel

Research theme
Complex dynamics of fluids

Participants
TU/e, M2i

Cooperations
Tata Steel, Almatis, Kerneos

Funded by
-

Funded %

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

Start of the project
2013

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Project leaders
L. Pel, O.C. Adan

Research theme
Complex dynamics of fluids

Participants
-

Cooperations
-

Funded by
STW

Funded %

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

Start of the project
2016

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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
- The wick action experiment has been done for glass beads with different particle sizes in order to compare the model and experimental 0result in more homogenous pore structure.

- Chloride binding during hydration of cement has been measured by NMR and resistivity sensor.

Dissertations
-

Scientific Publications
1. A simplified model for the combined wicking and evaporation of NaCl solution in limestone; Journal of Materials and Structures – submitted 12/2017.
2. Wick action in porous building materials as studied by NMR; Materials, Systems and Structures in Civil Engineering - August 2016. (conference proceeding).
3. NMR study of chloride transport in concrete during Wick action; The Fifth International Symposium on Life -Cycle Civil Engineering, IALCCE2016 (conference proceeding).

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

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.

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. Varying the relative humidity, and therefore the drying rate, showed interesting effects on the relaxation behavior of the water and polymer phases in the latex dispersions. Polymer mobility as a function of water availability in coating materials were studied and related to the glass transition temperatures. Profile analysis tensiometry is used to study surface phenomena on drying drops of the afore-mentioned latex dispersions. Clear changes in the mechanical properties of the drop surface are visible during drying, which is affected by the drying rate of the latex drop.

Dissertations

-

Scientific Publications

-

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, Drywood, AkzoNobel, TNO, NVVT, SHR, Océ

Funded by
TTW/NWO

Funded %

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

Start of the project
2014

Information
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Elementary Processes in Gas Discharges

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 en 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., Nobelen, J. C. P. Y. & Nijdam, S., A self-consistent model of ionic wind generation by negative corona discharges in air with experimental validation, Plasma Sources Science and Technology. 26, 9, 16 p., 095005, 2017.

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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Project leaders
S. Nijdam, J. van Dijk, G.M.W. Kroesen
Research theme
Complex dynamics of fluids
Participants
L.C.J. Heijmans
Cooperations
Together with WDY-group, TU/e. F. Toschi and H.J.H. Clercx with PhD student
Funded by
STW, ASML
Funded %

University	-
FOM	-
STW	62 %
NWO Other	-
Industry	38 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2013
Information
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Project Aim

In EUV lithography tools free floating particles are a cause for concern as they can land on the reticle (mask) where they should be avoided at any cost. However, on any surface inside such a machine there will be dust particles present which can be released by flow and/or plasma conditions. We want to study when and how particles are released from surfaces by (interaction of) flow and plasma under the conditions present in an Extreme-Ultraviolet (EUV) lithography tool and how plasma conditions can directly damage (collector) mirror surfaces in such a tool.

Progress

Two setups have been built. Both of these are used to first measure the adhesion between small spherical particles (100 μm) and a surface and then the effect of an RF plasma. This is done by applying an external force. One setup uses a vibrating piezo element and the other a centrifuge. Furthermore, we have seen an effect due to the plasma in both setups. The plasma effect differs significantly between differently manufactured, but otherwise similar particles. We have demonstrated that the plasma force is not an electric effect. For this, we have measured the charge on the particles, which showed that the electric force is negligible compared to other effects.

Dissertations

1. Heijmans, L. C. J., Quantifying plasma particle lofting, Technische Universiteit Eindhoven, 13-2-2017.

Scientific Publications

1. Heijmans, L. C. J., Neelis, T. W. C., van Leuken, D. P. J., Bouchut, A. & Nijdam, S., Plasma forces on microparticles on a surface: an experimental investigation, Plasma Sources Science and Technology. 26, 7, 12 p., 075010 (2017).

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

-

SCIENTIFIC PUBLICATIONS

1. van der Schans, M., Böhm, P., Teunissen, H. J., Nijdam, S., IJzerman, W. L. & Czarnetzki, U., Electric field measurements on plasma bullets in N2 using four-wave mixing, Plasma Sources Science and Technology. 26, 11, 15 p., 115006 (2017).

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

The large uncertainty of the vibrational-vibrational reaction kinetics that are crucial for the understanding of the CO2 dissociation is addressed. A method is setup to determine the vibrational reaction kinetics based on sampling several molecular collisions. For this purpose a potential energy surface (PES) is constructed for the internal and external interactions of the CO2 molecules. This PES is used in combination with the program VENUS96 to sample collisions efficiently. The first cross sections related to vibrational-vibrational and vibrational-translational processes are calculated.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Jesper Janssen, Jan van Dijk and Jos Suijker. On the calculation of vibrational-vibrational rates of CO2, 70th Annual Gaseous Electronics Conference (GEC), Pittsburgh, Pennsylvania, Monday–Friday, November 6–10, 2017.

Efficient Electrical to Chemical Energy Conversion vis Synergy Effects in Plasma- and Catalytic Technology

Project Aim

Transformation of CO_2 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 CO_2 and H_2O to CH_4 by advanced microwave plasma source design, diagnostics, modeling, and catalytic follow up chemistry. Dissociation of CO_2 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 H_2O to CO_2 dissociation in microwave plasma.

Progress

The large uncertainty of the vibrational-vibrational reaction kinetics that are crucial for the understanding of the CO_2 dissociation is addressed. A method is setup to determine the vibrational reaction kinetics based on sampling several molecular collisions. For this purpose a potential energy surface (PES) is constructed for the internal and external interactions of the CO_2 molecules. This PES is used in combination with the program VENUS96 to sample collisions efficiently. The first cross sections related to vibrational-vibrational and vibrational-translational processes are calculated.

Dissertations

-

Scientific Publications

1. Jesper Janssen, Jan van Dijk and Jos Suijker. On the calculation of vibrational-vibrational rates of CO_2, 70th Annual Gaseous Electronics Conference (GEC), Pittsburgh, Pennsylvania, Monday–Friday, November 6–10, 2017.

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

ir. P. M. J. (Peter) Koelman
dr. ir. J. F. J. (Jesper) Janssen
ir. S. Tadayon Mousavi

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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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
dr. ir. J. F. J. (Jesper) Janssen

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

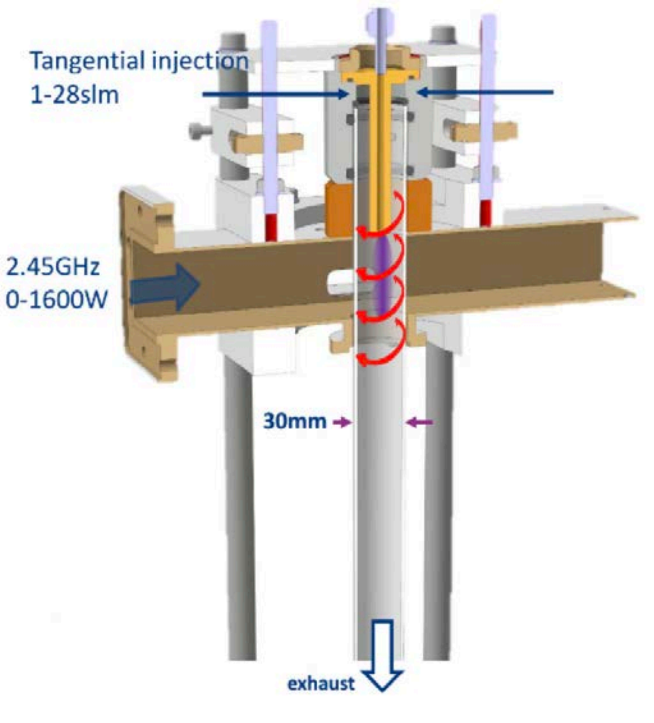
In order to achieve the goal of the project, we need a thorough understanding of the H2O chemistry. Therefore, we made, verified, and validated a global model for H2O-He mixture. The validation is done not only with available literature but also with electron density measurements. The measurement is done by our colleagues at DIFFER for the microwave reactor that is depicted in the figure below. The microwave interferometry diagnostic is used to measure the electron density.

Dissertations

-

Scientific Publications

-



Fuel feedstock production by a combined approach of controlled plasma conversion and membrane separation

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

With Principal Component Analysis (PCA) a coordinate transformation can be made of the chemical components in the model. This transformation allows to choose a new basis in which the first eigenvectors represent the axis at which the variation is the biggest. This allows to do reduced calculations, with only 2 eigenvectors instead of 73. Besides that we have shown that pathway analysis can be used to identify essential reactions for the uncertainty analysis of parameters in the model. This allows to reduce the analysis time significantly, without paying for the accuracy of the analysis.

Dissertations

-

Scientific Publications

-

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

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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

Traditional methods for heat recovery from underground geothermal reservoirs employ a static system of injector-producer wells leading to inefficient distribution of production fluid throughout the reservoir domain resulting in suboptimal performance. Recent studies in literature have shown that using a well-devised pumping scheme designed on the basis of chaos theory, through actuation of multiple injector-producer wells, can enhance performance of geothermal reservoirs. However, the effect of reservoir anisotropy and heterogeneity is unknown and has to be incorporated and studied for practical deployment in the field.

Progress

Activities to date primarily concentrated on numerically investigating the effect of homogenous anisotropic permeability (both magnitude and direction) on chaotic advection of passive tracers in a time-periodic Darcy flow within a 2D circular domain driven by periodically reoriented diametrically opposite source-sink pairs (2D RPM flow). Numerically computed Poincaré sections indicate that symmetries are key organizing mechanisms in the Poincaré sections and thus vital to fluid distribution and the “route to chaos”. Symmetries impose order and coherence upon the Lagrangian dynamics and thus play an essential role in the entrapment of production fluid in isotropic media (Fig. a). Anisotropy in general breaks the above symmetries and thus tend to promote disorder and chaotic advection (Fig. b). We are further investigating heat transfer in RPM flows to help quantify the performance and to determine its relation to the Lagrangian distribution of production fluid.

Dissertations

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Scientific Publications

1. Varghese, S., Speetjens, M.F.M. & Trieling, R.R. (2017). Lagrangian Transport and Chaotic Advection in Two-Dimensional Anisotropic Systems. Transport in Porous Media, 119(1), 225-246.

Project leaders
MFM Speetjens

Research theme
Complex dynamics of fluids

Participants
MFM Speetjens (TU/e-ET; co-promotor), RR Trieling (TU/e-WDY; co-promotor), F Toschi (TU/e-WDY; promotor)

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

Funded by
FOM (CSER programme)

Funded %

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

Start of the project
2014

Information

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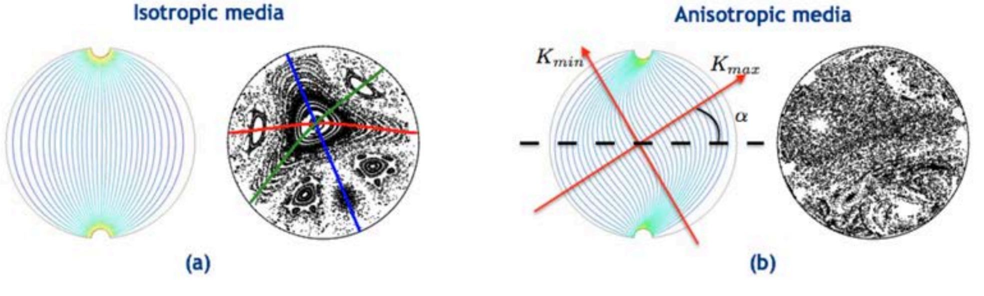

Comparison of velocity streamlines (left) and corresponding Poincaré sections along with symmetry curves (right) employing an 8-well configuration operating in (a) isotropic and (b) anisotropic porous media.

Frontier of transport phenomena in fluid flows: Three-dimensional chaotic advection

Project leaders
MFM Speetjens

Research theme
Complex dynamics of fluids

Participants
PS Contreras (PhD candidate)
MFM Speetjens (TU/e-ET; co-advisor)
HJH Clercx (TU/e-WDY; advisor)
DMJ Smeulders (TU/e-ET; 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: the 3D lid-driven cylinder flow and the buoyancy-driven flow in a differentially-heated cavity.

Progress

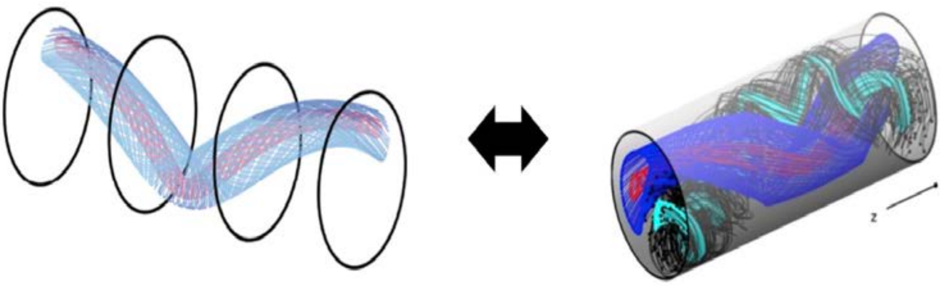
The results of the analysis of the buoyancy-driven flow were published. The research was also presented at the 2017 APS-DFD meeting (Denver, Colorado, USA) and SIAM DS 17 (Snowbird, Utah, USA). Moreover, analyses of the experimental time-periodic lid-driven cylinder flow have started. The results validate the formation of the main flow structures associated with resonance-induced merger (RIM). A journal publication of these results is currently in preparation.

Dissertations

-

Scientific Publications

1. P. S. Contreras, M. F. M. Speetjens & H. J. H. Clercx. 2017 Lagrangian transport in a class of three-dimensional buoyancy-driven flows. Journal of Fluid Mechanics, 832, 5-40.



Molecular modeling of sugar alcohols as seasonal heat storage materials

Project Aim

Sugar alcohols (SA) and their eutectic mixtures are promising seasonal heat storage medium. These materials are environmentally friendly, low cost, and high in storage capacity. Because of the large subcooling effect, SA can remain in liquid state thus enabling low loss storage. Nevertheless, the low nucleation and crystallization kinetics and the low heat conduction rate results in poorly controlled discharge power and introduces difficulties in large scale industrial applications. Using molecular modeling methods, we can tackle the details during the nucleation process and nanoscale heat transfer mechanism, depict the free energy landscape, and propose possible solutions to increase the nucleation and heat transfer kinetics.

Progress

Wtithin this project sugar alcohols are studied using nanoscale modeling methods and a few models beyond the nanoscale. The thermodynamic properties of sugar alcohols are studied by laboratory measurements and molecular dynamics simulations. The validity and performance of a few selected molecular models are investigated. The generalized AMBER force field is found to have the best performance. The transport properties are also studied by means of non-equilibrium simulations. Next the method to improve the heat conductivity of sugar alcohols by carbon nano-structures are presented. Here, two nanoscale heat transfer mechanisms, namely the “out-of-plane” carbon-to-liquid heat transfer and the “cross-plane” liquid-to-liquid heat transfer are distinguished. They are different in nature. A relationship between carbon nanotube’s diameter and cross-plane heat transfer coefficient is established and is found to be related to the phonon mode mismatch. Besides, the nucleation and crystal growth of sugar alcohols are studied. A novel method based on transition state sampling is developed to quantify the anisotropic solid-liquid interfacial free energy. In a lattice scale model, a kinetic Monte Carlo method is introduced to study the crystal growth of sugar alcohols. The results are backed by microscope measurements.

Dissertations

1. Zhang, H.. / On sugar alcohol based heat storage materials : a nanoscale study and beyond. Eindhoven : Technische Universiteit Eindhoven, 2017. 163 p.

Scientific Publications

1. Zhang, H., Duquesne, M., Godin, A., Niedermaier, S., Palomo del Barrio, E., Gaastra - Nedea, S. V., & Rindt, C. C. M. (2017). Experimental and in silico characterization of xylitol as seasonal heat storage material. DOI: 10.1016/j.fluid.2016.12.020.

Project leaders

David M.J. Smeulders, Silvia V. Nedea, Camilo C.M. Rindt

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Huaichen Zhang

Cooperations

-

Funded by

European Community‘s seventh Framework Program FP7/2007-2013; European Union’s Horizon 2020

Funded %

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

Start of the project

2012

Information

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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
Mohammadreza Gaeini
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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

1. Gaeini, M. (2017). Thermochemical seasonal heat storage for the built environment: a multi-scale investigation Eindhoven: Technische Universiteit Eindhoven.

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. 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. 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. DOI: 10.1016/j.est.2018.02.014.
4. Beving, M. A. J. M., van Alebeek, R., Scapino, L., Gaeini, M., Rindt, C. C. M., & Zondag, H. A. (Accepted/In press). Investigation of a household-scale open sorption energy storage system based on the Zeolite 13X/water reacting pair. DOI: 10.1016/j.applthermaleng.2018.04.092.
5. Gaeini, M., Wind, R., Donkers, P. A. J., Zondag, H. A., & Rindt, C. C. M. (2017). Development of a validated 2D model for flow, moisture and heat transport in a packed bed reactor using MRI experiment and a lab-scale reactor setup. DOI: 10.1016/j.ijheatmasstransfer.2017.06.034.
6. Gaeini, M., Javed, M. R., Ouwerkerk, H., Zondag, H. A., & Rindt, C. C. M. (2017). Realization of a 4kW thermochemical segmented reactor in household scale for seasonal heat storage. DOI: 10.1016/j.egypro.2017.09.491.

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. In this study simulations on single grains and eventually packed-bed reactors are performed and the hydration and dehydration reactions are studied to enhance knowledge on the effective energy density within a reactor. 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 will be linked to a CFD model simulating heat and vapor transport within the reactor. Supporting TGA DSC experiments on pure and encapsulated K2CO3 are being carried out.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. Beving, M. A. J. M., van Alebeek, R., Scapino, L., Gaeini, M., Rindt, C. C. M., & Zondag, H. A. (Accepted/In press). Investigation of a household-scale open sorption energy storage system based on the Zeolite 13X/water reacting pair. DOI: 10.1016/j.applthermaleng.2018.04.092.

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

Max 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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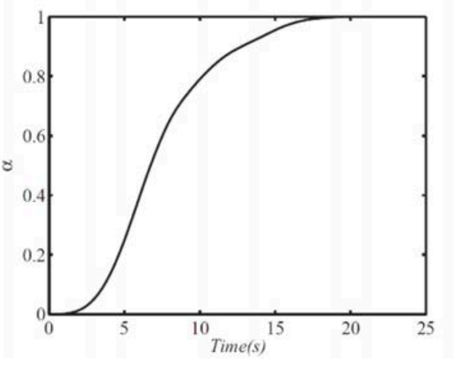
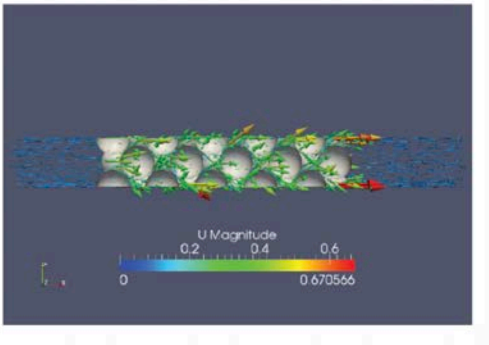


Fractional conversion of a salt hydrate averaged over 100 grains.



CFD model of packed bed reactor displaying velocity.

Project leaders
AJH Frijns

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
S.V. Nedea, M. Wolff, D.M.J. Smeulders, I Graur (AMU, F), P. Perrier (AMU, F), J. Stafford (Bell Labs, IR)

Cooperations
MIGRATE, ASML, Nokia Bell Labs, Aix

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

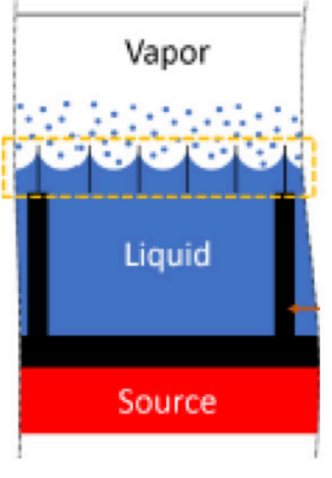
Molecular dynamics simulations of heat transfer in gases are computationally expensive when the wall molecules are explicitly modeled. To save computational time, an implicit boundary function is often used. In this work, the conceptual idea of Steele's potential was extended in order to simulate water-silicon and water-silica interfaces. A new wall potential model is developed by using the electronegativity-equalization method (EEM), a ReaxFF empirical force field and a non-reactive molecular dynamics package PumMa. Contact angle simulations were performed in order to validate the wall potential model. The MD results are in agreement with experimental values. The model is applied to evaporative microchannel cooling.

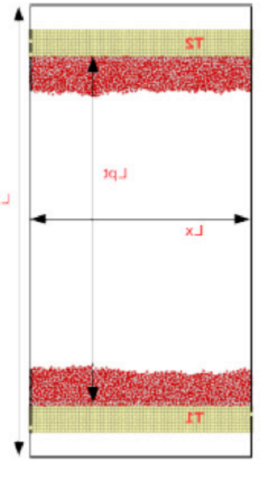
Dissertations

-

Scientific Publications

1. Wolf, M. C. W., Frijns, A. J. H., Nedea, S. V. & Enright, R. (2017) Molecular water layer evaporation & condensation Proceedings of the 2nd MIGRATE Workshop. Sofia, Bulgaria, blz. 47-48 MIGRATE2017:154795.





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 determine 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

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Scientific Publications

1. Sharma, M. K., Frijns, A. J. H., Mandamparambil, R., Kooman, J. P., & Smeulders, D. M. J. (2017). Ion-selective optical sensor for continuous on-line monitoring of dialysate sodium during dialysis. In I. Gannot (Ed.), Optical Fibers and Sensors for Medical Diagnostics and Treatment Applications XVII, 28 january 2017, San Francisco, California [1005804] (Proceedings of SPIE; Vol. 10058). DOI: 10.1117/12.2251923.

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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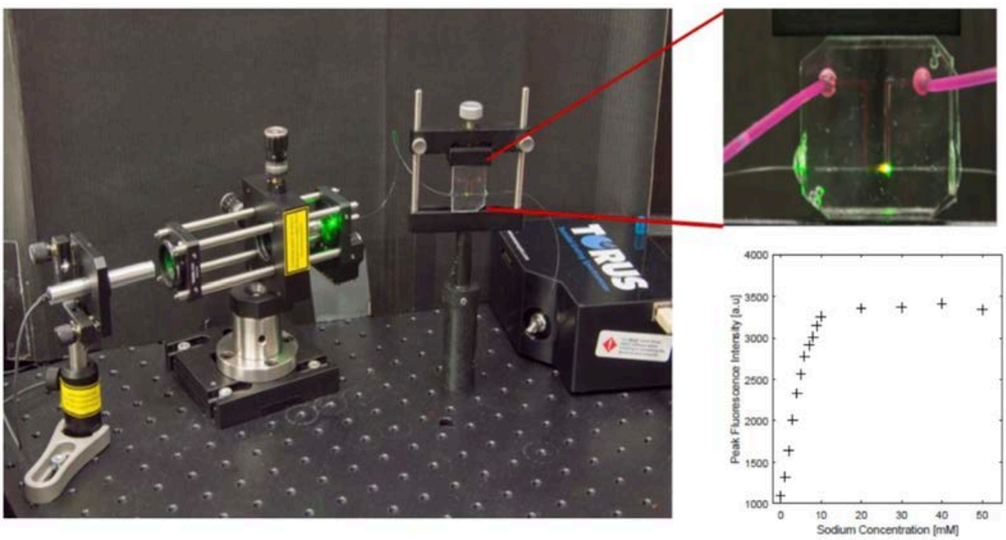

PROJECT LEADERS
AJH Frijns
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
S Veselá, BRM Kingma, H Pallubinsky, M te Kulve, L Schellen, L Schlangen, WD van Marken Lichtenbelt, DMJ Smeulders
COOPERATIONS
UM, MUMC+, Philips, TNO
FUNDED BY
RVO, STW, TU/e
FUNDED %

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

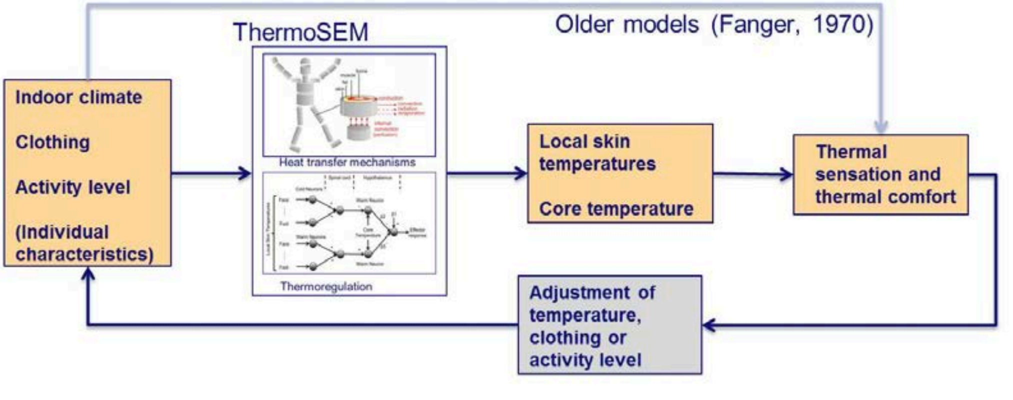
Recent research on local heating and cooling design show improvements in thermal comfort and energy consumption of office buildings. The impact of these measures on the occupants' local thermal sensation (LTS) the most important factors in the thermal modelling concept are studied and analysed using 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. Furthermore the effects on light intensities and light colour on thermal comfort is investigated.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Veselá, S., Kingma, B. R. M., & Frijns, A. J. H. (2017). Local thermal sensation modeling: a review on the necessity and availability of local clothing properties and local metabolic heat production. DOI: 10.1111/ina.12324.
2. te Kulve, M., Schlangen, L. J. M., Schellen, L., Frijns, A. J. H., & van Marken Lichtenbelt, W. (2017). The impact of morning light intensity and environmental temperature on body temperatures and alertness. DOI: 10.1016/j.physbeh.2017.03.043.



PROJECT AIM

Electronic devices will in the future be made more and more also as flexible system-in-foil (SIF) which can contain ultra-thin (15 – 50 micron) flexible embedded silicon chips. A challenge is given by the low thermal conductivity of the very thin polymeric package aggravating the heat management problem. The aim of this project to develop an integrated micro-fluidic cooling system.

PROGRESS

A new pulsating heat pipe (PHP) with integrated Tesla valves is successfully designed and tested. Its functionality and diodicity is tested by laminar single-phase modelling and by steady two-phase flow experiments. The valve is symmetrically integrated in a single-turn PHP, which reduces variabilities to give a more thorough understanding of the behavior in PHPs. Two transparent bottom-heated PHPs, one with and one without valves, are manufactured and the flow behavior and thermal performance is studied. The valves produced a diodicity which lead to a difference in velocity of 25% for the different flow directions. Furthermore, a decrease of 14% in thermal resistance was observed due to the addition of the Tesla valves.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. de Vries, S. F., Florea, D., Homburg, F. G. A., & Frijns, A. J. H. (2017). Design and operation of a Tesla-type valve for pulsating heat pipes. DOI: 10.1016/j.ijheatmasstransfer.2016.09.062.

PROJECT LEADERS
AJH Frijns

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
AA van Steenhoven, D. Florea, E. Homburg, JMJ den Toonder

COOPERATIONS
Philips, Holst Centre

FUNDED BY
STW

FUNDED %

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

START OF THE PROJECT
2011

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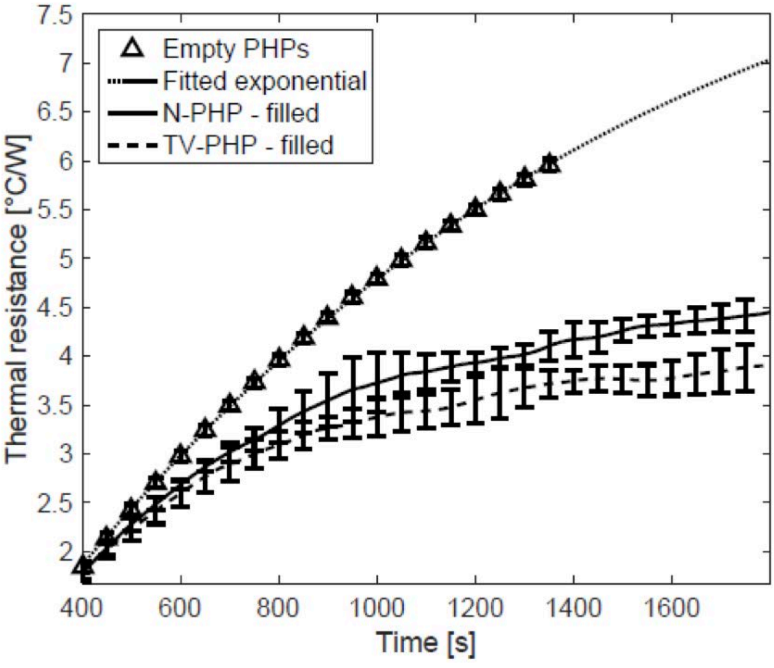

Image-based modeling of imbibition processes in porous media: application to inkjet printing

PROJECT LEADERS
prof.dr.ir. E. Harald van Brummelen

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
prof.dr.ir. H.M.A. (Herman) Wijshoff
dr.ir. Clemens Verhoosel
ir. Gertjan van Zwieten
Tuong Hoang
Frits de Prenter

COOPERATIONS
Majid Hassanizadeh, Department of Earth Sciences, Utrecht University

FUNDED BY
FOM, Océ, Darcy Center (TUE)

FUNDED %

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

START OF THE PROJECT
2016

INFORMATION
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Project Aim

Imbibition processes of ink in papers plays an important role in the performance of inkjet printing. Due to the difficulty in experimental visualizations, the pore-scale modeling has been widely used in the study of multiphase in porous media. In this project, we aim to develop an image-based pore-scale model of two-phase in porous media. The model will be used to understand the fundamentals of ink imbibition processes in a coating paper and a plain paper. To this end, the developed model should, in particular, possess the capabilities of the tracking of complex phase interfaces and three-phase contact lines.

Progress

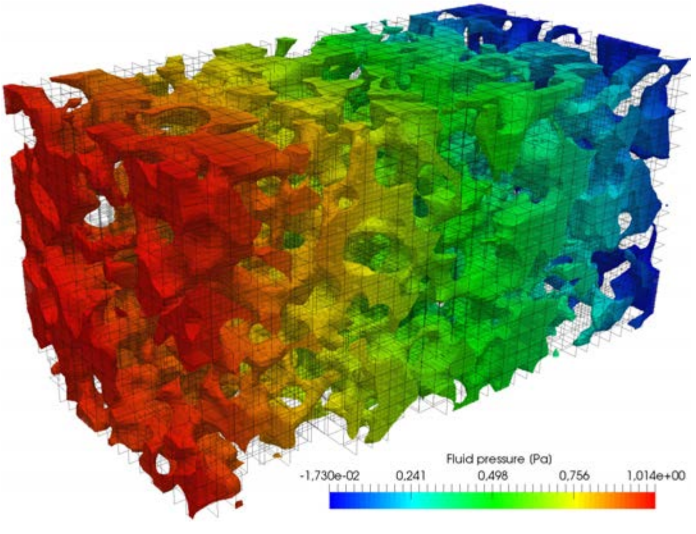
We tested two methods of segmentation of CT data of a sintered-glass-beads porous medium. One is the voxel representation of solid-void interfaces. The other is to smoothly represent the interfaces with a level set function. Sing-phase flow and reactive transport has been conducted to highlight the importance of proper representation of solid-void interfaces. It is also expected to play an important role in two-phase flow in porous media.

Dissertations

-

Scientific Publications

1. van Brummelen, E.H., Zhuk, S. & van Zwieten, G.J. (2017). Worst-case multi-objective error estimation and adaptivity. Computer Methods in Applied Mechanics and Engineering, 313, 723-743.
2. Zhuang, Luwen, Hassanizadeh, S. Majid, Qin, Chao Zhong & de Waal, Arjen (2017). Experimental investigation of hysteretic dynamic capillarity effect in unsaturated flow. Water Resources Research, 53(11), 9078-9088.
3. Hoang, T., Verhoosel, C.V., Auricchio, F., van Brummelen, E.H. & Reali, A. (2017). Mixed isogeometric finite cell methods for the Stokes problem. Computer Methods in Applied Mechanics and Engineering, 316, 400–423-400–423.



Isogeometric Finite Cell Methods for Fluid-Structure Interaction of Thin Embedded Structures

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. We have contributed to this field in the last two years by the development of dedicated preconditioners and aim to keep on making contributions to this field in the next two years.

Progress

* We have published a paper on the behavior of Nitsche's method on unfitted grids together with Christoph Lehrenfeld from the University of Göttingen and André Massing from the University of Umeå.

* We have generalized the preconditioning technique that was published in Computer Methods in Applied Mechanics & Engineering to a preconditioning technique for immersed finite element methods that is flexible with respect to both the basis and the PDE that is solved. A manuscript on this is submitted and is currently in the review process.

* Together with the group of Prof. Rank at the Technical University of Munich we have developed and implemented a preconditioner for immersed finite element methods with multi-level hp-discretizations. We are preparing a manuscript on this that will be submitted to a scientific journal in 2018.

* Frits de Prenter has visited the group of John Evans at the University of Colorado in Boulder where he has developed a multi-grid preconditioner for immersed finite element methods. We plan to write a manuscript on this that can be published in a scientific journal in 2018.

Dissertations

-

Scientific Publications

1. de Prenter, F., Verhoosel, C.V., van Zwieten, G.J. & van Brummelen, E.H. (2017). Condition number analysis and preconditioning of the finite cell method. Computer Methods in Applied Mechanics and Engineering, 316, 297-327.

Project leaders

Harald van Brummelen and Clemens Verhoosel

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Frits de Prenter

Cooperations

-

Funded by

NWO

Funded %

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

Start of the project

2015

Information

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Adaptive algorithms for multiscale model hierarchies of the Boltzmann equation

Project leaders
EH van Brummelen
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
Michael Abdelmalik
EH van Brummelen (HL)
Cooperations
M Torrilhon (RWTH Aachen)
Funded by
TUE
Funded %

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

Start of the project
2012
Information
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Project Aim

The aim of this project is to create a paradigm for adaptive multiscale models for the Boltzmann equation.

Progress

An a-posteriori goal-oriented error analysis for a numerical approximation of the steady Boltzmann equation. The numerical approximation of the Boltzmann equation is based on a moment sustem approximation in velocity dependence and a discontinuous Galerkin finite element (DGFE) approximation in position dependence. We derive computable error estimates and bounds for general target functionals of solutions of the steady Boltzmann equation based on the DGFE moment approximation. The a-posteriori error estimate and bounds are used to guide a model adaptive algorithm for optimal approximations of the goal functional in question.

Dissertations

-

Scientific Publications

1. Abdelmalik, M.R.A. & van Brummelen, E.H. (2017). Error estimation and adaptive moment hierarchies for goal-oriented approximations of the Boltzmann equation. Computer Methods in Applied Mechanics and Engineering, 325, 219-239.

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

Multiphase & reactive flows

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.

3PX: Three Power Crossover (Energy flows of the future)

Project leaders
B.F.W. Vermeltfoort, N.J. Dam
Research theme
Complex dynamics of fluids
Participants
L.P.H. de Goey
Cooperations
Liander B.V.
Funded by
Liander B.V.
Funded %

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

Start of the project
2013
Information
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Project Aim

In this project an innovative concept is studied to combine domestic heating, decentralized electricity generation and mobility. The goal of the project is to prove that this concept can lead to less CO2 emission, lower energy cost and more flexibility in the energy system, leading to a potential increase in renewable energy.

Progress

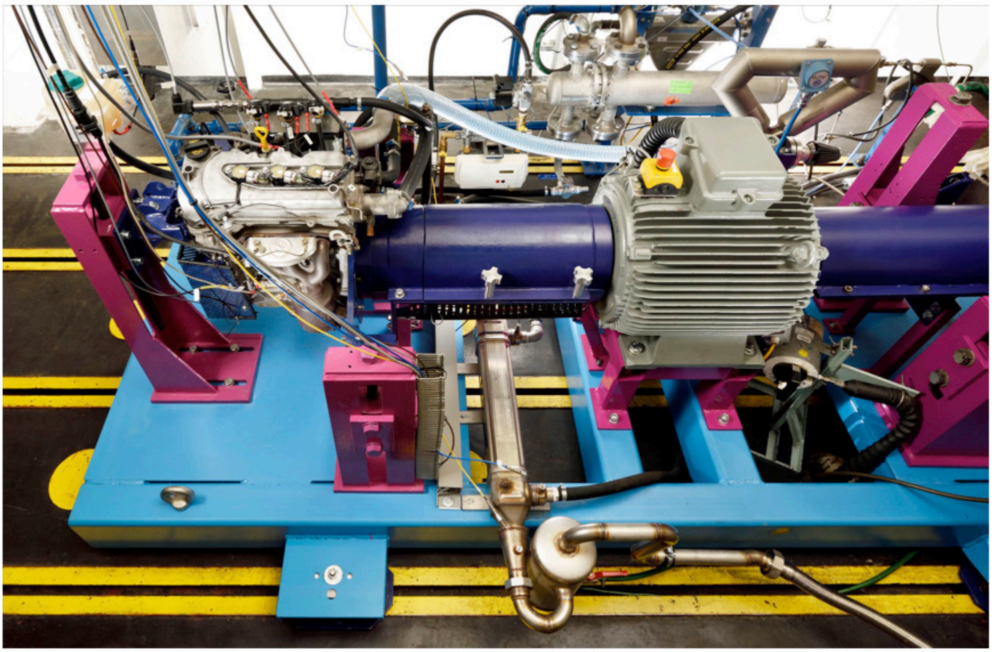
Simulations show that by utilizing a plug-in hybrid electric vehicle as a combined heat and power (CHP) plant, there is a big potential to decrease greenhouse gas emissions and energy costs with relatively low initial investment. In this concept the hybrid car will use natural gas as a fuel to provide the household with heat, electricity and mobility. It is therefore a "bridge" between the three biggest household energy needs. The extra flexibility that this concept delivers can potentially increase the availability of intermittent renewable energy sources. A proof-of-concept setup was build (see figure below) and it has proven the fundamentals of the concept, furthermore it gave valuable insight in possible future optimization. A prototype car based on a Nissan Leave was developed and built and the feasibility of the 3PX concept was proven. Heat consists of 65 % while electrical energy of 35 % of the energy produced.

Dissertations

1. Vermeltfoort. (2018). 3PX: Three Power Crossover. Eindhoven: Technische Universiteit Eindhoven.

Scientific Publications

-



PROJECT AIM

The aim of the project is to study the breakdown and reappearance of aromatics in vaporized liquid fuel diffusion 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

A code has been written to simulate Raman spectra of diatomic molecules and water. The simulated spectra are fitted to measurement data to extract temperature and composition information. Reference measurements of pure gases like H2, CO, CO2, are used for calibration in order to get absolute number densities of individual species. A spectral database of CO2 is created up to temperatures of 2000 K, based on measurements on a CO2-diluted H2 flame (Fig. 2). The Raman scattered signal of intermediate species like C2H2 and C2H4 is quantified using Placzek's double harmonic approximation. Non-premixed flames of methane, ethylene, propane, heptane, and heptane/toluene have been analyzed in terms of local flame temperature and composition. Intermediate single-ring aromatic molecules have not been identified. Numerical simulations of the methane, ethylene and propane flames have been compared with experimental results and show very good agreement.

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	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2015

INFORMATION

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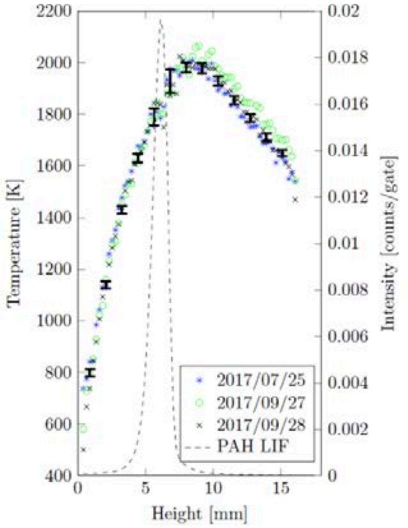
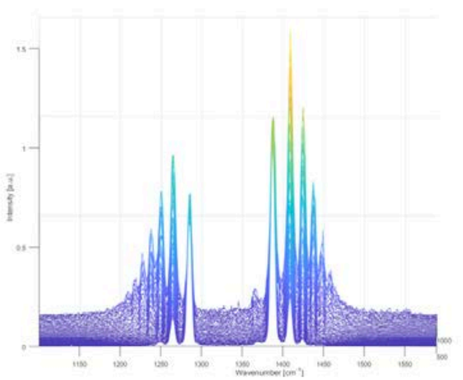
Methane flame center-line temperature profile, resulting from the N2 rovibrational spectrum.



CO2 Raman spectra, additional lines appear with increasing temperature (for T from 300-1400 K in this figure).



Tracking Joules: Flame-wall interaction in Diesel Spray Combustion

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.

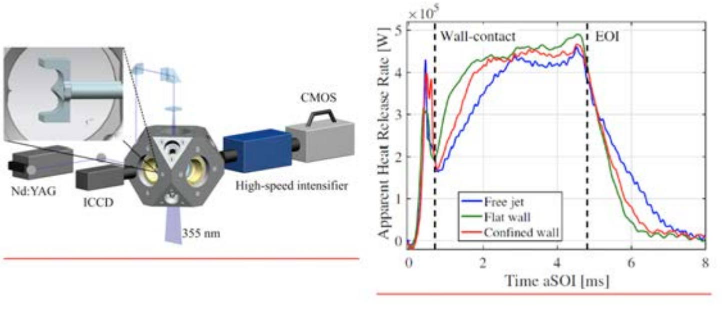
Dissertations

-

Scientific Publications

1. P.C. Bakker, N. Maes, N. Dam, “The potential of on-and off-resonant formaldehyde imaging combined with bootstrapping in diesel sprays,” Combust. Flame 182:20-27, 2017, doi: 10.1016/j.combustflame.2017.03.032.
2. N. Maes, P.C. Bakker, N. Dam, B. Somers, “Transient flame development in a constant-volume vessel using a split-scheme injection strategy,” SAE Int. J. Fuels Lubr. 10(2):318-327, 2017, doi:10.4271/2017-01-0815.
3. T. Lucchini, A. Della Torre, G. D’Errico, A. Onorati, N. Maes, L.M.T. Somers, G. Hardy, “A comprehensive methodology for computational fluid dynamics combustion modeling of industrial diesel engines,” International Journal of Engine Research 18 (1-2), 26-38, 2017, doi:10.1177/1468087416679570.

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.



Towards a HiEff engine

Project Aim

Focus is on Reactivity Controlled Compression Ignition (RCCI) engines with high thermal efficiency and low emissions compared to conventional Diesel combustion. In RCCI concept premixed fuel is introduced early within the cycle and as there is no spark plugs, direct control over combustion phasing is difficult. In order to control auto-ignition, two fuels with different chemical properties are supplied to the combustion chamber, which allows tailoring of the in-cylinder reactivity. By doing so, start of combustion can be adjusted. Within this project an extensive numerical and experimental research has been conducted to comprehensively measure, model, and control RCCI engines.

Progress

Major task is on code implementation, model development, and simulation of RCCI engines. Started from 15 May 2017 following milestones were reached: A) Compiling OpenFOAM and Lib-ICE in the TU/e cluster and enabling parallel processing. B) Implementing FGMflameletLibrary class into the OpenFOAM source code. C) Validation of implemented FGM class by ECN Spray A condition. D) Spray oriented grid generation for RCCI engines. Performed validation for non-reacting and reacting conditions of Spray A are represented in figure below.

Dissertations

-

Scientific Publications

-

Project leaders

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

Research theme

Complex dynamics of fluids

Participants

A.Maghbouli, R.C. Willems, N.G. Deen

Cooperations

DAF Trucks, TNO, Shell Global Solutions, Delphi Diesel Systems, Sensata, 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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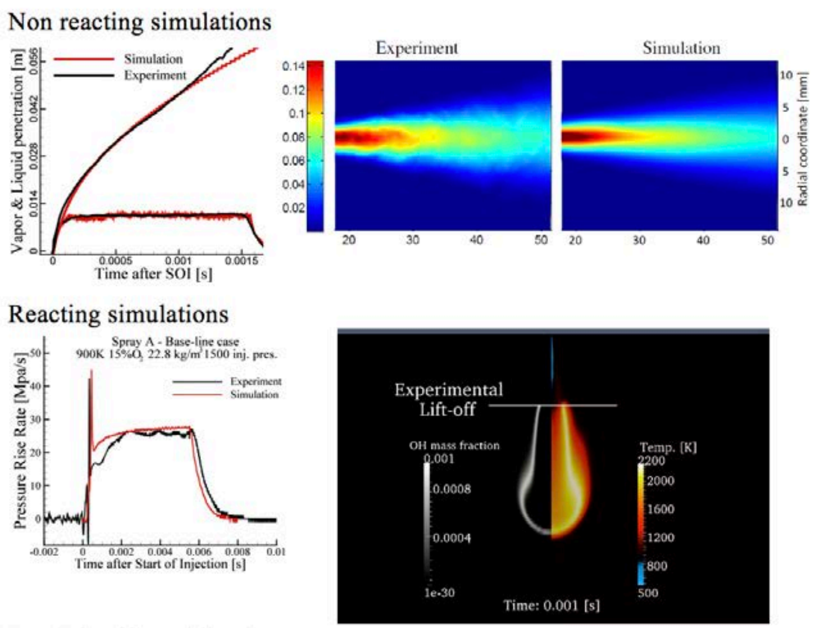

Fate of Forgotten Fuel

Project leaders
L.M.T. Somers, N.J. Dam, B.H. Johansson, N.G. Deen

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
H.Y. Akargün, P.C. Bakker

Cooperations
DAF Trucks, TNO, Delphi, Shell Global Solutions

Funded by
TTW
Shell Global Solutions

Funded %

University	-
FOM	-
STW	51 %
NWO Other	-
Industry	49 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2014

Information
H.Y. Akargun
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www.tue.nl/mrf

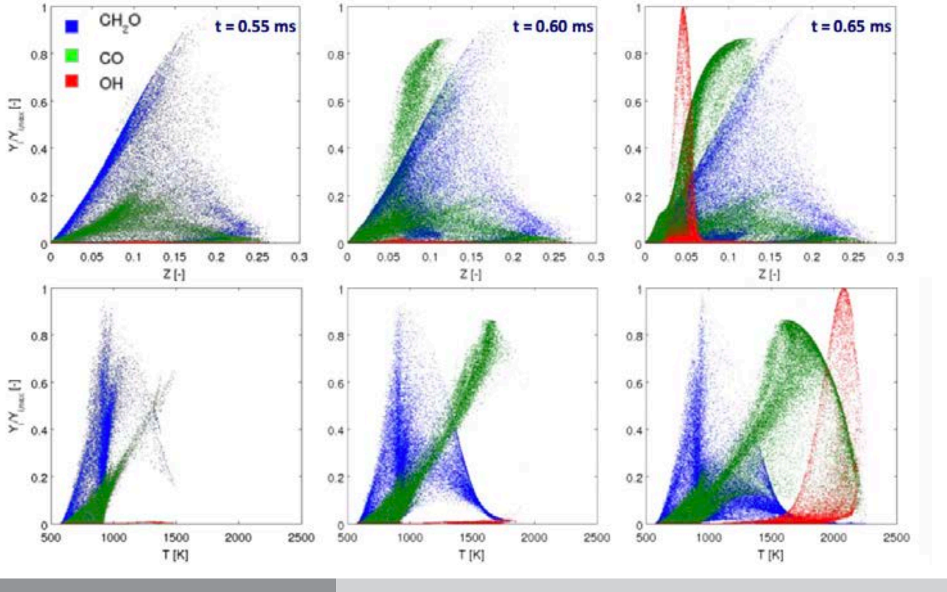
Project aim
Investigation of the burn-out phase: the late combustion of "forgotten fuel", left-overs from the main heat release in the conventional diesel combustion regime. Numerical part of the project will focus on testing and extending the chemistry reduction method Flamelet-Generated Manifold (FGM), towards the burn-out phase. For that purpose; FGM will be applied in a Large-Eddy Simulation (LES) approach and validation studies will be performed for a series of well-documented benchmark cases from the engine combustion network (https://ecn.sandia.gov/ , i.e. spray A) and optical engine (D5-optical set-up at TU/e) cases.

Progress
- Detailed investigation of the auto-ignition process (Figure 1) and quasi-steady state of the diesel spray combustion, Spray A case of the Engine Combustion Network (ECN), by using Large Eddy Simulation (LES).
- Multiple LES realizations of the Spray A case are simulated in order to study variability among results due to varying perturbations at the fuel inlet boundary condition.
- Literature review on the soot modeling for non-premixed combustion including polycyclic aromatics hydrocarbons (PAHs).
- Multi-step phenomenological soot model implementation to 1D detailed flame solver as PAHs being soot precursor.

Dissertations
-

Scientific publications
-

Evolution of normalized mass fractions of key species (CH2O, CO and OH) through auto-ignition process as a function of mixture fraction (top) and temperature (bottom) for the Spray A case from the ECN



Fuel and Combustion Stratification Study of Partially Premixed Combustion Using Advanced Laser Diagnostic Techniques

Project Aim

- Better understanding of the concept of Partially Premixed Combustion by investigation of combustion, fuel and thermal stratification during this phenomenon.
- Application of different laser diagnostic techniques in a light duty optical engine.
- Accurate quantification of laser diagnostic technique's outcomes in creative manners.
- Successive sharing of experimental results to help other researchers particularly numeric ones.

Progress

- Detailed investigation of the combustion stratification based on the Fourier analysis of high-speed OH* chemiluminescence images .
- PIV measurements inside the piston bowl and squish region: Obtaining the in-cylinder flow field of PPC with high temporal resolution and high spatial resolution; Understanding fuel air interaction and mixing; Evaluation of the turbulence.
- High-speed Spectroscopy study: A method has been developed to distinguish chemiluminescence from thermal radiation, and different chemiluminescing species (OH*, CH* and C2*) could be identified based on spectral signature analysis of different combustion modes.
- Fuel Tracer LIF study: Fuel concentrations are measured using toluene fuel-tracer LIF in non-reactive conditions. Measurements are quantified based on calibration measurements (fluorescence temperature dependency of toluene) and using a thermodynamic model (Figure).

Dissertations

1. Izadi Najafabadi. (2017). Optical Study of Stratification for Partially Premixed Combustion. Eindhoven: Technische Universiteit Eindhoven.

Scientific Publications

-

Project leaders

L.M.T. Somers, N.J. Dam, B.H. Johansson, N.G. Deen

Research theme

Complex dynamics of fluids

Participants

M. Izadi Najafabadi

Cooperations

Lund University
Imperial College London
Shell Global Solutions

Funded by

ECCO-MATE, Marie Curie Actions

Funded %

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

Start of the project

2014

Information

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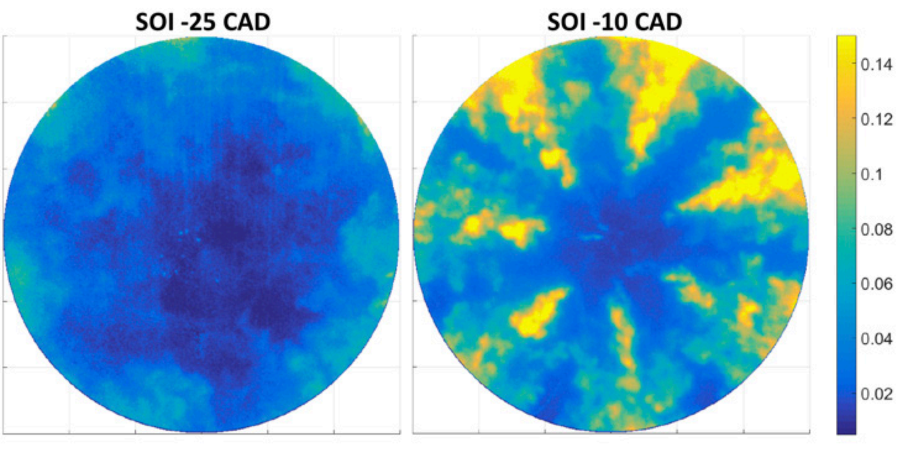
Fuel distribution (mass fraction) at TDC for different start of injections (SOI)



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 validated with experimental data.

PROGRESS

The numerical model is validated further for different operating points of oxidizer composition and temperature with constant volume application. Furthermore, the performance of the FGM-CFD model is assessed for double injection strategy with various dwell time. The results show that one chemical reaction mechanism is capable of capturing the global parameters, ignition delay and lift off length, accurately in addition to fairly accurate rate of heat release curves, as shown in Figure 1, which is one case of dwell time variations. For the other cases, similar results are obtained. Moreover, the numerical model is extended for soot and NOx modeling. In this respect, solid-phase soot reactions are coupled with gas-phase reactions and additional NOx reaction are added to the gas-phase reactions. Besides, progress variable definition is altered for the emissions. The results show fairly accurate qualitative results; however, quantitative comparisons show that the current application of the emission models are not accurate enough to capture the experimental results. Additionally, FGM-CFD model is utilized for DAF heavy duty diesel engine. Initial results show a good agreement for the motorized cycle. Furthermore, reacting cases are being simulated. Preliminary results are promising for accurate cylinder pressure and temperature traces.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Akkurt, B., Somers, L.M.T., Deen, N.G., "Heat2Control: Spray Combustion Modeling with FGM for Double Injection Strategy with Dwell Time Variation", Exhibited at Combura Symposium, The Netherlands, October 12, 2017.
2. Akargun, H.Y., Akkurt, B., Deen, N.G., and Somers, L.M.T. (2017). Extending the flamelet generated manifold for soot and NOx modeling in diesel spray combustion. The 9th International Conference on Modeling and Diagnostics for Advanced Engine Systems, July 25-28, 2017, Okayama, Japan.
3. B. Akkurt, H.Y. Akargun, R. Novella et.al., (2017), An insight on the spray-A combustion characteristics by means of RANS and LES using flamelet-based combustion models, SAE Technical Paper 2017-01-0577, SAE World Congress, USA, April 4-6, 2017.

Project Aim

This research targets a premixed combustion concept called reactivity-controlled compression ignition (RCCI), which potentially facilitates high thermal efficiency and low levels of nitrogen oxides (NOx) and soot emissions. As fuel is administered early within the cycle, RCCI lacks direct control of combustion phasing. In order to control auto-ignition, two fuels with different chemical properties are supplied to the combustion chamber, which allows tailoring of the in-cylinder reactivity. By doing so, start of combustion can be adjusted. Furthermore, RCCI is plagued by high emissions of unburned hydrocarbons and carbon monoxide due to locally lean conditions and fuel being trapped in crevice volumes. The main goals of this project are to maximize both thermal and combustion efficiencies, and investigate control possibilities for this future combustion concept.

Progress

Initial RCCI experiments have been conducted on the existing heavy-duty engine setup (Cyclops) by supplying two fuels simultaneously to the test cylinder. Two PFI fuels (gasoline/ethanol) and two DI fuels (EN590/GTL) are selected for the experiments to investigate the influence of chemical reactivity gradients in the combustion chamber. Furthermore, different PFI/DI blend ratios, as well as varying DI injection timings are employed to further study the stratification of in-cylinder air-excess ratios. A new heavy-duty engine setup is installed in the engine cells and will be commissioned early 2018. The experimental campaign will be continued on this contemporary engine setup.

Dissertations

-

Scientific Publications

-

Project leaders

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

Research theme

Complex dynamics of fluids

Participants

R.C. Willems, M.E.E. Oom, L. Xia, A. Maghbouli

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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Fuel effects in ultra-clean and efficient engine combustion concepts

Project leaders
L.M.T. Somers, N.G. Deen
Research theme
Complex dynamics of fluids
Participants
J. 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

Future combustion concept like partially premixed combustion (PPC) and reactivity controlled compression ignition (RCCI) are promising in keeping a low emission level and maintaining high thermal efficiency simultaneously. Nevertheless, specific fuels are needed to satisfy these requirements. The goal of our project will consist of following: Metal engine tests applying special fuels like PRF, alcohol fuels and cycloalkanes (toluene 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. Intensive study on emission soot size, particulate matters numbers concentration and distribution with these specific fuels will be conducted. Detailed optical measurements (optical engines and burners) will also be used to understand the new combustion concept like soot formation, injection spray etc.

Progress

The research started with a literature study; publications of previous research of the partially premixed combustion have been studied, as well as papers from other institutes, related to the alternative fuels. The state of art of recent progress has been studied. With the help of colleague, the Cyclops experimental setup operation has been learned. The next step would be multi-injections measurements on cyclops with PRF to test influence on efficiency, emission, combustion stability and controllability.

Dissertations

-

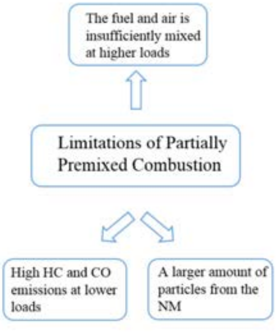
Scientific Publications

-

PROJECT AIM

The diesel engine is widely used in modern society due to its merits of superior reliability, engine power and fuel economy. However, a costly after-treatment system is required to curb its high emissions of soot and NOx in order to meet stringent emission regulations. Gasoline partially premixed combustion ignition (gasoline PPC) strategy is proposed. In this gasoline PPC concept, the advantage of the high resistance to ignition of high-octane fuel is taken to gain higher ignition delays, and low soot and NOx emissions are achieved simultaneously. Our goal is to conduct an intensive study on PPC using various high-octane blends, to investigate their combustion and emission characteristics. After extensive research on PPC, we also found many limitations of PPC.

PROGRESS



DISSERTATIONS

1. Wang, S. (2017). Limitations of Partially Premixed Combustion. Eindhoven: Technische Universiteit Eindhoven.

SCIENTIFIC PUBLICATIONS

1. S. Wang, X. Zhu, L. M. T. Somers, and L. P. H. de Goey, “Effects of exhaust gas recirculation at various loads on diesel engine performance and exhaust particle size distribution using four blends with a research octane number of 70 and diesel”, Energy Conversion and Management, 2017.
2. S. Wang, K. V. D. Waart, L. M. T. Somers, and L. P. H. de Goey, “Experimental study on the potential of higher octane number fuels for lowload partially premixed combustion”, SAE Technical Paper 2017-01-0750, 2017.
3. M. Fathi, O. Jahanian, DD. Ganji, S. Wang, and L. M. T. Somers, “Stand-alone singleand multi-zone modeling or direct injection homogeneous charge compression ignition (DI-HCCI) combustion engines”, Applied Thermal Engineering, 125 , 1181-1190, 2017.
4. S. Wang, S. Sprengers, L. M. T. Somers, and L. P. H. de Goey, “Particulate Matter Emission from a Heavy-duty Diesel Engine with Three Binary Blends”, 12th conference on sustainable development of energy, water and environment systems, Dubrovnik, 2017.
5. Wang, S. (2017). Limitations of partially premixed combustion. Eindhoven: Technische Universiteit Eindhoven. ((Co-)promot.: Philip de Goey & Bart Somers).

PROJECT LEADERS
L.P.H. de Goey, L.M.T. Somers

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
S. Wang

COOPERATIONS
-

FUNDED BY
China Scholarship Council

FUNDED %

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

START OF THE PROJECT
2013

INFORMATION

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PROJECT LEADERS
M. Golombok, M.D. Boot, N.G. Deen
RESEARCH THEME
Complex structures of fluids
PARTICIPANTS
M. Cuijpers
COOPERATIONS
Shell
FUNDED BY
Shell
FUNDED %

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

START OF THE PROJECT
2014
INFORMATION
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PROJECT AIM

Heavy oil is seen as one of the ways to address increasing oil demand. Subcritical water (SCW) has been shown to effectively reduce the viscosity of these heavy hydrocarbons. We use the two properties of SCW: the dielectric constant of water is decreased, enabling the solution of heavy oil components and the enhanced dissociation constant enables the cracking of heavy hydrocarbons into lighter components. A number of physical and chemical analytical methods are used to deduce the source of change in properties due to SCW and compare it to pure pyrolysis.

PROGRESS

Reductions in viscosity of up to 80% have been observed and could be achieved within a few hours. The SCW induced viscosity reduction correlates well with reductions in sulphur content, average molecular weight and average unbranched segment length, along with an increase in volatility. This all suggests that the heavy oil is being cracked. SCW treatment results in the formation of H2S which suggests that not only C-C, but also C-S or C-S-C bonds are cleaved. In order to discern between pure thermal cracking and that induced by the hydroxyl and hydrogen ions that are characteristic to SCW, a pyrolysis experiment was carried out under similar process conditions. Following pyrolysis, no H2S generation and a viscosity reduction of only 22% were observed.

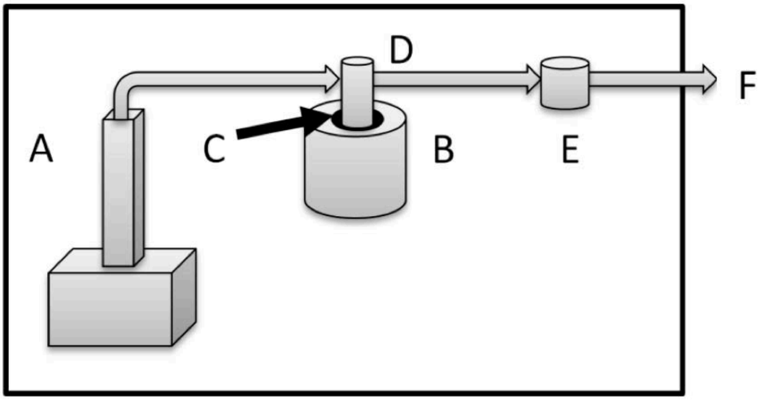
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Cuijpers, M., Golombok, M., Avendonk, H. Van, Boot, M., 2017. Preliminary Investigation of a Bio-Based Low Sulfur Heavy Fuel Oil. doi:10.4271/2017-24-0114.
2. Cuijpers, M.C.M., Boot, M.D., Golombok, M., 2017. Enhanced viscosity reduction in heavy oils by subcritical water. J. Pet. Explor. Prod. Technol. doi:10.1007/s13202-017-0370-y.

Schematic overview of the subcritical water setup (A: Isco 500D Syringe pump; B: Premex
electric heating mantle; C: Hastelloy C Premex autoclave; D: Premex magnetic stirrer; E: Backpressure regulator; F: External exhaust).



Development of Reliable Emission and Atomization Models for Combustor Design

Project Aim

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

The FGM method accounting for additional time scales of reaction kinetics has been further improved, focusing on a higher accuracy for prediction of pollutants. An FGM with one extra chemically reactive dimension has been developed for the 2D laminar premixed simulations involving the effects of flame/wall interactions. Including a second chemically reactive degree of freedom resulted in improved accuracy for the FGM prediction of CO concentrations.

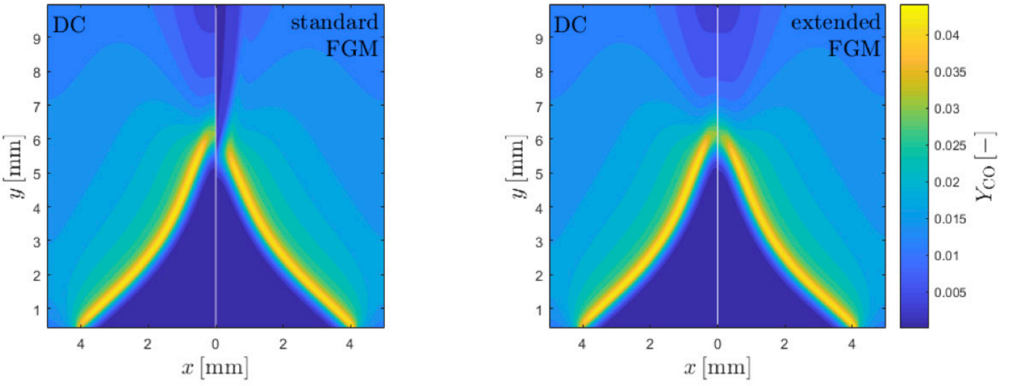
Dissertations

-

Scientific Publications

-

CO mass fraction found with the standard and the extended FGM's 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. For all simulations a vertical cold wall (Twall=300 K) is located at x=0 cm over the entire height of the domain.



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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Project leaders
J.A. van Oijen
Research theme
Complex dynamics of fluids
Participants
M.U. Göktolga, A. Vasavan, J.A. van Oijen
Cooperations
-
Funded by
NWO (VIDI)
Funded %

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

Start of the project
2010
Information
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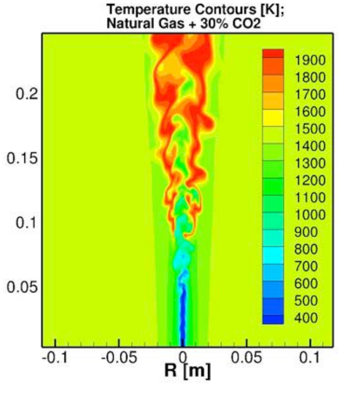
Temperature contours of a MILD flame



Project Aim

The focus of this project is on MILD combustion, which is characterized by a high degree of preheating and dilution of the reactants and offers the possibility of a sustainable, near emission-free energy production. The project encompasses a multi-scale approach that starts with an exploration of the small-scale fundamental processes causing the outstanding properties of MILD combustion. This fundamental knowledge is then translated via numerical studies of lab-scale burners into design tools for large-scale industrial combustion devices. To investigate the reaction structures that arise in MILD combustion, high-fidelity numerical models are employed.

Progress

A study of ignition of biogas under MILD environment in igniting mixing layers was conducted, and it was shown that presence of CO2 in fuel has a negligible influence on the ignition delays. Oldenhof's JHC experiments with DNG as fuel were investigated in LES simulations using FGM, with a boundary condition that took into consideration the varying temperature and oxygen mass fraction. The effect of increased oxygen levels close to the fuel jet lead to reduction in flame lift off height. A transported subgrid-scale mixture fraction variance equation predicts higher variance levels, predicting temperature levels that matches with that found in experiments. The influence of subgrid-scale variance model was studied for the Cabra vitiated coflow experiment, it was shown that the transport model predicts the same lift off heights as the algebraic models for variance, ensuring the validity of the approach.

Dissertations

-

Scientific Publications

1. Abtahizadeh, E., de Goey, P. & van Oijen, J. (2017). LES of Delft Jet-in-Hot Coflow burner to investigate the effect of preferential diffusion on autoignition of CH4/H2 flames. Fuel, 191, 36-45.
2. Göktolga, M.U., van Oijen, J.A. & de Goey, L.P.H. (2017). Modeling MILD combustion using a novel multistage FGM method. Proceedings of the Combustion Institute, 36(3), 4269-4277.
3. Sorrentino, G., Göktolga, M.U., de Joannon, M., van Oijen, J.A., Cavaliere, A. & de Goey, L.P.H.(2017). An experimental and numerical study of MILD combustion in a Cyclonic burner. Energy Procedia, 120, 649-656.

PROJECT AIM

Hydrogen blending with hydrocarbon fuels is a potential approach for further extending the lean flammability limit and reducing emissions. However, it is a challenge to design combustors or burners which can operate near the lean limit using hydrogen-blended fuel. The combustion characteristics of hydrogen-blended fuel significantly differ from the traditional hydrocarbon fuels because addition of hydrogen reduces mixture Lewis number. Therefore, understanding of the Lewis number effect on lean limit combustion characteristics is crucial for the design of the combustors and burners operating at the lean limit conditions.

PROGRESS

Ph.D. thesis has been written.

DISSERTATIONS

1. Zhou, Z. (2017). Flame balls at earth gravity. Eindhoven: Technische Universiteit Eindhoven.

SCIENTIFIC PUBLICATIONS

1. Z. Zhou, Y. Shoshin, F. Hernández-Pérez, J. van Oijen, L.P.H. de Goey, Effect of pressure on the lean limit flames of H2-CH4-Air mixture in tubes, Combustion and Flame, 2017 (183): 113-125.
2. Z. Zhou, F. Hernández-Pérez, Y. Shoshin, J. van Oijen, L.P.H. de Goey, Effect of Soret diffusion on lean hydrogen/air flames at normal and elevated pressure and temperature, Combustion Theory and Modelling, 2017 (21): 879-896.

PROJECT LEADERS

L.P.H. de Goey

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Z. Zhou, Y. Shoshin, J.A. van Oijen

COOPERATIONS

-

FUNDED BY

Chinese Scholarship council

FUNDED %

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

START OF THE PROJECT

2013

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Development of non-thermal DBD microplasma reactor for combustion applications

Project leaders
J.A. van Oijen, L.P.H. de Goey
Research theme
Complex dynamics of fluids
Participants
A. Elkholy
Cooperations
CWI's research group (Ute Ebert)
Physics department in TUE (Eddie veldhousen - Sander Nijdam)
Funded by
Egyptian government
Funded %

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

Start of the project
2014
Information
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Project Aim

The aim of the project is to investigate experimentally low temperature plasma-flame interaction for CH4 premixed flame in a flat flame burner with a dielectric barrier discharge (DBD) Plasma technique. We desire to investigate the effect of Nano-second plasma discharge on flame stabilization, emissions, CH4 oxidation rate, radical and ion formation and their effect on flame propagation speed.

Progress

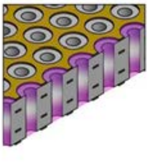
- Design and construction of CH4 flat flame burner.
- Design and construction of dielectric barrier discharge (DBD) plasma generator which consisting of disk electrodes, pulse generator, signal amplifier and oscilloscope.
- Studying different holes patterns to get the suitable plasma discharge inside/around the holes.
- OES (optical emission spectroscopy) to measure the plasma temperature and active spices concentration
- Studying the blow-off limits using plasma discharge
- Performing an emission study to evaluate the plasma effect on flame emissions.
- Performing PIV to study the local effect of the plasma discharge on the burning velocity.

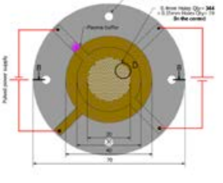
Dissertations

-

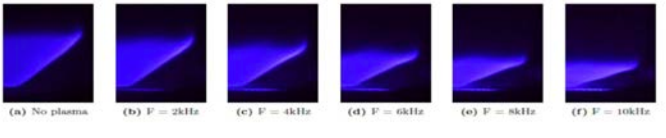
Scientific Publications

1. Elkholy, A.H.E., Shoshyn, Y., Nijdam, S., van Veldhuizen, E.M., van Oijen, J.A. & de Goey, L.P.H. 'Burning velocity measurement of methane-air flame in a new DBD microplasma burner platform', Experimental Thermal Fluid Science Journal, in press, 2018.
2. Elkholy, A.H.E., Veldhuizen, E., Nijdam, S., Ebert, U.M., van Oijen, J.A., Dam, N.J. & de Goey, L.P.H. 'Characteristics of a novel nanosecond DBD microplasma reactor for flow applications', submitted to Journal of Physics D: Applied Physics -2017.
3. Elkholy, A.H.E., Shoshyn, Y., Nijdam, S., van Veldhuizen, E.M., van Oijen, J.A. & de Goey, L.P.H. 'A new DBD microplasma burner for measuring the effect of nanosecond plasma discharge on burning velocity of methane-air flames'. MCS-10 : Tenth Mediterranean Combustion Symposium, 17-21 September 2017, napoli, Italy.





CH chemiluminescence images for methane-air flame at different plasma



PROJECT AIM

The dynamics of a premixed flame front is governed by its local propagation speed, i.e. the burning velocity which is affected by the interaction of the flame front with surrounding flow. These interactions are cumulatively referred to as "flame stretch." It becomes mandatory to model these effects accurately as they impact the mass burning rate of the flame. Hence an accurate flame stretch model has to be developed both numerically and mathematically to make accurate prediction of flame dynamics.

PROGRESS

Premixed flames in a stagnation counter-flow, where the jets of mixture collide from opposite sides, was chosen to study flame stretch effects. These flames when subjected to oscillating flow straining, showed many non-linear and unsteady effects. Unsteady stretch effects were predominantly caused by thickness variations of the flame. These unsteady stretch effects were found to affect the stability and quenching of the flames at high strain rates.

DISSERTATIONS

1. Iyer, A.G. (2018), Investigation of unsteady stretch effects using premixed counterflow flames. Eindhoven Technische Universiteit Eindhoven ((CO) promotor. Philip de Goey, Jeroen van Oijen & Jan ten Thije Boonkkamp.

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

L.P.H. de Goey, J.A. van Oijen, J.H.M. ten Thije Boonkkamp

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

A. G. Iyer

COOPERATIONS

-

FUNDED BY

TTW Simon Stevin

FUNDED %

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

START OF THE PROJECT

2011

INFORMATION

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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

An OpenFOAM library is constructed to simulate premixed and non-premixed combustion. The solver can handle adiabatic and non-adiabatic conditions. Turbulence-chemistry interaction is modelled by using beta pdf. The solver is tested on Stagnation Point Reverse Flow (SPRF) and DLR burners with premixed configuration.

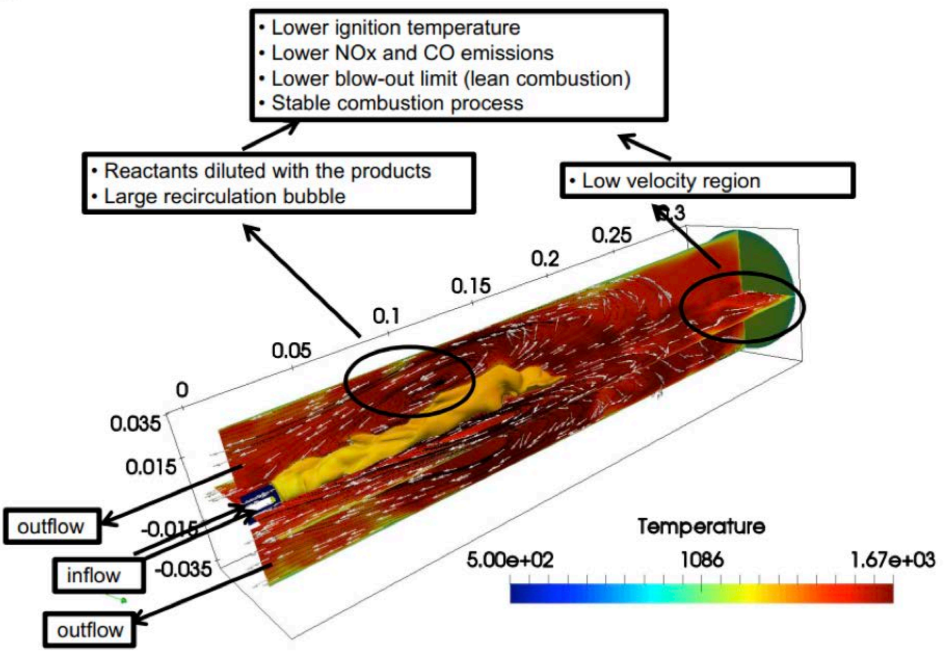
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Stagnation Point Reverse Flow combustor configuration



Numerical and Experimental Study of Thermoacoustics of Domestic Burner with Heat Exchanger

Project Aim

The goal of the project is to investigate the interactions between a burner and a heat exchanger looking from a thermoacoustic and hydrodynamic point of view. This goal is thought to be achieved by both laboratory measurements and numerical experiments. A laboratory with the test setup to measure the flame transfer function is available. On the numerical front, simple premixed flames and tube heat exchangers are modelled to study the interactions. The results obtained from measurements and simulations are used in to predict the system stability. Finally, design rules need to be defined to shorten the time to market for heating equipment with minimum thermoacoustic instabilities.

Progress

In the numerical front, the 2D CFD model is developed for inclusion of heat exchanger. Extensive combustion verifications have been performed to ensure correct thermoacoustic properties for a vast variety of conditions, with and without heat exchanger. With the CFD model, it is possible to predict the thermoacoustic behavior of a simplified boiler using the properties of its components for varying distances between them. The results of his investigation will soon be submitted to the Combustion and Flame journal. A separate publication will also be prepared about the 3D effects in simulating the flame transfer function. Two joint studies with Technische Universität München in Germany and Keele University in England have been performed to investigate this approach using other numerical and analytical tools. The results have been submitted to ICSV23. An FEM solver and a linear network model have been used to predict the instabilities in a heating equipment with heat sources and heat sinks. The results show that it is crucial to include the active thermoacoustic effects of both elements in order to have a correct prediction of the system stability.

Dissertations

-

Scientific Publications

-

Project leaders

L.P.H. de Goey, V. Kornilov, O.J. Teerling, I. Lopez Arteaga

Research theme

Complex dynamics of fluids

Participants

N. Hosseini

Cooperations

Bekaert Combustion Technology
Technische Universität München
Keele University

Funded by

TTW, EC, Bekaert Combustion Technology

Funded %

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

Start of the project

2013

Information

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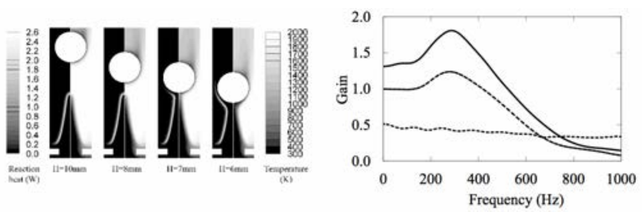
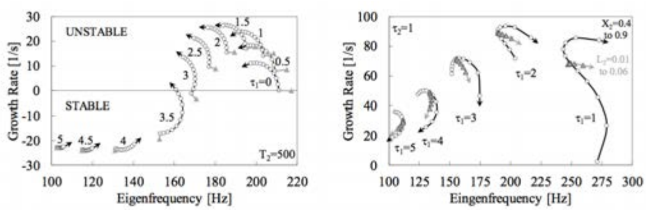
The simulation contours of temperature and reaction rate (left) and the gain of the transfer function of the flame, heat exchanger and complete system (right)



The eigenfrequency and growth rate of a Rijke tube with heat source and sinks of varying time delays (left) and the location and compactness of the sink (right)



PROJECT LEADERS
J.G.M. Kuerten
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
A. Awasthi
COOPERATIONS
B.J. Geurts (UT), SHELL
FUNDED BY
FOM, SHELL
FUNDED %

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

START OF THE PROJECT
2013
INFORMATION
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PROJECT AIM

A computational method will be developed to simulate the combined combustion of biomass and coal in biomass co-fired power plants. Realistic operation conditions of power plants involve particle volume fractions (typically 3x10-4) that require incorporation of two-way interaction between particles and surrounding gas in terms of mass, momentum and energy, and particle-particle interaction by radiative heat transfer. The model would enable optimization of the combustion time, ash quality and emissions of the power plant by varying the particle composition and size. Effects of increased biomass fraction on the process efficiency will be quantified.

PROGRESS

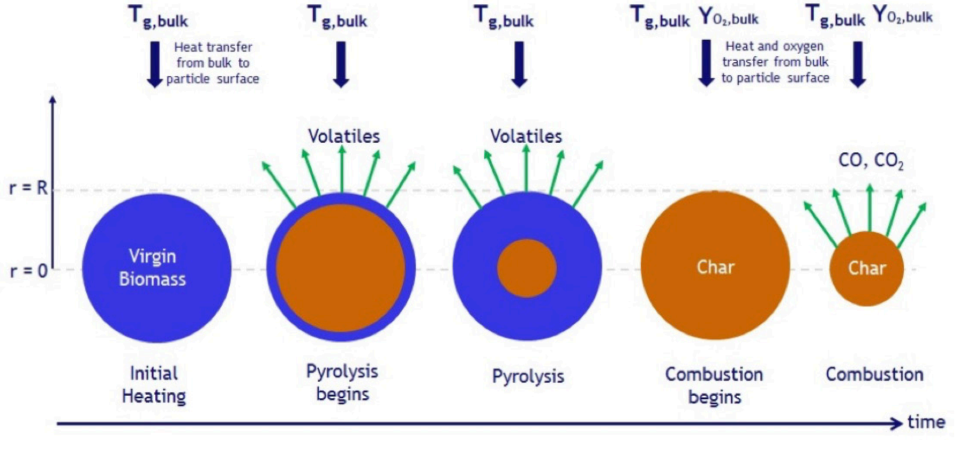
A model for coal particles in order to enable a study of co-combustion of biomass in coal-fired power plants has been developed. A method has been found that enables the simulation of high numbers of particles by using virtual particles that represent a number of real particles. The accuracy of the model as a function of the number of real particles represented by a virtual particle has been determined. The PhD thesis has been finished.

DISSERTATIONS

1. Awasthi, DNS of biomass pyrolysis and combustion in co-firing power plants, PhD Thesis, Eindhoven University of Technology, 2017.

SCIENTIFIC PUBLICATIONS

-



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:

(1) the model will be extended to incorporate the presence and influence of surfactants;

(2) to investigate the impact of neighboring droplets, a generalization to three dimensions is proposed;

(3) the absorption into the porous substrate will be extended to comprise more general types of porous substrates.

Progress

A new PhD-student (R.T. van Gaalen) has started working on extending the existing lubrication model to incorporate the presence and influence of surfactants. A convection-diffusion model has been implemented to model the transport of dissolved surfactants through the bulk and a literature study has been carried out to examine the existing data on surfactants in droplets.

Dissertations

-

Scientific Publications

1. C. Diddens, H. Tan, P. Lv, M. Versluis, J.G.M. Kuerten, X. Zhang, D. Lohse, Evaporating pure, binary & ternary droplets: thermal effects & axial symmetry breaking, J. Fluid Mech. 823, 470-497 (2017).
2. C. Diddens, J.G.M. Kuerten, C.W.M. van der Geld and H.M.A. Wijshoff, Modeling the evaporation of sessile multi-component droplets, J. Coll. Interf. Sc. 487, 426-436 (2017).
3. C. Diddens, Detailed finite element modeling of evaporating multi-component droplets, J. Comp. Phys. 340, 670-687 (2017).
4. H. Tan, C. Diddens, M. Versluis, et al., Self-wrapping of an ouzo drop induced by evaporation on a superamphiphobic surface, Soft Matter 13, 2749-2759 (2017).

Project leaders

J.G.M. Kuerten

Research theme

Complex dynamics of fluids

Participants

C. Diddens, C.W.M van der Geld, H.M.A. Wijshoff, R.T. van Gaalen

Cooperations

Océ

Funded by

FOM (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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PROJECT LEADERS
J.C.H. Zeegers, J.G.M. Kuerten, A.A. Darhuber

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
R. Dellaert, S. Tajfirooz

COOPERATIONS
TU Delft, UTwente, UU, Radboud University, and several companies, part of Perspectief programme TTW

FUNDED BY
TTW, Umincorp, Sumitomo, Syngenta, Dimaen, FNLI, AEB

FUNDED %

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

START OF THE PROJECT
2016

INFORMATION
www.tue.nl/mrf

PROJECT AIM

The project consists of two sub-projects. The aim of the first sub-project is to investigate the temporal and spatial characteristics of turbulence behind a honeycomb structure. The goal is to minimize the turbulence level behind the flow straightener used in the MDS setup. The second sub-project aims at investigation of particle-fluid-particle interactions in an MDS setup. A combination of experimental and numerical studies are carried out. And the combined research outcomes of the two sub-projects will be used for optimizing the magnetic density separation technology.

PROGRESS

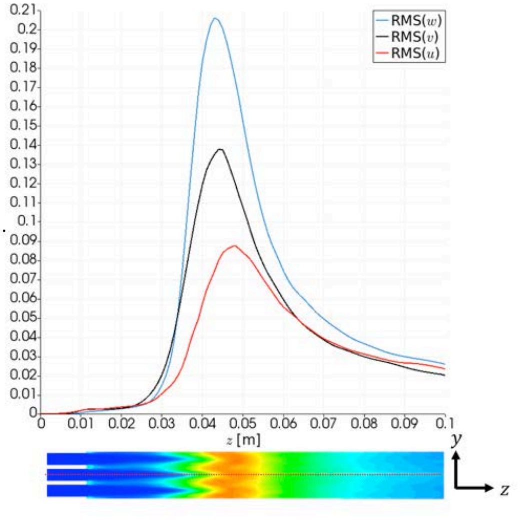
Direct numerical simulations are carried out to investigate the generated flow instabilities behind a honeycomb-like flow manipulator. Decay behavior of velocity fluctuations downstream of a honeycomb is shown in the figure below. In order to study the particle-laden flow occurring in MDS, a point-particle approach is implemented. The two-way interaction between the fluid and the particles and the particle collisions, alongside the effect of magnetic forces are taken into account in the model. A small-scale wind tunnel is designed and constructed to investigate the turbulence behind flow manipulators such as honeycombs and grids using PIV and LDV measurement techniques. Another experimental setup is designed to investigate the particle-fluid-particle interactions with and without the presence of magnetic forces.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



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 good 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.

4. Testing of new designs for heat pipes.

Progress

- Investigation on computational fluid dynamics and phase transition model;
- Implementation of a mass transfer model (Lee model) in OpenFOAM;
- Investigation of a mass transfer model based on energy equation;
- Implementation of PLIC on an un-orthogonal mesh with arbitrary quadrilateral cells in OpenFOAM.

Dissertations

-

Scientific Publications

-

Project leaders

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

Research theme

Complex dynamics of fluids

Participants

H. Wang

Cooperations

-

Funded by

China Scholarship Council

Funded %

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

Start of the project

2015

Information

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Boiling Flow Regime Maps for Safe Designing

Project leaders
C.W.M. van der Geld, J.G.M. Kuerten, B.J. Geurts

Research theme
Complex dynamics of fluids

Participants
G. Priems, P. Cifani, W. Michałek, C. van der Geld, J. Kuerten, B. Geurts

Cooperations
UT, Stork, NEM, NRG

Funded by
Stork Thermeq, NEM, NRG.

Funded %

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

Start of the project
2013

Information
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Project Aim

The intended main results of this project are twofold: (1) flow pattern maps for heated two-phase flows, of water-steam and of the model system HFE7000 and its vapor, and (2) a multi-scale numerical method to determine such flow pattern maps which is validated for the measurement conditions for which these maps have been established.

Progress

Giel Priems almost finalized the test rigs, as well as of the measurement equipment; first measurement results are expected within a few months; he also progressed on reporting the design criteria and decisions. Paolo Cifani finished his thesis. The final method takes a step forward in the direction of DNS of turbulent channel flows loaded with thousands of bubbles and mass density ratios closer to a real air-water system at atmospheric pressure. The method was used to investigate the flow statistics at higher mass density ratios of up to 100 and different bubble sizes. Wiktor Michałek performed stable simulations for water properties at 1 bar and with a presence of a boiling model. For a spherical bubble surrounded by superheated liquid good agreement with analytical solutions was obtained. Moreover, a nucleation model has been implemented as a supplement to the boiling model. This part of the project has been finished in June.

Dissertations

1. Cifani, P. (2017). DNS of turbulent bubble-laden channel flows Enschede DOI: 10.3990/1.9789036544160.

Scientific Publications

-

Electrical connection to heated section

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). By closely controlling this process, high quality advanced strength steel can be produced without additives. During quenching of steel at high temperature (900 °C), the boiling process has quite extraordinary features. Rewetting, i.e. contact with the surface, occurs at temperatures far beyond the boiling temperature. The first goal is to get proper understanding on the rewetting phenomena, based on direct observations of the stagnation zone during quenching. The second goal is to develop heat transfer coefficients correlations to implement in the process control system of the ROT.

Progress

The current experimental setup only allows quenching of static steel plates (see Figure below), but we aim to study quenching of moving steel plates. For that reason, different moving table setup concepts were evaluated and a new setup has been designed. The new setup will be constructed using the urrent water circuit and the steel plate will be moved at speeds up to 10 m/s using a linear unit (belt driven and wheel guided) below the jet. Additionally, we studied the effect of surface roughness on rewetting using static plates. Plates with different surface topology were quenched and high speed recordings of the stagnation zone were compared. We observed clear differences on rewetting behavior depending on the surface topology. The next step is the quantification of this surface topology effect on terms of surface heat flux or jet cooling capacity.

Dissertations

-

Scientific Publications

-

Project leaders

B.P.M. van Esch, C.W.M. van der Geld

Research theme

Complex dynamics of fluids

Participants

C.F. Gomez

Cooperations

TATA Steel R&D Ijmuiden, M2i

Funded by

NWO-I, TATA Steel R&D IJmuiden

Funded %

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

Start of the project

2016

Information

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Experimental setup. From top to bottom: Water storage tank, pneumatic valve and jet nozzle, LEDs illumination ring, steel plate and isolation support.

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
TTW
FUNDED BY
TTW
FUNDED %

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

START OF THE PROJECT
2016
INFORMATION
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PROJECT AIM

Studying phase-transitional flows with a Diffuse Interface Model.

PROGRESS

Exploration of equations of state and influence on liquid-vapor equilibrium and surface tension. Implementation of wall boundary conditions for simulations of wetting and nucleation processes. Three dimensional simulations of droplet collisions. Simplification of the artificial interface enlargement technique for isothermal simulations.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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 a “living” model of breast-cancer prior to invasion into surrounding tissue, using microfluidic tools to control local properties of the extracellular matrix (ECM). By employing encapsulation and micro-droplet technologies, a physiologically relevant heterogeneous tissue model will be constructed, with controlled and reproducible physical properties. This model will then be employed to systematically investigate the interplay between these properties and a signaling pathway relevant to cancer cell invasion: the Notch pathway.

PROGRESS

In 2017, we have developed a cell encapsulation chip for embedding breast cancer cells into (bio-) hydrogel beads. Integrated heat exchangers for local temperature control enabled droplet generation and subsequent gelation in the same microfluidic device. By sandwiching the generated (Matrigel) beads in between two layers of collagen, the heterogeneous tissue model was established for the first time. Using the model, we have been able to observe, live, the invasion of tumor cells from the primary tissue site into the stuurounding matrix. `next, we will vary matrix properties to investigate the infkuence on the invasion behavior.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Sleeboom, Jelle J.F. et al. “Modeling the pore-invasive breast cancer microenvironment usinfg high-throughput microfluidic cell encapsulation”, MaTe poster contest entry, Eindhoven, Dec. 2017.

PROJECT LEADERS

JMJ den Toonder, C Sahlgren

RESEARCH THEME

Complex structures of fluids

PARTICIPANTS

Jelle Jan Freerk Sleeboom

COOPERATIONS

-

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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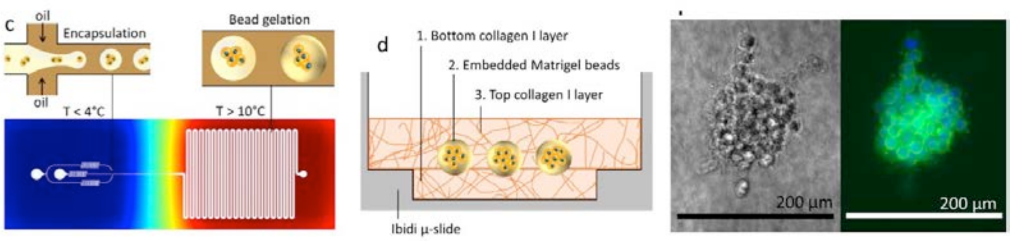

Magnetic control of micro-particles and integrated micro-actuators for high precision handheld diagnostics

Project leaders
JMJ. den Toonder
Research theme
Complex structures of fluids
Participants
Eriola Shanko
Cooperations
Philips Healthcare
Funded by
HTSM-TKI
Funded %

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

Start of the project
2016
Information
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Project Aim

Magnetic particles actuated by magnetic fields are an attractive approach in the medical field, since they can be used in various applications, for example to capture and concentrate specific analyte, to mix fluids, and as labels for detection). In addition, to magnetic particles, also magnetic micro- actuators integrated into microfluidic devices can be used to control liquid flow and induce mixing, using externally generated magnetic fields. The aim of this project is to develop novel approaches on solving mixing problems to reach homogeneity of reagents and achieve high precision handheld diagnostics by using actuated magnetic particles and integrated magnetic micro-actuators.

Progress

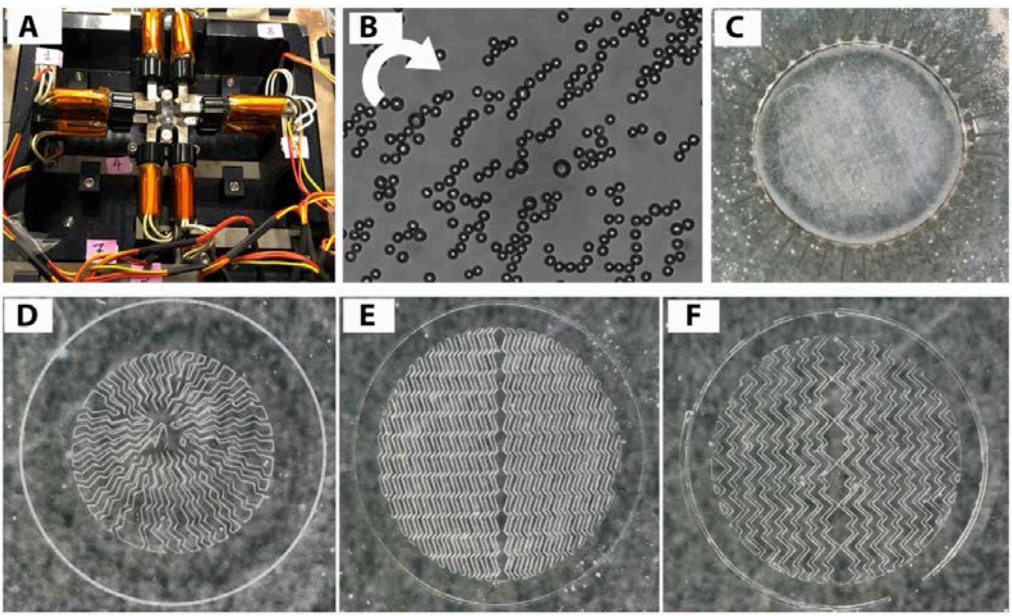
We have started studying the combination of active magnetic mixing with passive staggered herringbone structures, aiming for increased mixing efficiency in no-flow-through microreaction chambers. Microfluidic chips with circular microchambers having various passive mixing patters were fabricated. Experiments 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. Additional soft-magnetic structures are added along the periphery of the microchamber resulting in particle motion and perfect mixing along the chamber circumference. Our first results show that the passive structures do indeed contribute to the overall mixing by inducing vortices in the center. The mixing efficiency index is to be fully characterized.

Dissertations

-

Scientific Publications

1. S. Eriola Shanko et al. "Magnetic mixing in microfluidic: the "swarming effect", MaTe poster contest entry, Eindhoven, Dec. 2017.



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 (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. ARTIFICIAL MINI-HEART - AN INTERNAL MICROPUMP BASED ON MAGNETIC ARTIFICIAL CILIA THAT CAN INDUCE FLOWS IN A MICROFLUIDIC CHANNEL NETWORK; MicroTAS, Savannah, October 2017.
2. Zhang, S., Wang, Y., Lavrijsen, R., Onck, P.R. & Toonder, J.M.J. den (2017). Versatile microfluidic flow generated by moulded magnetic artificial cilia. Sensors & Actuators B, accepted.

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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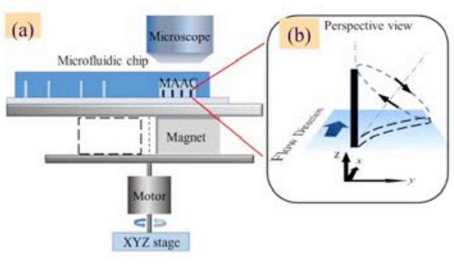

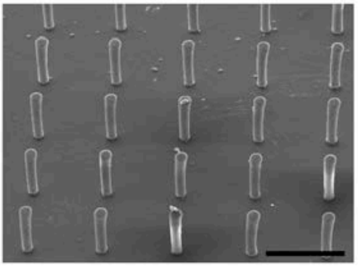

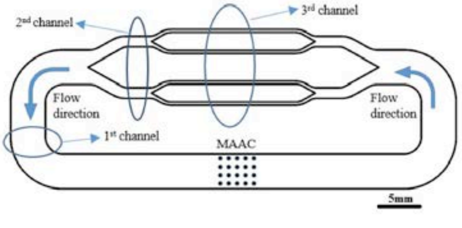

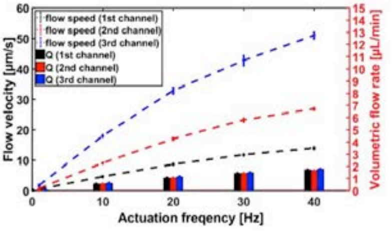

PROJECT LEADERS
JMJ den Toonder, AJH Frijns
RESEARCH THEME
Complex structures of fluids
PARTICIPANTS
S van Pelt
COOPERATIONS
-
FUNDED BY
CATRENE, PASTEUR
FUNDED %

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

START OF THE PROJECT
2009
INFORMATION
Stijn van Pelt
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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

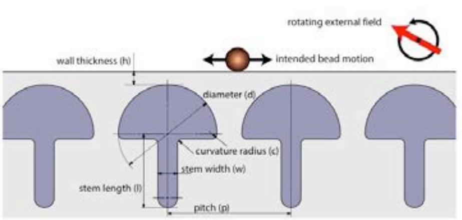
We have shown a new method for the actuation of agglomerates of magnetic beads in a microfluidic environment, using an external rotating eld. By careful design of magnetic structures just below the surface of a microfluidic chip, the local magnetic field will show a motion that can be used to move magnetic beads similar to a conveyer belt.

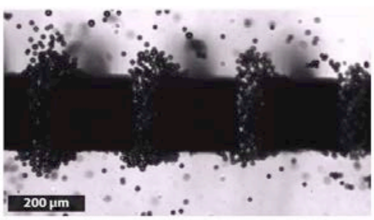
DISSERTATIONS

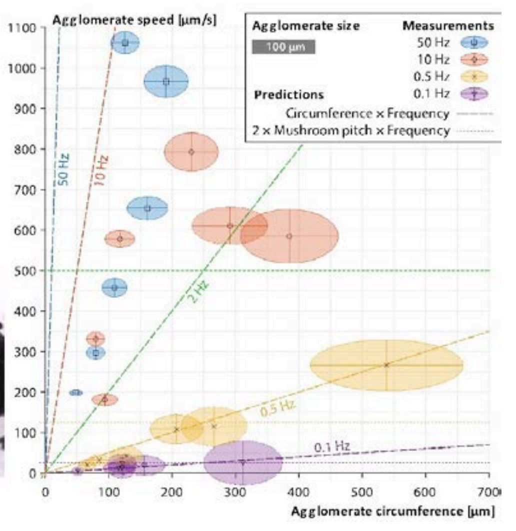
-

SCIENTIFIC PUBLICATIONS

1. Pelt, S. van, Frijns, A.J.H. & Toonder, J.M.J. den (2017). Microfluidic magnetic conveyor belt. Lab on a Chip, 17, 3826 – 3840. DOI: 10.1039/C7LC00718C.







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

Two sub-projects are created: 1, droplet propulsion using surface travelling waves and 2, wetting control by surface topography change using magnetically actuated surfaces.

1. A surface travelling wave setup was built in-house and used to study droplet propulsion mechanisms. Initial experiments successfully demonstrated the feasibility of such droplet motion. We have combined experiments and numerical simulation (carried out at RUG) to study the factors influencing this phenomenon, such as fluid properties, wave parameters and interfaces.

2. A thin PDMS film containing magnetic particles was mounted on a array of micropillars. Using an external magnet, local surface topography could be created on the surface of this PDMS film. Droplets sitting on the surface could be transported overt the surfecs in any direction using controlled translation of the magnet.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Ye Wang et al. "Climbing drops:Liquid drop transportation on atravelling wave", MaTe poster contest entry, Eindhoven, Dec. 2017.
2. Hongbo Yuan et al. "Buckling waves for self-cleaning", MaTe poster contest entry, Eindhoven, Dec. 2017.

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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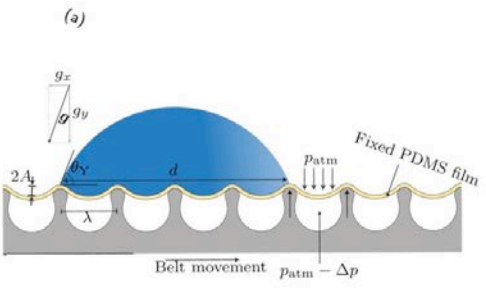

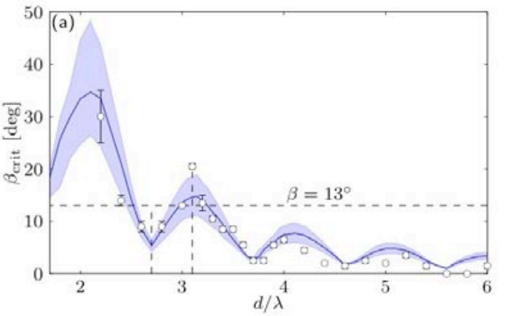

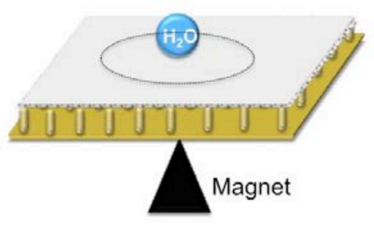

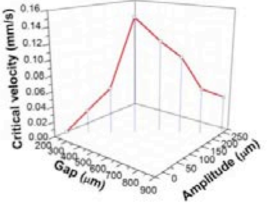

PROJECT LEADERS
JMJ den Toonder, R Luttge
RESEARCH THEME
Complex structures of fluids
PARTICIPANTS
Hossein Eslami Amirabadi
COOPERATIONS
-
FUNDED BY
STW 100%
FUNDED %

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

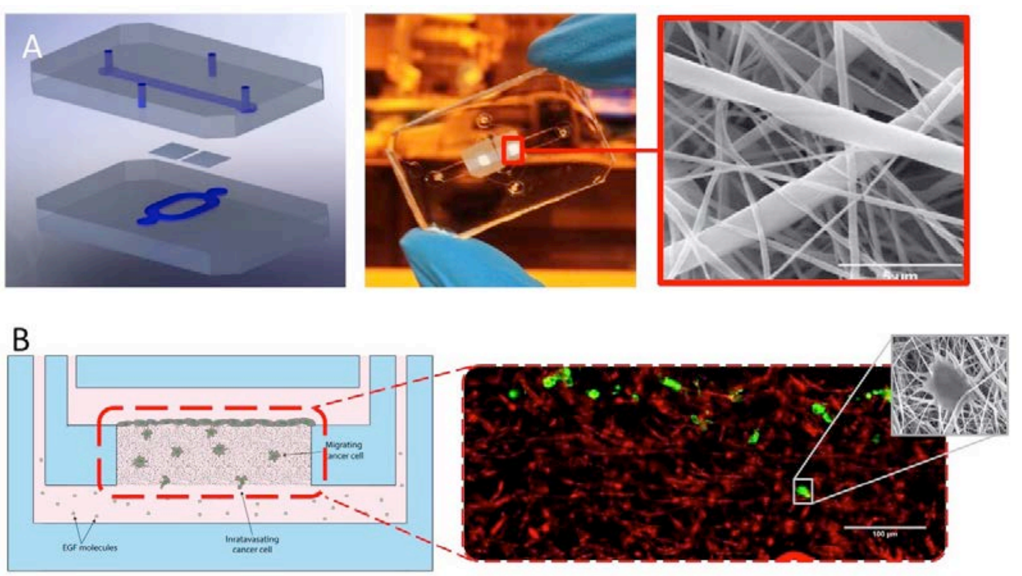
We have developed a new microfabrication method, called selective curing, to integrate ECM-mimicking layers between two microfluidic channels. This method enables us to study the effect of 3D matrices with controlled architecture, beyond the conventionally used hydrogels, on cancer invasion in a controlled environment. As a proof of principle, we have integrated two electrospun Polycaprolactone (PCL) matrices with different fiber diameters in one chip. We then studied the 3D migration of MDA-MB-231 breast cancer cells into the matrices under the influence of a chemotactic gradient. The results show that neither the invasion distance nor the general cell morphology is affected significantly by the difference in fiber size of these matrices.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Eslami Amirabadi, H., Sahebali, S., Frimat, J.P., Luttge, R. & Toonder, J.M.J. den (2017). A novel method to understand tumor cell invasion: integrating extracellular matrix mimicking layers in microfluidic chips by "Selective Curing". Biomedical Microdevices 19: 92. https://doi.org/10.1007/s10544-017-0234-8.



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

A start has been made with a literature survey on cancer, US imaging, and current approaches to creating vessel-like structures in a chip.

- Some first potential concepts for realizing vasculature on a chip have been identified (see Figure), in particular wire casting, viscous finger patterning, and self-organization / growth through angogenesis. In our final approach, a combination of these techniques will also be a possibility.
- Some first trials with the wire casting method have resulted in the successful creation of straight and curved lumens in PDMS with a round cross section down to 200 μm.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. A.M.A.O. Pollet et al. “Locate - Integrated platform to design novel cancer localization strategies by ultrasound microvasculature imaging”, MaTe poster contest entry, Eindhoven, Dec. 2017.

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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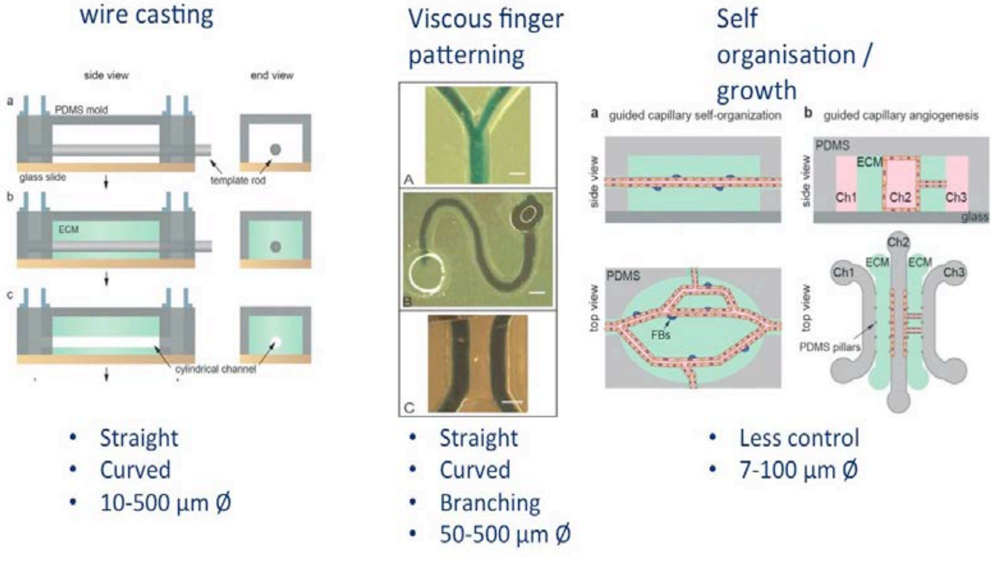


Multiphase rectors

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 roughness of the granular materials has been shown to have a significant effect on stresses. The particles can rotate due to surface friction during collisions. Attempts to quantify the friction effect have been somewhat limited. In rapid granular flows, the particle-wall collisions cause random fluctuations of the grain velocities, which are responsible for the transport of momentum and fluctuation energy through the flow. The aim of this project is to modify the current KTGF by including particle rotation and particle surface friction, and derive appropriate boundary conditions distinguishing between sliding and sticking collisions in the two fluid model.

PROGRESS

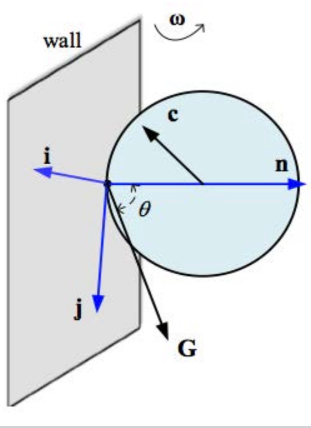
Currently, the derivation of the theory and implementation in the in-house code have been accomplished. Validation of the modified KTGF model followed from a comparison with the DPM model, in which friction can be modeled with reasonable accuracy, and also by comparing with one-to-one PIV-DIA experiments. Besides, appropriate boundary conditions has been established. Further validations of current KTGF and boundary conditions have been carried out. In addition, our current KTGF model has been incorporated into our in-house 3D cylindrical Cartesian to study the hydrodynamics in dense bubbling lab-scale fluidized beds.

DISSERTATIONS

1. L. Yang, Kinetic theory for rough spheres: Numerical and experimental study of dense gas-solid fluidized beds, PhD thesis, 2017, Eindhoven University of Technology.

SCIENTIFIC PUBLICATIONS

1. Yang, L., Padding, J.T. & Kuipers, J.A.M. (2017). Partial slip boundary conditions for collisional granular flows at flat frictional walls. AIChE Journal, 63(6), 1853–1871.
2. Yang, L., Padding, J.T. & Kuipers, J.A.M. (2017). Investigation of collisional parameters for rough spheres in fluidized beds. Powder Technology, 316, 256-264.
3. Yang, L., Padding, J.T., Buist, K.A. & Kuipers, J.A.M. (2017). Three-dimensional fluidized beds with rough spheres: validation of a two fluid model by magnetic particle tracking and discrete particle simulations. Chemical Engineering Science, 174, 238-258.



Sketch for particle-wall collision

PROJECT LEADERS
J.A.M. Kuipers

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
L. Yang, J.T. Padding, J.A.M. Kuipers

COOPERATIONS
-

FUNDED BY
European Research Council (ERC)

FUNDED %

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

START OF THE PROJECT
2013

INFORMATION

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PROJECT LEADERS
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RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
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R.A. van Santen
J.A.M. Kuipers
COOPERATIONS
Coopeartion with Dr. Ivo Filot (SMK group, Department of Chemical Engineering and Chemistry, Tue)
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.

PROGRESS

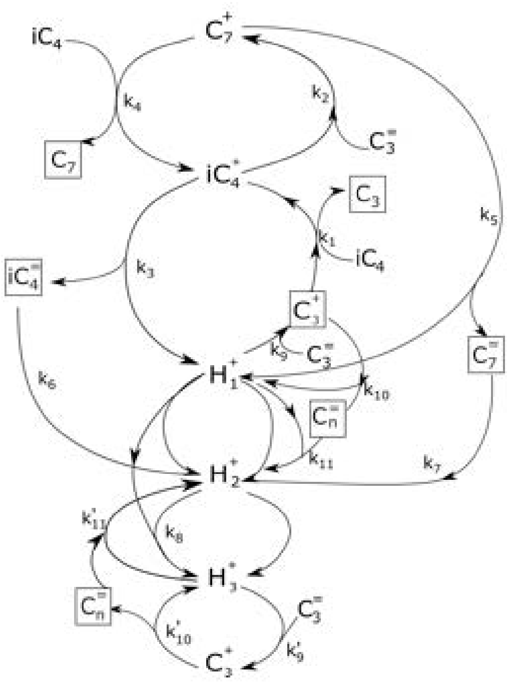
Model development using SRD (Stochastic rotation dynamics) completed. A nonlinear catalyst deactivation model was studied under mean-field and stochastic conditions. The results generated from this study are to be incorporated with the SRD mechanism. Inclusion of complex reaction mechanisms on a catalyst where reactions happen over the surface of a sphere or a planar wall.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. A. Sengar, J.A.M. Kuipers, R.A. van Santen, and J.T. Padding (2017), Particle-based modeling of heterogeneous chemical kinetics including mass transfer, Phys. Rev. E 96, 022115.



Example of a complex nonlinear catalyst deactivation scheme.

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 in-house flow solver is extended to allow for the direct numerical simulation of boiling flows. The energy equation is treated with two different approaches: Smooth interface approach and Sharp interface approach. The smooth interface approach uses one fluid formulation to solve the energy equation with an interfacial source term accounting for phase change. This interfacial source term enforces the saturation temperature at the interface. However, in the sharp interface approach, the saturation temperature is imposed as a boundary condition at the interface. Both phases are assumed to be incompressible; however; the expansion due to phase change is incorporated by modifying the divergence-free velocity field condition at the interface [2]. The implementation is validated with standard test cases and a critical comparison of smooth and sharp interface approach is carried out.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. A.H. Rajkotwala, H. Mirsandi, E.A.J.F. Peters, M.W. Baltussen, C.W.M. van der Geld, J.G.M. Kuerten and J.A.M. Kuipers (2017), Controlled coalescence with local front reconstruction method, In Proceedings of 12th International Conference on CFD in Oil & Gas, Metallurgical and Process Industries SINTEF, Trondheim, Norway.

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

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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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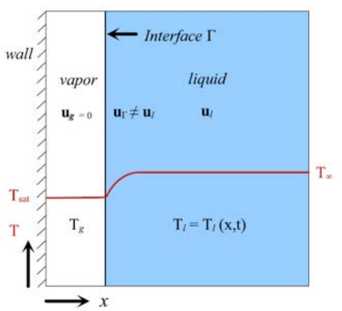
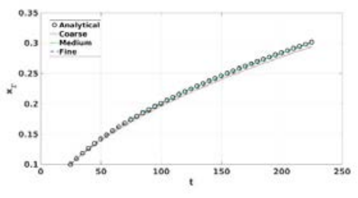
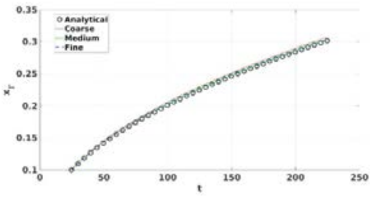
Schematic of Sucking Problem (Irfan and Muradoglu, 2017)



Variation of interface location x_Γ with time obtained using sharp interface approach.





Variation of interface location x_Γ with time obtained using smooth interface approach.

Project leaders
J.A.M. Kuipers

Research theme
Complex dynamics of fluids

Participants
A.E. Carlos Varas
K.A. Buist
J.A.M. Kuipers

Cooperations
-

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
Develop a quantitative understanding of the hydrodynamics of a spray of pyrolysis oil droplets moving through the combustion chamber after they have been sprayed from (one or multiple) nozzles. For this, a stochastic Euler-Lagrange CFD model is used. An important input for the model is the initial droplet size and velocity distribution at a suitable short distance from the nozzle. To this end, phase-doppler anemometry (PDA) measurements will be performed on a model spray using a model liquid with the same physical properties as pyrolysis oil. These measurements will also be used to validate the CFD model to predict the further evolution of droplet size and velocity.

Progress
The flow of a single-hole diesel injector is being characterized by means of LDA/PDA to collect large experimental datasets of droplet sizes and velocities. Preliminary experiments were performed on a water spray with a swirl-nozzle atomizer, where larger drops were found at the spray cone edges, where coalescence phenomena are dominant. Regarding simulations, a sensitivity analysis has been performed in order to analyze the influence of cell size, turbulence on the spray dynamics, showing little influence on the spray flow. Besides, the combustion chamber mesh has been generated and a suitable collision model implemented.

Dissertations
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Scientific publications
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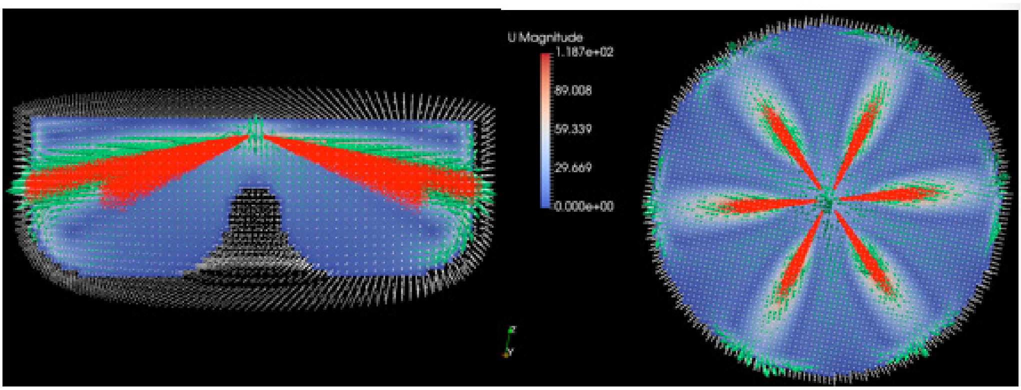
CFD simulation of a multi-hole injector spray in a combustion chamber after 1 ms (side and top view). White dots: Cartesian cell centers. Red dots: droplets. Red-blue color map: Gas velocity magnitude. Green arrows: Gas velocity vectors.



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

During the first half year the development of a Direct Numerical Simulations model has started with a three phase flow-solver with stagnant solid phase. An energy model was implemented and validated. In addition, a balanced force model was implemented for more accurate curvature and surface tension calculations A numerical study is conducted on the droplet interaction on spherical surfaces.

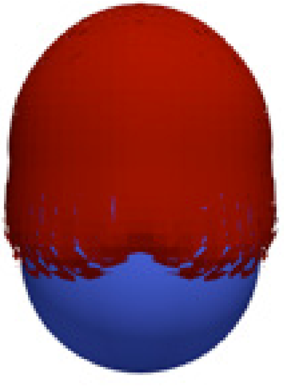
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Droplet wetting a spherical particle



PROJECT LEADERS

J.A.M. Kuipers

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

E. Milacic
M.W. Baltussen
J.A.M. Kuipers

COOPERATIONS

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I. Roghair
M. van Sint Annaland
N.G. Deen

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

Project leaders
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Research theme
Complex dynamics of fluids
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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

Mass transfer and transport is immensely important in chemical engineering, but local measurement is extremely difficult in multiphase flow due to complicated optical issues, in this project dual LIF technique is employed and developed to overcome the problems.

Progress

A new approach has been developed to overcome optical issues with classical LIF-techniques: Laser Induced Fluorescence incorporating a dual-emission dye. The dye has two emission bands corresponding to pH changes. The two bands act as a reference for one another, consequently the contribution of illumination intensity cancels out.

Both the evolution of the mass transfer and mass transfer details can be visualized by this technique (Figure 1). Optical issues are overcome, and quantitative results are guaranteed by the principle of this technique. Therefore, it shows great potential to produce local and quantitative mass transfer data.

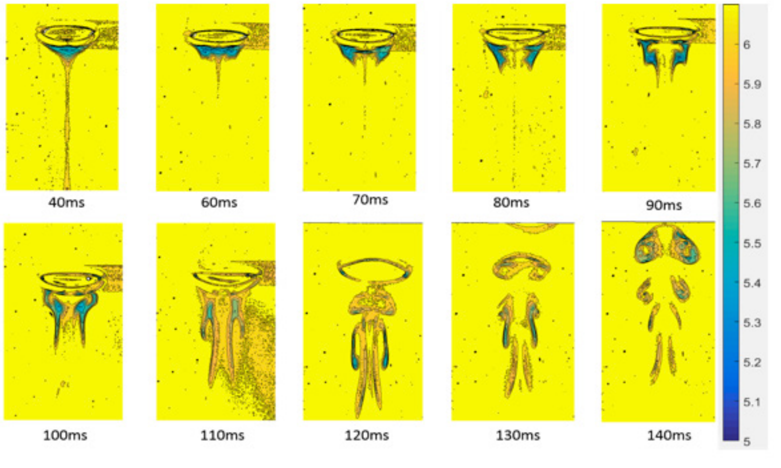
Dissertations

-

Scientific Publications

1. Kong, G., Buist, K.A., Peters, E.A.J.F., Kuipers, J.A.M., Dual emission LIF technique for pH and concentration field measurement around a rising bubble. Exp. Therm. Fluid Sci. 93, 186–194. doi:10.1016/j.expthermflusci.2017.12.032.

pH-field around the rising bubble (equivalent diameter 2mm) for 40 to 140 ms after injection.



Multiscale Experiments and Simulations of Agglomeration in Spray Driers

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. 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 will be validated with laser optical technique on a milk spray.

Progress

The droplet-droplet collision experimental set up, based on generation of two impacting steams of monodispersed drops, has been used at firs with glycerol solutions. Experiments on droplet-droplet collisions of milk solutions at three different concentrations has been successfully terminated. The model for the boundaries demarcating the collision outcomes are developed. see Fig.1, are used as closure for the macro scale numerical spray model.

The study of spray dryer on a large scale is be also numerical and experimental. An Eulerian-Lagrangian method is used to describe the dynamics of liquid droplets atomized in a high pressure spray nozzle. The droplet collision rate is detected stochastically with a Direct Numerical Simulation (DSMC) approach. Because the air is introduced in the spray at high velocities a self-induced turbulent gas flow is generated and need to be solved with a turbulent dispersion method, which is included to account for the instantaneous fluid velocities along the particles trajectories. Drying model for the dispersed phase has been coupled with heat and mass transfer equations of the continuous phase.

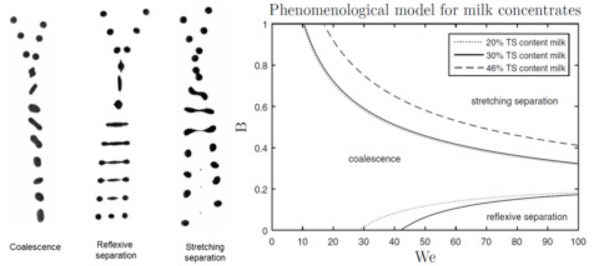
The macro scale experiments are characterized by the investigation on a spray. Phase Doppler Anemometry (PDA) is used to analyze the size and velocity distributions along the spray. These distributions are strongly affected by the viscosity and rheology of the liquid. The design of the spray setup is terminated and first test cases are in progress.

Dissertations

-

Scientific Publications

1. Kong, G., Buist, K.A., Peters, E.A.J.F., Kuipers, J.A.M., Dual emission LIF technique for pH and concentration field measurement around a rising bubble. Exp. Therm. Fluid Sci. 93, 186–194. doi:10.1016/j.expthermflusci.2017.12.032.



Collision regimes boundaries for different milk concentrates

Project leaders
J.A.M Kuipers

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
G. Finotello
K.A. Buist
J.T. Padding
J.A.M. Kuipers

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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Direct Numerical Simulation of Phase Transition in Dense Bubbly Flows

PROJECT LEADERS
J.A.M. Kuipers
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
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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

During this period, we performed DNS to investigate the influences of shear flow on the dynamics of bubble growth. In parallel, we performed experiments to provide data for validation of the present numerical model. Figure 1 shows the comparison of the results for the bubble shape at different shear rates. The figure clearly shows a good match between the experimental results and the numerical results (presented by the red lines). Therefore, the numerical model can be used to determine closures for the bubble formation in the presence of shear flow. This will enable the a priori prediction of the bubble size in a bubble column.

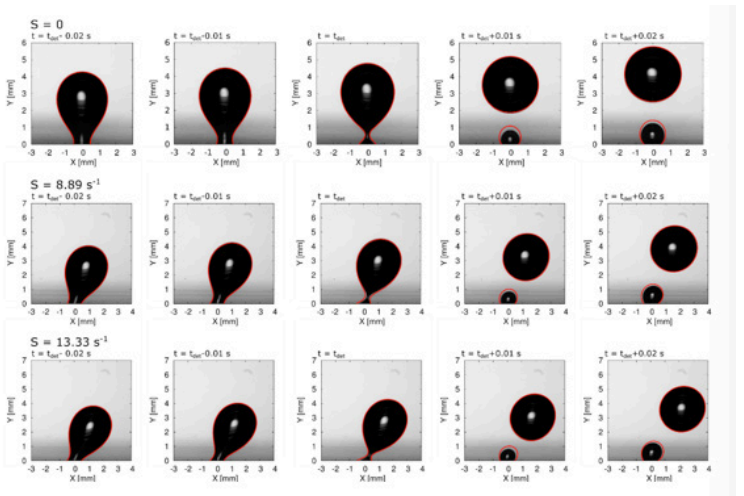
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Comparison between experimental results and the predictions of the Local Front Reconstruction Method (red lines are the contours). From the top to the bottom, the shear rate increases from 0 s-1 to 13.33 s-1.



Project Aim

Quantitatively model the mass transport chain for realistic processes with multicomponent reactant and product mixtures, polydisperse particles and catalytic reaction kinetics. With this full synthesized model, it is expected to give prediction of the performance of an industrial catalytic conversion process by computer simulation, which will give insight in the interplay of transport and reactivity, and therefore real chemical processes can be optimized.

Progress

An efficient ghost-cell based immersed boundary method is introduced to perform direct numerical simulation (DNS) of mass transfer problems in particulate flows. The unique feature of this method is its capability to handle mixed boundary conditions at the exact position of the particle surface as encountered in systems with interplay between surface reactions and diffusion. This interplay is characterized by the dimensionless Damköhler number. With the Damköhler number changing from zero to infinity, the catalytic reaction goes from reaction rate limiting to external mass transfer rate limiting.

Dissertations

-

Scientific Publications

1. Lu, J., Das, S., Peters, E.A.J.F., Kuipers, J.A.M., 2018. Direct numerical simulation of fluid flow and mass transfer in dense fluid-particle systems with surface reactions. Chemical Engineering Science 176, 1-18.
2. Lu, J., Peters, E.A.J.F., Kuipers, J.A.M., 2017. Direct Numerical Simulation of Coupled Heat and Mass Transfer in Fluid-Solid Systems, in: Olsen, J.E., Johansen, S.T. (Eds.), 12th International Conference on Computational Fluid Dynamics in the Oil & Gas, Metallurgical and Process Industries. SINTEF Academic Press, Trondheim, Norway.

Project leaders

J.A.M. Kuipers

Research theme

Complex dynamics of fluids

Participants

J. Lu
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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

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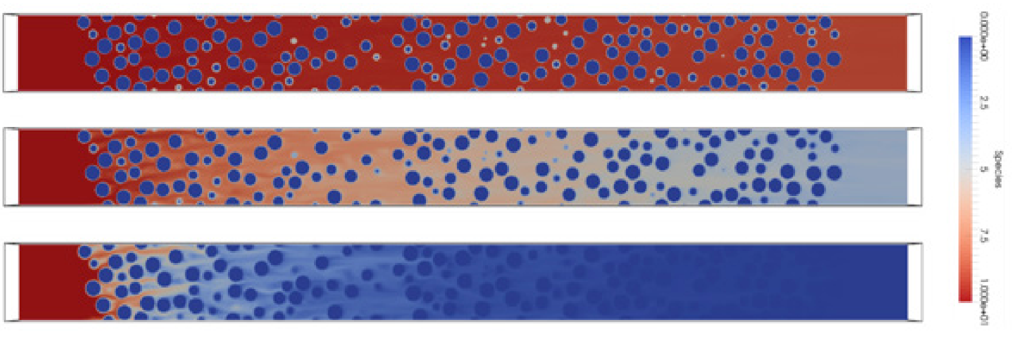

Concentration distribution in the dense particle array. From top to bottom, Damköhler number is 0.1, 1 and 10 respectively.

PROJECT LEADERS
J.A.M. Kuipers
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
H. Patel
E.A.J.F. Peters
J.A.M. Kuipers
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 widely encountered 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. The focus of this project is 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

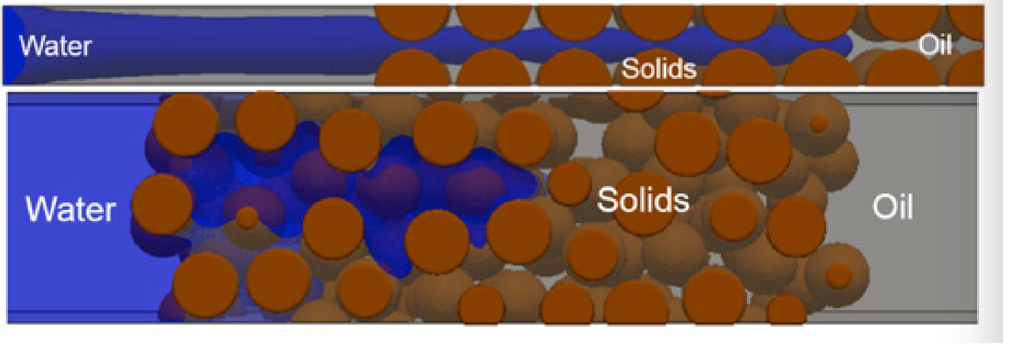
A numerical methodology is developed for simulating 3D multiphase flows through complex geometries on a non-body conformal Cartesian computational grid. Water flooding simulations are performed on two type of periodic porous structures: i) regular single pore and ii) random multi-pore arrangement. Porous structures are fully saturated with oil initially and then pressurized water displaces oil out of pores (Fig.1). We measured temporal evolution of phase pressure difference and oil saturation with time as the viscous finger/s penetrate/s pore/s. Residual oil saturation has also been quantified at the end of water flooding process. Obtained trend of results matches quite well with that of experimental and numerical results of the literature.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Patel, H.V., Das, S., Kuipers, J.A.M., Padding, J.T. and Peters, E.A.J.F., 2017. A coupled Volume of Fluid and Immersed Boundary Method for simulating 3D multiphase flows with contact line dynamics in complex geometries. Chemical Engineering Science, 166, pp.28-41.
2. Patel, H.V., Kuipers, J.A.M. and Peters, E.A.J.F., 2017. Multiphase direct numerical simulations (DNS) of oil-water flows through homogeneous porous rocks. CFD 2017 conference, Trondheim.



Viscous finger/s penetrating through a bed of regular single pore (above) and random multi pores (below) respectively

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 ow 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 a 3D CFD model is developed. A 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 figure below.

Dissertations

-

Scientific Publications

1. Maitri, R., Koimtzoglou, I., Das, S., Kuipers, J.A.M., Padding, J.T. & Peters, E.A.J.F. (2017). Direct numerical simulation of proppant transport in a narrow channel for hydraulic fracturing application. In S.T. Johansen & J.E. Olsen (Eds.), Progress in Applied CFD – CFD2017 (pp. 179-184). Oslo: SINTEF Academic Press.
2. De, S., Koesen, S.P., Maitri, R., Golombok, M., Padding, J.T. & van Santvoort, J.F.M. (2018). Flow of viscoelastic surfactants through porous media. AIChE Journal, 64(2), 773-781.

Project leaders
J.A.M. Kuipers

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
R. Maitri
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J.T. Padding
J.A.M. Kuipers

Cooperations
J. Romate, Shell

Funded by
FOM & Shell

Funded %

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

Start of the project
2014

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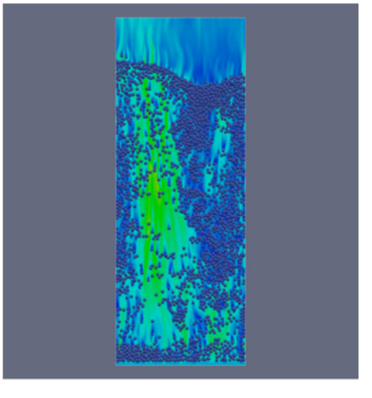

Integrated and structured FCC reactor: G(L)S multi-scale modelling of a riser reactor with draft tube for intensified and uniform phase contacting

Project leaders
N.G. Deen

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
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N.G. Deen
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 full flex 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 a first step heat transfer in a bubbling fluidized bed was studied using the open source simulation software OpenFOAM/CFDEM/LIGGGHTS. Good correspondence was found with literature data. Second a riser reactor was modelled with side inlet and as a next step a model system of ozone decomposition in a riser will be studied. This acts as a stepping stone to numerically investigate the interplay between the gas-solid hydrodynamics and chemical conversion in fluidized bed chemical conversion of biomass.

Dissertations

-

Scientific Publications

-

Flow Structure Formation and Coupling with Turbulence in Large-Scale Slurry Bubble Column

Project Aim

Our aim is to obtain a better understanding of the hydrodynamics and heat- and mass-transfer limitations, and the role of turbulence in large scale slurry bubble columns using state-of-the-art computer simulations. We are concentrating on development of a high performance parallel code and new models and approaches to predict phase interactions and aim to achieve a detailed resolution of turbulent structures and prediction of the bubble dynamics by using Direct Simulation Monte Carlo (DSMC).

Progress

Detached-Eddy Simulation (DES) method based on three RANS turbulence models was verified and validated. Tested models are: k-epsilon, SST and Spalart-Allmaras. Method was applied to square-sectioned bubble column and showed very good accuracy. Results match well with experimental data and reference numerical data. In addition, Large-Eddy Simulation with two sub-grid scale models (Vreman and Smagorinsky) were performed and compared with DES simulation. Geometry of the domain and comparison of simulated and experimental velocity profiles are shown on fig. 1 and fig. 2 respectively.

Dissertations

-

Scientific Publications

-

Project leaders

J.A.M. Kuipers

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

M.V. Masterov
M.W. Baltussen
J.A.M. Kuipers

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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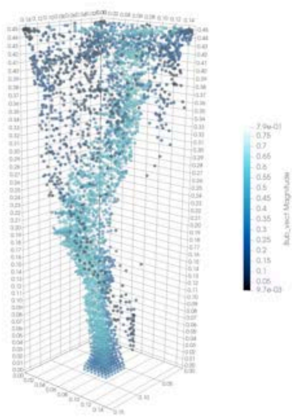
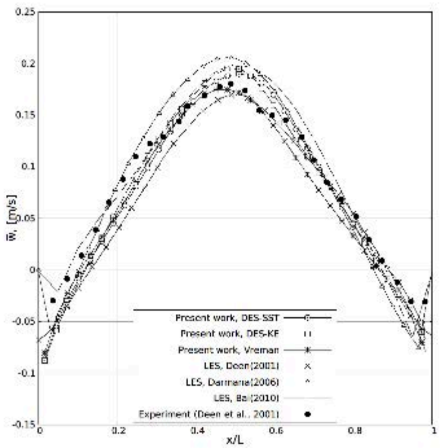


Instantaneous distribution of gas inclusions.



Time average axial liquid velocity

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
A. Panda
E.A.J.F. Peters
M.W. Baltussen
J.A.M. Kuipers

Cooperations
-

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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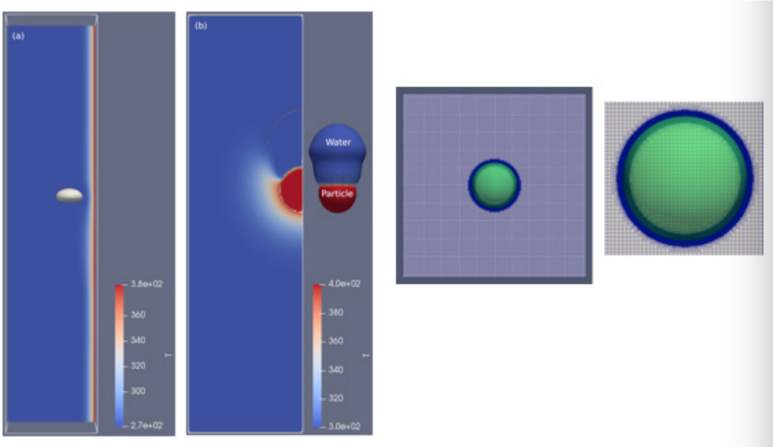
Project Aim
The aim of the project is to model and simulate heat and mass transport with chemical reactions in dense bubbly flows. One of the challenge is to accurately predict the closures for realistic gas-liquid systems that have a separation of scales at which these transport processes occur. The 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
A numerical methodology is developed for simulating the scalar transport equation on dynamically refined adaptive grids which allows for fully resolved simulations of mass transport. On the other hand, a numerical code has been implemented for simulating the heat transport using a single field formulation which has been further extended to study periodic bubble swarm using the Local Front Reconstruction Method and it has also been extended with the VOF method and contact angle implementation to study the effects on wettability on heat transfer characteristics. A snapshot of a bubble rising near a hot wall can be seen in Fig 1(a) whereas Figure 1(b) shows the effect of contact angle on temperature profile in submerged particle and Figure 1(c) shows the adaptively refined grid at the bubble interface for fully resolved mass boundary layer.

Dissertations
-

Scientific Publications
1. Panda, A., Peters, E. A. J. F., Baltussen, M. W., Kuipers, J. A. M., "Multiscale approach to fully resolved boundary layers using adaptive grids", CFD 2017 Conference, Trondheim.

(a) Single bubble rising near a hot wall (b) Water droplet impact on hot spherical particle (c) Adaptively refined mesh at the gas liquid interface.



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 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, filled with mono-disperse spheres and at moderate column-to-particle diameter ratios, was studied numerically using a CFD approach based on the IBM-DNS method. Irregular particle arrangements within the reactors were generated using an available open-source DEM code (LIGGGHTS). The research activity was focused on mass transfer phenomena and two different case studies (spheres with diameters of 3 and 5 mm) were selected for numerical analysis. The CFD analysis provided useful data (Fig. 1) that can be applied for a deeper understanding of the fundamental transport phenomena in packed beds.

Dissertations

-

Scientific Publications

-

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	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2014

Information

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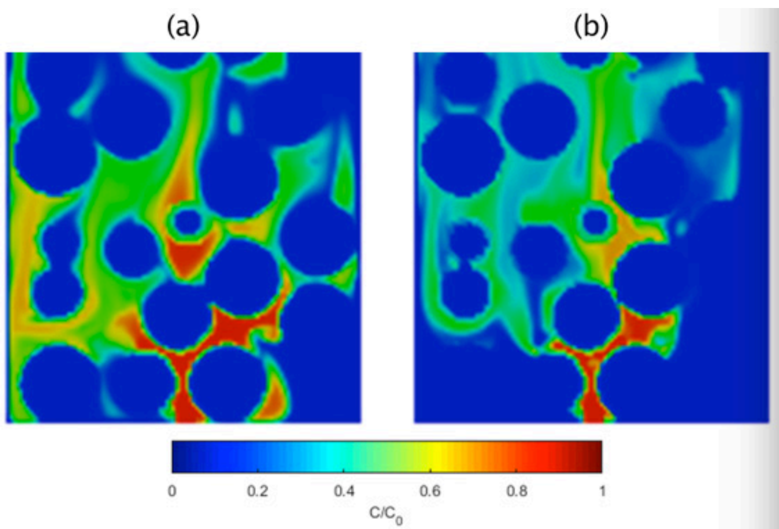
Steady-state snapshots for IBM-DNS simulations of tracer dispersion along the longitudinal direction in a packed bed of spheres with a column-to-particle diameter ratio of 4.2 at different values of the molecular Peclet number: Pem=104 in (a) and Pem=105 in (b).



PROJECT LEADERS
J.A.M. Kuipers

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
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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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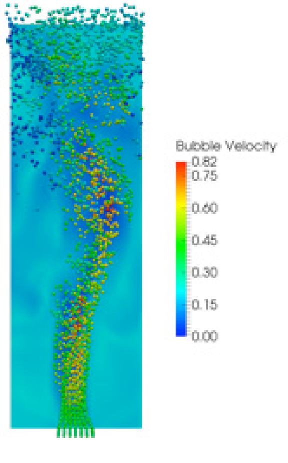
PROJECT AIM
To develop a model for large scale slurry bubble columns using stochastic Euler-Lagrangian methods. Deterministic methods like the Discrete Bubble Model provide detailed enough information on the type of flow and also track the position of all bubbles at the same time. This becomes computationally 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.

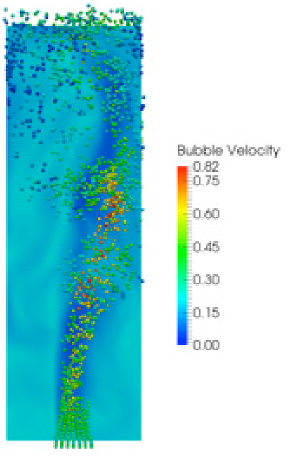
PROGRESS
A stochastic DSMC model has been verified with a DBM model within a 3D periodic system and validated with the experimental data of a lab scale bubble column (Deen 2001). The model is currently being parallelized and also being coupled with an equivalently parallelized flow solver. In addition a free surface and particles are being added to the system 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.
2. Kamath, S.S., Padding, J.T., Buist, K.A. & Kuipers, J.A.M. (2017). Stochastic DSMC model for large scale dense bubbly flows. Progress in Applied CFD – CFD2017, SINTEF Academic Press.

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





Modeling of dynamic solid particle bed and liquid behavior – applied to the blast furnace hearth

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

For the simulations, the CFD-DEM model is currently undergoing verification. Appropriate models were selected for each of the interaction forces: Archimedes force, Pressure gradient force, Viscous force, Drag force, Lift force, Virtual mass force. For experiments, a set-up was designed. Properties of existing, industrial scale blast furnaces were used to size the set-up to the scale of the Magnetic Particle Tracking (MPT) device, whilst keeping its flow properties as constant as possible. Furthermore, materials were selected based on desired physical properties, practical applicability and costs.

Dissertations

-

Scientific Publications

-

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

2018

Information

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Direct Numerical Simulation of heat and mass transport in micro-structured catalysts

Project leaders
J.A.M. Kuipers

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
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E.A.J.F. Peters

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

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Project Aim

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 heat and mass transport within these catalysts using Direct Numerical Simulation (DNS) techniques. A finite-volume based Immersed Boundary Method will be used to fully resolve transport phenomena at the pore-scale level.

Progress

The mass transfer of reactants in fixed bed reactors represents 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 the in-house CFD code. The species balance equation was solved in a spatially periodic unit cell consisting of an idealized representation of open-cell foams. Figure 1 pictorially represents the dispersion of the tracer solute for different Peclet numbers (Pe). It is found that dispersion increases quadratically as a function of the Peclet number which indicates that dispersion in ordered porous media follows a similar trend as Taylor dispersion in cylindrical tubes.

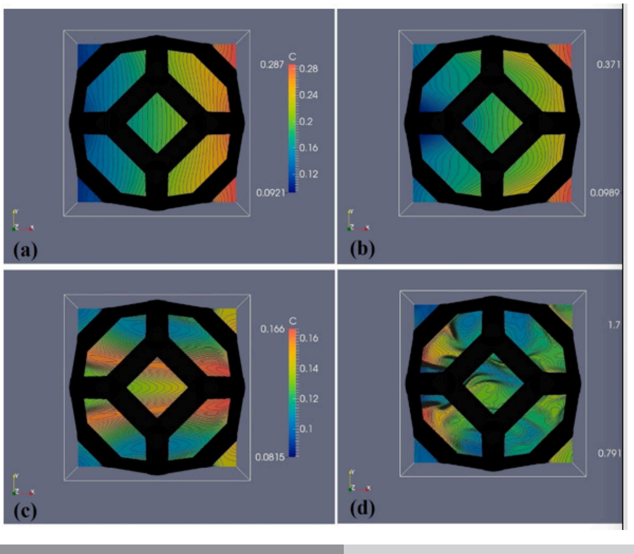
Dissertations

-

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



Direct Numerical Simulation (DNS) of transport and chemical reaction in three-phase flows

Project Aim

From the previous decades, a wide study on the mass transfer of a fluid particle is ongoing due to its many industrial applications. Mass transfer from a rising bubble or droplet is still challenging, both numerically and experimentally due to its complex hydrodynamic interactions along an embedded interface. The species boundary layer along the embedded interface is comparatively thinner than the momentum boundary layer. Hence, a fine grid would be needed to fully resolve the species boundary layer due to its sharp concentration gradient in the vicinity of the bubble interface. Especially at a high Schmidt number, such a fine grid of Direct Numerical Simulation (DNS) would make 3D simulations computationally very expensive. Therefore, in the present study, a boundary layer approach is introduced to model the species boundary layer along the bubble interface. The Navier-Stokes equations are solved on a relatively coarse grid using the front-tracking method to represent a bubble interface. Away from the interface the convection-diffusion equation is also solved on this coarse-grid, while being coupled to the mass boundary-layer at the bubble interface. Due to the coupling of the mass boundary layer method with a front tracking method, the computation becomes feasible.

Progress

In the present work, we have implemented the mass boundary layer method which is embedded with our 3D in-house Front Tracking code. With this implementation, spherical, ellipsoidal, spherical cap and wobbling bubbles are simulated at different Eötvös and Reynolds numbers. In these simulations, an industrial scale bubble diameter is considered at different viscosity ratios to investigate the mass transfer phenomena. The simulated local Sh number for a spherical bubble and simulated global Sh number for a spherical, ellipsoidal, spherical cap and wobbling bubble are compared with the Sh correlation at different Reynolds and Péclet number.

Dissertations

-

Scientific Publications

-

Project leaders

J.A.M. Kuipers

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

S. Islam
M.W. Baltussen
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

2014

Information

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Chemical process intensification

Prof.dr.ir. M van Sint Annaland

Chemical Process Intensification /Multiphase Reactors Group / Dept. of Chemical Engineering & Chemistry / TUE

The research group Chemical Process Intensification (SPI) is part of the faculty of Chemical Engineering and Chemistry at the Eindhoven University of Technology. The main objective of the research group is the development of novel integrated reactor concepts based on improved fundamental knowledge using validated advanced (multi-phase) reactor models. This is achieved by employing a combination of state-of-the-art numerical models (at different levels of detail using the multi-level modeling approach), advanced (non-invasive) experimental techniques and experimental demonstration of novel reactor concepts (proof of concept).

A key competence of the group is the development and use of use of advanced (multi-phase) reactor models, coupled to mass and heat transfer and chemical reactions, in order to study integrated reactor concepts. Our modelling work ranges from ‘as detailed as necessary’ to ‘as large-scale as possible’; we employ models for redox kinetics on a single particle scale and detailed simulations of gas-liquid flows, discrete bubble/particle models, up to industrial-scale phenomenological models and process systems modelling. We use both in-house created models and open-source based models. A cornerstone of our research is careful (experimental) validation and verification.

Another aspect is the development of advanced, non-intrusive, experimental techniques to measure key quantities (i.e. local volume fractions and velocities of the dispersed and continuous phase). We have developed a PIV-DIA technique (particle image velocimetry coupled to digital image analysis) that measures accurately, in a non-intrusive manner, the solids fluxes in (dense) gas-solid fluidized beds. Moreover, we established an infra-red technique for whole-field concentration measurements in gas-solid fluidized beds, and we have demonstrated and built a facility that can measure gas and solids fluxes under reactive conditions (i.e. elevated temperatures up to 400 °C) using endoscopic PIV. The group also owns state of the art equipment for catalyst characterization, membrane characterization and reactor characterization. The equipment list includes – but is not limited to – magnetic suspension balance, two TGA’s, DSC, XRD, SEM, AES, viscometers, different membrane permeation setups, kinetic setups, etc.

Our experimental and modelling expertises form a strong alliance in the development of novel intensified reactor concepts. As an example we mention here the development of a fluidized bed membrane reactor concept for the production of ultra-pure hydrogen with integrated CO2 capture via chemical looping. This involves dedicated studies into various oxygen carriers used for chemical looping by experiments (e.g. thermogravimetric analysis) in conjunction with detailed particle models to describe the redox kinetics, fundamental studies into reactor design and operation of fluidized bed membrane reactors using multiphase flow models (accounting for mass transport and perm-selective membranes), and process systems modelling on industrial scale. The knowledge and tools developed in our group provide a sound basis to place this research activity on a firm footing.

Project Aim

The main objective of this project is to understand 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), there are several uncertainties on design optimization and safety management. Moreover, wet particles will form agglomerates and fouling on the walls, which causes downtime for cleaning operations. For this purpose, we will develop a range of numerical models of decreasing complexity and increasing scale, from high-detailed direct numerical simulations (in collaboration with Prof. Kuipers/Evan Milacic), through meso-scale Euler-Lagrange models to a full scale FB reactor using a phenomenological approach. This research forms part of the research programme of DPI, project #803.

Progress

We are setting up a phenomenological model for a fluidized bed gas-phase polymerization process in presence of a liquid (used as an evaporating cooling agent), solving mass and energy balances coupled to the hydrodynamics. This model takes account coupled material and heat transport, chemical reactions and liquid evaporation. In the future, these balances will be completed and refined using results from smaller-scale simulations, e.g. taking into account the presence of liquid on the hydrodynamics of fluidization.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir M. van Sint Annaland
Prof.dr.ir. N.G. Deen
Dr.ir. I. Roghair

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Dario M. Balice

Cooperations

Prof.dr.ir. J.A.M. Kuipers
Dr.ir. M.W. Baltussen
Evan Milacic

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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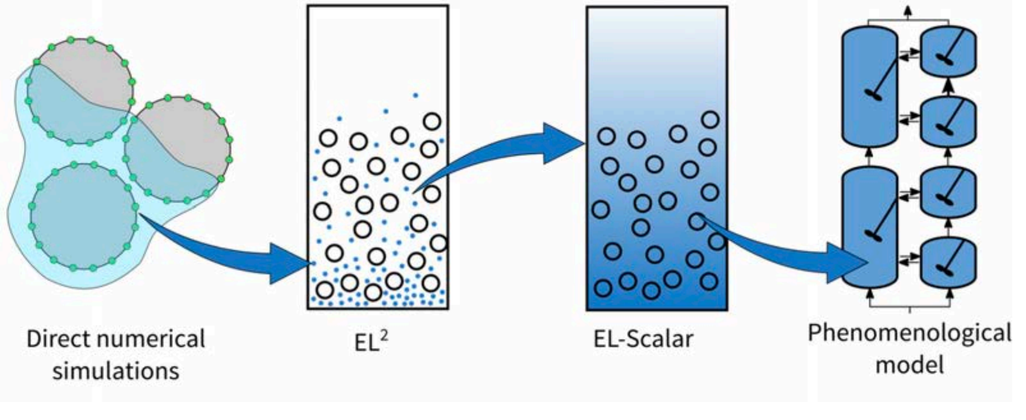

Chemical Looping Reforming for pure hydrogen production with integrated CO2 capture (ClingCO2)

Project leaders
F Gallucci
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
RJW Voncken, JA Medrano Jimenez
I Roghair, M van Sint Annaland
Cooperations
TTW, Sintef, Tecnalia, Shell, ECN, Air Products, Hygear
Funded by
TTW / NWO
Funded %

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

Start of the project
2013
Information
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Project Aim

The project aims to develop a novel reactor concept for the production of ultra-pure hydrogen with integrated CO2 capture. The reactor concept is based on overall auto-thermal reforming of methane in a fluidized bed reactor where immersed hydrogen perm-selective membranes are used to extract and simultaneously purify the hydrogen, whilst driving the chemical equilibria towards the desired hydrogen product. The project aim is to obtain hydrodynamic, mass transfer and reaction rate data for fluidized bed membrane reactors. The reactor concept will be researched and developed with a Two-Fluid Model. Mass transfer limitations from the emulsion phase to the membranes, the effect of membranes on the hydrodynamics and the effect of membranes on the reaction rates will be studied.

Progress

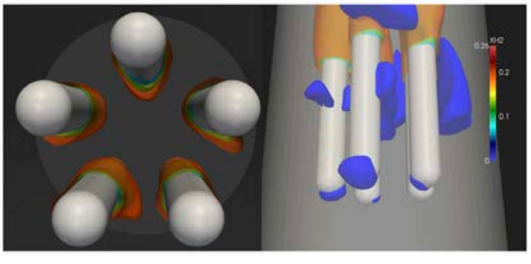
- A geometric study on fluidized beds with vertically immersed membranes has quantified concentration polarization in these type of reactors, and shows how the concentration polarization zones of multiple membranes can interact with one another. The bubble sizes are affected by the membranes, however, the bubbles still mainly move through the center of the reactor, even when a membrane is present at this location (Figure 1).
- Hydrogen extraction via membranes significantly increases the reaction rates of the Steam Methane Reforming and Water Gas Shift reaction. Interesting observations are the increased reaction rates in densified zones on top of membranes, and the reduced reaction rates in gas pockets underneath horizontal membranes. Most of the hydrogen bypassing occurs near the walls, so different fluidized bed membrane reactor designs are required to reduce this.

Dissertations

-

Scientific Publications

1. A. Helmi, R.J.W. Voncken, A.J. Raijmakers, I. Roghair, F. Gallucci, M. van Sint Annaland. “On concentration polarization in fluidized bed membrane reactors”, Chem. Eng. J. 322.
2. R.J.W. Voncken, I. Roghair, M. van Sint Annaland. “Mass transfer phenomena in fluidized beds with horizontally immersed membranes”, Proceedings of the 12th International Conference on CFD in Oil and Gas, Metallurgical and Process Industries.
3. R.J.W. Voncken, I. Roghair, M. van Sint Annaland. “A Two-Fluid Model study of hydrogen production via Water Gas Shift in fluidized bed membrane reactors”, Proceedings of the 12th International Conference on CFD in Oil and Gas, Metallurgical and Process Industries.



Snapshot of a fluidized bed membrane reactor with 5 vertically immersed membranes; the contours around the membranes represent the H2 concentrations, the blue objects are gas bubbles.

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

An Eulerian-Lagrangian solver has been completely set up and validated, including mass transfer. The supersaturation algorithm developed last year has been updated and extended to be grid independent and include discrete nucleation sites on a surface. The bubble collision part has been corrected for some bugs. A first draft of a Front-Tracking-based free surface has been included, which is currently being debugged and completed. A comparison between the E-E and the OpenFOAM Two Fluid Model (TFM) has been started. The TFM has been used to simulate heat transfer between two plates and compared to experiments from another subproject.

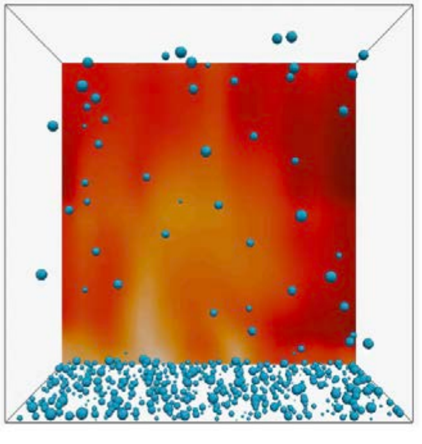
Dissertations

-

Scientific Publications

1. Battistella, A., van Schijndel, S.J.G., Baltussen, M.W., Roghair, I., and van Sint Annaland, M., (2017) Front-Tracking simulations of bubbles rising in non-Newtonian fluids. 12th International conference on CFD in Oil & Gas, Metallurgical and Process Industries, May 30th – June 1st, Trondheim, Norway.
2. Battistella, A., Aelen, S.S.C., Roghair, I., and van Sint Annaland, M., (2017) Large scale modeling of bubble formation and growth in a supersaturated liquid. 12th International conference on CFD in Oil & Gas, Metallurgical and Process Industries, May 30th – June 1st, Trondheim, Norway.

Simulation of Heat & Mass Transport and Phase Transitions in Dense Bubbly Flows at Intermediate and Large Scale



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), AkzoNobel, 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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PROJECT LEADERS
Prof.dr.ir. M. Van Sint Annaland

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
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Dr.ir. Ivo Roghair

COOPERATIONS
-

FUNDED BY
-

FUNDED %

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

START OF THE PROJECT
2017

INFORMATION
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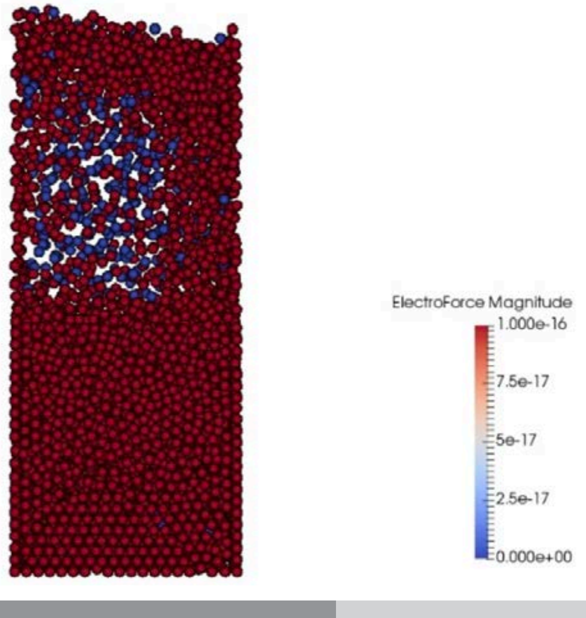
PROJECT AIM
The main objective of this project is to provide fundamental understanding of fouling and agglomerate formation in fluidized beds due to the effect of charge generation in fluidized bed. By extending the discrete particle model (DPM) with tribo-electrification and frictional charging due to particle-particle and particle-wall collisions and adding the inter-particle electrostatic force, formation of clusters and fouling in surface can be anticipated. The effect of the electrostatic force in fluidized beds on properties like bubble size, void fraction and particle clustering will be investigated. We are validating the model results using experimental data.

PROGRESS
The electrostatic force with constant-charged particles has been added to the DPM, and systems of mono charged and double charged particles are compared to each other. It was shown that in the system of highly charged particles, wall sheeting appears (indicating the onset of fouling). In the next step, accumulation of charges in particles due to collisions has been implemented based on the condenser model.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-

Electrostatic force of predefined charge particle in gas-solid fluidized bed system



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 discrete particle model is used to investigate the influence temperature on the fluidization behavior. We have indications from earlier experimental work that inter-particle forces (such as van der Waals forces) may be accountable for this effect. Initial simulation results show indeed the influence of VdW forces, which are higher for Geldart A particles than for Geldart B particles. It was also found that due to this force particles could form agglomerates. 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

1. Mihajlovic, M., Roghair, I., and van Sint Annaland, M. (2017). High temperature fluidization -influence of inter-particle forces on fluidization behavior. 12th International Conference on Computational Fluid Dynamics In the Oil & Gas, Metallurgical and Process Industries, 30. May – 1. June 2017, Trondheim, Norway.

Project leaders

Prof.dr.ir. M. Van Sint Annaland

Research theme

Complex dynamics of fluids

Participants

Milan Mihajlović, MSc
Prof.dr.ir. M. Van Sint Annaland
Dr.ir. Ivo Roghair

Cooperations

-

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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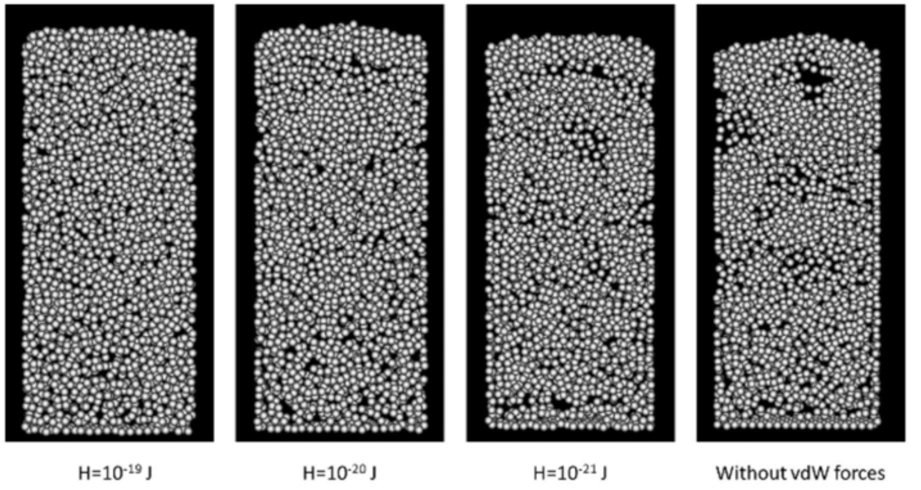
Snapshots of fluidized bed simulations with various Hamaker constants, which influences the magnitude of the Van Der Waals force.



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

By a combined experimental and numerical study it will be investigated how problems related to fouling, process reliability and flow instability in the miniaturization of evaporators can be avoided by changing the contact area between liquid and solid. The project is aimed and enhancing our understanding of controlled evaporation and at developing an engineering simulation model for use at practical scales.

PROGRESS

The aim of the project part carried out by L. Boer is the design and commissioning of two experimental test rigs for research on phase change heat transfer. The research aims to improve our current understanding of phase change heat transfer and aids the validation of numerical models for multiphase non-isothermal flows.

The first experiment focusses on the evaporation of droplets on porous substrates. Focal point is the effect of imbibition on the evaporation process. The droplet is placed on a heated substrate and the droplet shape and temperature are recorded by high speed and thermal imaging.

The second experiment involves boiling heat transfer in microchannel. In these small structures boiling can occur rather violently due to explosive bubble growth. Also fouling is a common problem in industrial applications. It is investigated if injection of a non-condensable gas onto the heated channel wall can overcome these issues.

The topics of study are defined and the experimental approach has been established, including required equipment and measurement strategies. As by the end of 2017, the equipment is being set up and commissioned. Relevant measurements are expected to take place mid-2018.

The progress of other parts of this project have been reported via other participants.

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

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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.

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 framework for numerical simulations of the Drift Flux Model. We established the order of merit of existing numerical schemes and also conducted accurate analysis of conditional hyperbolicity of the model. We implemented the standard projection based approaches in conjunction with hyper-reduction techniques on several benchmark problems (in the field of fluid dynamics) and investigated their effectiveness as a reduced-order modelling technique. We investigated unconventional model order reduction techniques to mitigate the challenges observed in classical reduced-order representation of convection dominated problems.

Dissertations

-

Scientific Publications

-

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)

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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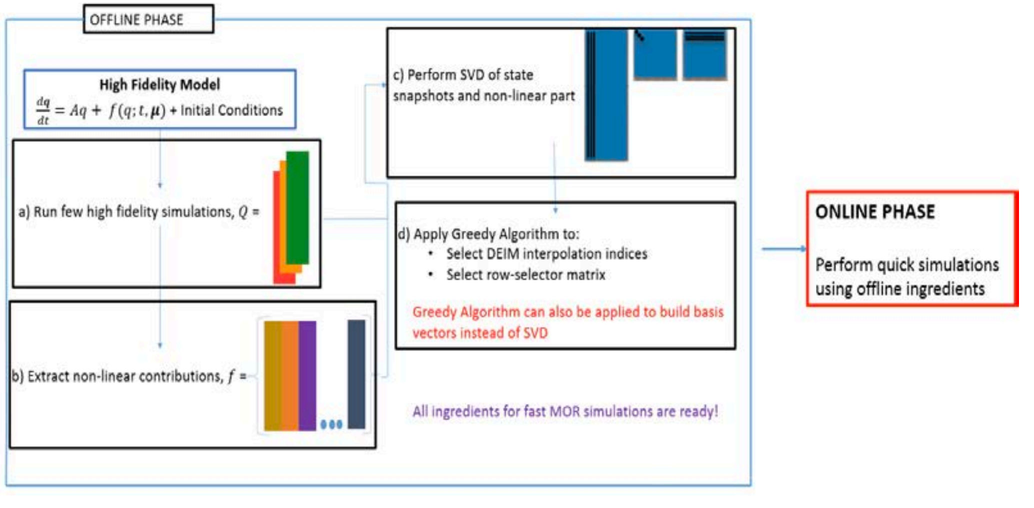
Model Order Reduction Strategy



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 a cut-cell approach. Discrete exact conservation statements were derived for the method. The method has been implemented in 2D and was tested on a set of benchmark flows, like the flow around a cylinder and the flow around an airfoil. Accurate results close to the reference solutions were obtained and the discrete exact conservation statements were verified. Currently the method is being implemented in 3D.

Dissertations

-

Scientific Publications

1. R. Beltman, M.J.H. Anthonissen, B. Koren, Mimetic staggered discretization of incompressible Navier-Stokes for barycentric dual mesh, International Conference on Finite Volumes for Complex Applications (2017) 467-475.

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 thermally 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 it has been improved upon by use of a new limiter. Several test cases were numerically simulated to validate the method.

Dissertations

-

Scientific Publications

-

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
dr. M.E. Hochstenbach (supervision)
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	50 %
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

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Project Aim

The goal of the project is to develop a fully stochastic approach to include correlation of wind and waves in calculating the loads on wind turbines, by making use of the probability distribution in wind loads and existing wind-wave models. The challenge is to develop efficient and realistic modelling by enabling treatment of different sources of uncertainty in one single computational space. When this is combined with smart sampling techniques, calculation times will be drastically reduced.

Progress

In 2017, a new method for dependency analysis has been developed. In this way, dependencies in data sets which serve as an input for simulations can be detected. This method can deal with strong, nonlinear dependencies, in contrast to several widely-used methods. Research has continued by developing a stable emulation method, such that the dependency analysis method can also be used for sensitivity analysis. The goal is that these methods can then be used to estimate the distribution of the loads on wind turbines for different models.

Dissertations

-

Scientific Publications

-

Project Aim

The project is primarily aimed towards developing sophisticated numerical techniques for studying the flow of incompressible fluids. The developed numerical methods will be used for investigating turbulent wind farm wakes and for designing optimal wind farms.

Progress

We have developed and implemented spatial discretization methods for the approximation of flux functions involved in nonlinear flow problems. The numerical flux is computed from a two-point local boundary value problem (BVP). The computed flux depends on the local Péclet number (ratio of the convective and viscous force) and source term, e.g., the pressure gradient. The local BVP methods result in a three point coupling (in each direction) and are second-order convergent. The resulting spatial discretization is robust and does not introduce any spurious oscillations even on coarse grids (high Péclet numbers).

Dissertations

1. Flux approximation schemes for flow problems using local boundary value problems, N. Kumar, Eindhoven University of Technology.

Scientific Publications

1. N. Kumar, J.H.M. ten Thije Boonkkamp, B. Koren and A. Linke, A nonlinear flux approximation scheme for the viscous Burgers equation, Proceedings in Mathematics & Statistics (200): 457−465 , Springer, 2017.

Project leaders

prof.dr.ir. B. Koren
dr.ir. J.H.M. ten Thije Boonkkamp

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

N. Kumar (PhD-student)

Cooperations

Shell-NWO Program-Computational Sciences for Energy Research

Funded by

FOM

Funded %

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

Start of the project

2013

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 the porous media. The main focus is on heterogeneous and fractured systems and on non-equilibrium models where dynamic or hysteresis effects are included in the difference between the two phase pressures, and/or in the relative permeabilities.

Progress

This year we have: 1) Published our results on traveling waves for non-equilibrium models in gravity driven porous flows; 2) Published our results for a new linear domain decomposition scheme for unsaturated/partially saturated porous media flows; 3) Completed the work on a new hysteresis model for capillary pressure in multiphase flow through porous media. The new model incorporates the non-vertical scanning curves seen from experiments and predicts all cases of horizontal redistribution. 4) Formulated a new linear iteration scheme for nonlinear parabolic equations rising from diffusion problems such as multiphase flow through porous media. The scheme is simple, stable and fast (see Figure 1).

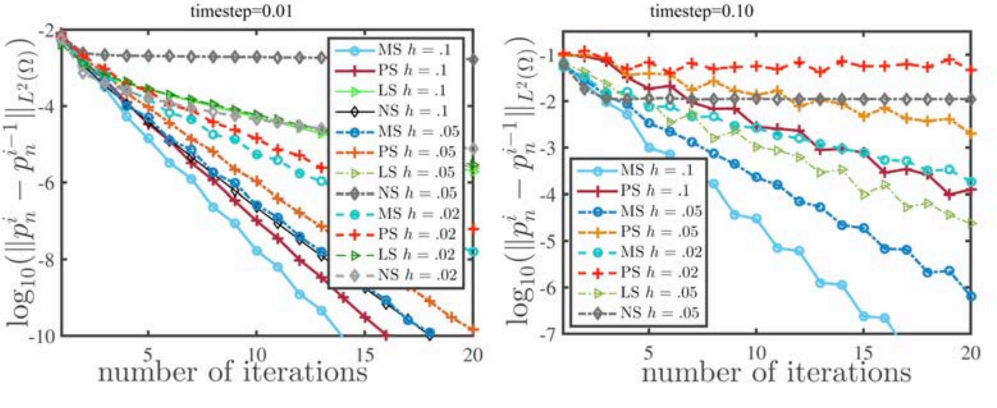
Dissertations

-

Scientific Publications

1. van Duijn, C. J., Mitra, K., & Pop, I.S., Travelling wave solutions for the Richards equation incorporating non-equilibrium effects in the capillarity pressure. Nonlinear Analysis: Real World Applications, 41 (2018), 232-268.
2. Seus, D., Mitra, K., Pop, I.S., Radu, F.A., & Rohde, C. A linear domain decomposition method for partially saturated flow in porous media. Computer Methods in Applied Mechanics and Engineering, (2018), 333, 331 – 355.
3. van Duijn, C. J. & K. Mitra. Hysteresis and Horizontal Redistribution in Porous Media. Transport in Porous Media (2018), 1-25.
4. Mitra, K., & Pop, I.S. A modified L-Scheme to solve nonlinear diffusion problems. submitted in Computers & Mathematics with Applications.

The L^2-errors of different schemes with linearization iterations. MS is the scheme proposed; PS is the Picard scheme; NS is the Newton scheme and LS the L-scheme. The results are presented for two timesteps. It shows that the proposed scheme is both faster and more stable than other, more conventional schemes.



SLING, project 2: Free-Surface Instabilities and Uncertainty Quantification

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 thermally 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

Constructed a UQ method which is suitable for discontinuous model responses.

Constructed a UQ method which is suitable for constructing parametric solutions of PDEs.

Simulated advanced sloshing simulations with an open-source SPH code (DualSPHysics).

Dissertations

-

Scientific Publications

-

Project leaders

Prof. dr. ir. B. Koren (TU/e),
Dr. ir. B. Sanderse (CWI) (supervisor)

Research theme

Complex dynamics of fluids

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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Comparison between hypervelocity impact of particles and pulsed laser thermal impact models on glue bonded laminates under cryogenic conditions

Project leaders
Prof.dr.ir. B.Koren

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
I. Zisis and dr.ir. B.J. van der Linden

Cooperations
Applied Analysis chair, CASA, TU/e Department of Mathematics & Statistics, Dalhousie University, Canada -Mathematics Institute, University of Warwick, United Kingdom

Funded by
Materials Innovation Institute m2i and Laboratory for Industrial Mathematics Eindhoven, LIME BV.

Funded %

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

Start of the project
2011

Information
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Project Aim

The final goal of this project is to study hypervelocity impacts into laminated materials. For that purpose we extend the capabilities of the Smoothed Particle Hydroynamics (SPH) method, modify existing algorithms and create a computational tool.

Progress

In June 2017, the project concluded with the publishing and successful defense of Iason Zisis' doctoral thesis. Additionally, after a long-review period, an important result of the current project was published in the prestigious journal Zeitschrift fur Angewandte Mathematik und Mechanik (ZAMM). Finally, unpublished research from the current project is being prepared for submission to the Journal of Computational Physics.

Dissertations

1. I.Zisis; From Continuum Mechanics to Smoothed Particle Hydrodynamics for Shocks through Inhomogeneous Media, June 2017 – TU Eindhoven.

Scientific Publications

1. J.E.Evers, I. A. Zisis, B. van der Linden and M.H. Duong; From continuum mechanics to SPH particle systems and back: systematic derivation and convergence, ZAMM Zeitschrift fur Angewandte Mathematik und Mechanik 98(1), pp. 106-133, 2018.

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

Different finite volume techniques have been tested on single- and multi-phase flow as a stepping stone to simulate drilling procedures for oil and gas. The single- and multi-phase flow solvers are upgraded for the case of area discontinuities in the drilling pipes and these upgraded solvers are connected to build a drilling simulator amenable for realistic drilling test cases. The platform has been validated against field data as well. As the first step toward the final goal of the project, the Reduced Basis (RB) method has been applied on the system with considering only single-phase flow inside the drilling pipes which reduces the CPU time by the approximate factor of 20.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

Nathan van de Wouw, W.H.A. 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)
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 exterior CHTC at high Reynolds number for building applications to be able to provide new insights and develop new and improved CHTC expressions. This leads to the following subobjectives:

1) Obtaining windtunnel data of CHTC at high Reynolds numbers for CFD validation.

2) Development of new wall functions for CFD simulations of CHTC.

4) Analysis of the influence of different parameters, e.g. building geometry, on CHTC.

6) Development of new generalized CHTC expressions.

PROGRESS

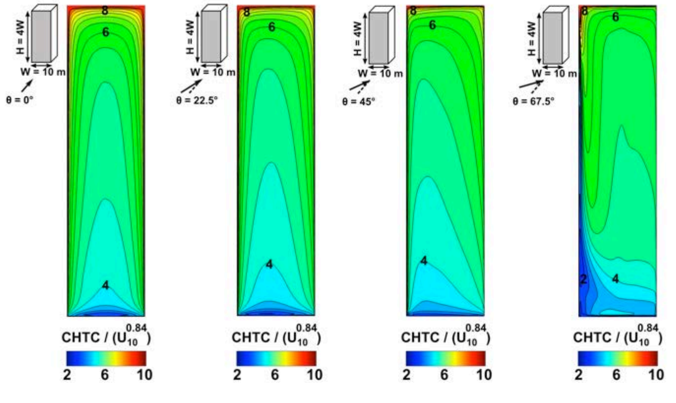
The performance of non-conformal grids, consisting entirely of cubic cells, for LES simulations of wind flow and convective heat transfer around a wall-mounted cubic obstacle was investigated. In addition, CFD simulations were performed to investigate the complex interaction between the forced CHTC, reference wind speed at 10 m height (U10), building dimensions and wind direction. The results led to new generalized CHTC expressions for different building facades and roofs as a function of these parameters. The following figure shows the CHTC/(U100.84) distribution across the windward facade of a building for different reference wind directions.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Montazeri H., Blocken B. New generalized expressions for forced convective heat transfer coefficients at building facades and roofs. Building and Environment 119 (2017) 153-168.
2. Iousef S., Montazeri H., Blocken B., van Wesemael P. On the use of non-conformal grids for LES of flow field and convective heat transfer for a wall-mounted cube. Building and Environment 119 (2017) 44-61.
3. Antoniou N., Montazeri H., Wigo H., Neophytou M., Blocken B., Sandberg M. CFD and wind tunnel analysis of outdoor ventilation in a real compact heterogeneous urban area: Evaluation using “air delay”. Building and Environment 126 (2017) 355-372.



PROJECT LEADERS

Prof.dr.ir. Bert Blocken

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Hamid Montazeri

COOPERATIONS

-

FUNDED BY

Research Foundation – Flanders (FWO)

FUNDED %

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

START OF THE PROJECT

2015

INFORMATION

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Analysis of ventilation flow in slot-ventilated enclosures by temporal forcing of the inlet jet

Project leaders
Twan van Hooff, Bert Blocken

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Twan van Hooff, Bert Blocken

Cooperations
GertJan van Heijst (TU/e, Applied Physics)

Funded by
Research Foundation – Flanders (FWO), project no. 12R9718N

Funded %

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

Start of the project
2014

Information
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www.twanvanhooff.nl

Project Aim

The indoor environmental quality in buildings and other enclosures heavily depends on ventilation, while the amount of ventilation should be controlled to reduce energy demands for heating and cooling. In the present study, the effect of temporal forcing on enclosure airflow will be investigated, not only with the aim to increase the mixing efficiency of the jet, but, more importantly, also with the aim to break up airflow recirculation cells in the enclosure. The research is conducted using state-of-the art experimental and numerical techniques for both a generic enclosure and more realistic enclosures.

Progress

A time-dependent supply condition can enhance mixing and locally decrease contaminant concentrations with up to 50% without increasing volume flow rates in a generic mixing ventilation case. However, the numerical analysis of mixing ventilation flows subjected to temporal forcing is very computationally expensive and the number of investigated parameters has therefore, up until now, been limited. At the moment, this project aims at introducing and developing two advanced numerical techniques, i.e. recurrence computational fluid dynamics (rCFD) and fast fluid dynamics (FFD), which can reduce computation time.

Dissertations

-

Scientific Publications

1. van Hooff T, Blocken B. The influence of physical and numerical diffusion on the flow field and contaminant distribution for low-Reynolds number mixing ventilation flows. Building Simulation 10(4): 589-606. doi:10.1007/s12273-017-0354-3.
2. van Hooff T, Blocken B, Tominaga Y, 2017. On the accuracy of CFD simulations of cross-ventilation flows for a generic isolated building: Comparison of RANS, LES and experiments. Building and Environment 114, 148-165. doi:10.1016/j.buildenv.2016.12.019.
3. Khayrullina A, van Hooff T, Blocken B, van Heijst GJF. 2017. PIV measurements of isothermal plane turbulent impinging jets at moderate Reynolds numbers. Experiments in Fluids 58(4), Article 31. doi:10.1007/s00348-017-2315-0.
4. van Hooff T, Blocken B, 2017. Mixing Ventilation Flows driven by two Opposite Out-of-Phase Wall Jets: Comparison of URANS and LES. 10th International Symposium on Heating Ventilation and Air Conditioning (ISHVAC) 2017, 19-22 October, Jinan, China.
5. van Hooff T, Blocken B, 2017. Assessment of time-periodic mixing ventilation using a sine function and a step function. Healthy Buildings Europe 2017, 2-5 July 2017, Lublin, Poland.
6. van Hooff T, Blocken B, Tominaga Y, 2017. Validation of RANS CFD models for contaminant transport in a cross-ventilated isolated building. Healthy Buildings Europe 2017, 2-5 July 2017, Lublin, Poland.
7. Kosutova K, Vanderwel C, van Hooff T, Blocken B, Hensen JLM, 2017. Wind tunnel experiments of cross-ventilative cooling in a generic isolated building with heated wall. Proceedings of the 7th European and African Conference on Wind Engineering (EACWE 2017), 4-7 July 2017, Liege, Belgium.

8. Vasaturo R, Kalkman I, van Hooff T, Blocken B, van Wesemael P, 2017. On the effect of passive building technologies and orientation on the energy demand of an isolated lightweight house. International Conference on Urban Comfort and Environmental Quality (URBANCEQ-2017), 28-29 September 2017, Genova, Italy.
9. Thysen JH, van Hooff T, Blocken B, van Heijst GJF, 2017. Numerical study of time-periodic mixing ventilation: effect of amplitude. Healthy Buildings Europe 2017, 2-5 July 2017, Lublin, Poland.

PROJECT LEADERS
B. Blocken

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Thijs van Druenen

COOPERATIONS
Cycling Team LottoNL-Jumbo

FUNDED BY
-

FUNDED %

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

START OF THE PROJECT
2017

INFORMATION
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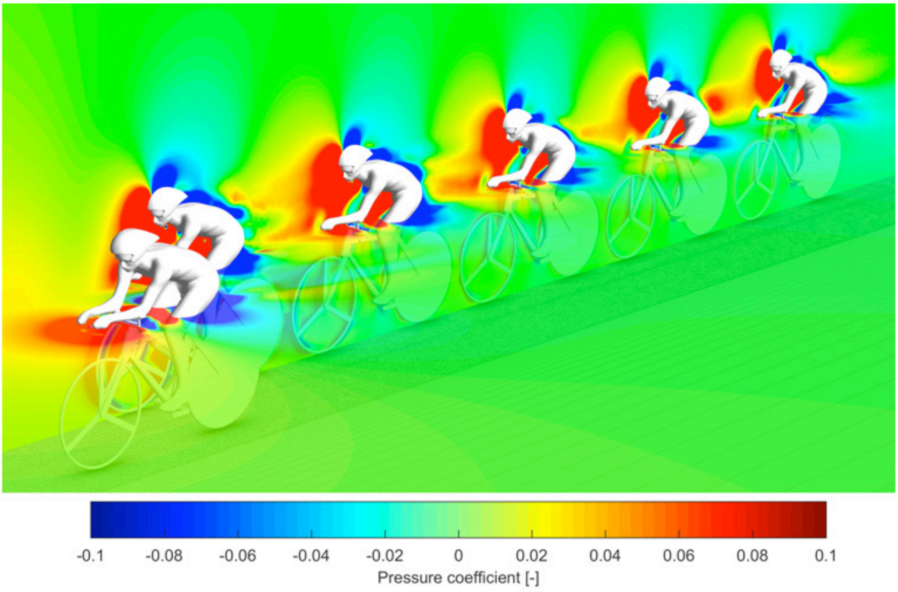
PROJECT AIM
During a team time trial, the cyclists' drag is dependent on the position in the paceline. When riding in a group, the leading cyclist can experience a drag reduction up to 3%, while for the following cyclists reductions over 50% are reported. To benefit from this drag reduction equally, cyclists rotate their positions during the race. In this study, computational simulations (CFD) are performed to investigate the aerodynamic forces acting on the cycling team during this rotation, and wind-tunnel experiments are carried out for validation.

PROGRESS
A grid-sensitivity analysis resulted in a grid containing high resolution of cells in the boundary-layer of the cyclist, with the wall-adjacent cell center point at 10 μm from the body surface. Validation with wind-tunnel measurements is performed for four trailing cyclists and yielded a maximum deviation in drag of 6% for the third cyclist. For studying the team time trial rotation, 6 cyclists are considered (see Fig. 1). Currently, CFD simulations are performed for investigating different longitudinal and lateral displacement distances, and how this affects the flow field and aerodynamic forces acting on the team.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
1. van Druenen, T., Toparlar, Y., Blocken, B.J.E. & Andrianne, T. (2017). Numerical analysis of the aerodynamics of cyclists during team time trial rotation. Proceedings of the 7th European and African Conference on Wind Engineering (EACWE 2017), 4-7 July 2017, Liege, Belgium.

Instantaneous pressure coefficient in a vertical and a horizontal (transparent) plane



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 that may be useful for optimizing the aerodynamic performance of Para-athletes.

Progress

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) Grid and turbulence modelling sensitivity studies for CFD analyses, (2) crosswinds research using both CFD simulations and wind-tunnel experiments, (3) Equipment and athlete posture/position variations. The first two steps of this approach are complete for both Para-cycling disciplines.

Dissertations

-

Scientific Publications

1. Mannion, P., Toparlar, Y., Blocken, B., Hajdukiewicz, M., Andrianne, T., & Clifford, E. (2017). Improving CFD prediction of drag on Paralympic tandem athletes: Influence of grid resolution and turbulence model. Sports Engineering. In press. http://doi.org/10.1007/s12283-017-0258-6.
2. Mannion, P., Toparlar, Y., Blocken, B., Hajdukiewicz, M., Andrianne, T., Clifford, E. (2017). An investigation of tandem cycling aerodynamics. Proceedings of the European-African Conference on Wind Engineering (EACWE 2017). 4-7 July 2017, Liege, Belgium.

Project leaders

Bert Blocken, Eoghan Clifford (NUI Galway)

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Paul Mannion, Yasin Toparlar

Cooperations

National University of Ireland Galway, Ireland, KU Leuven, 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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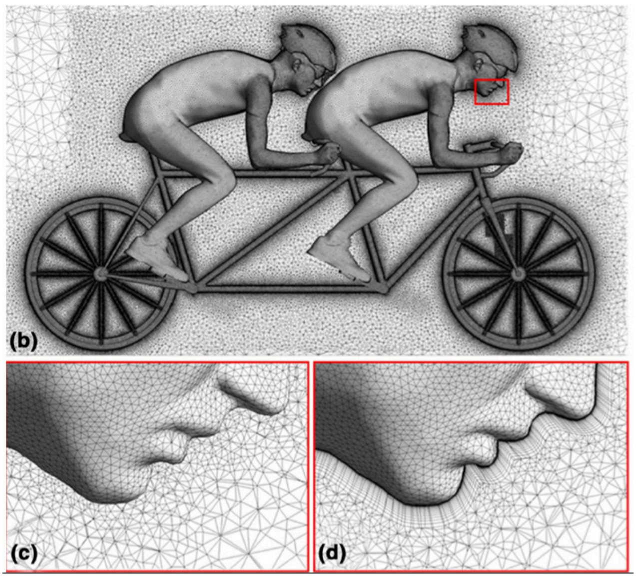

Aerodynamic optimization of particulate matter removal using electrostatic precipitator units

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, Province of North Brabant, ANSYS CFD

Funded by
Eindhoven University of Technology
ENS Technology

Funded %

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

Start of the project
2016

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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. In urban environments, traffic provides a major contribution to PM pollution due to high traffic intensities and corresponding tailpipe emissions and tire and brake wear. Semi-enclosed parking garages are examples of locations, where emissions are high and PM accumulates, which subsequently disperses into the city. In this study, the indoor and outdoor PM concentration reduction potential, by local removal of PM by positive ionization units (70% PM10 removal efficiency per unit of 9,000 m3/h) inside semi-enclosed parking garages, 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 for two specific parking garages. Preliminary results show that application of positive ionization units can reduce PM inside the parking garage with up to 59%. This also means that ambient PM10 concentrations around the parking garage will be reduced, since air from the parking garage is exhausted into its urban surroundings. Further work focuses on the further simulation and validation of the results.

Dissertations

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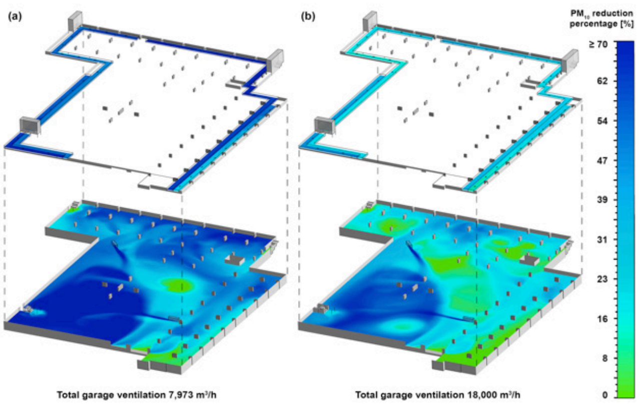
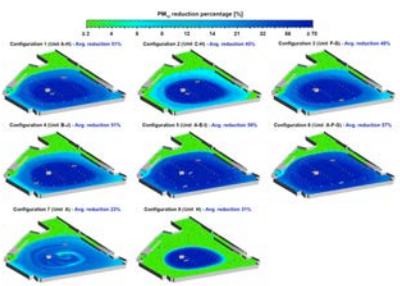
Scientific Publications

-



PM10 reduction percentage in a semi-enclosed parking garage (garage #1) for the measured (a) and designed (b) ventilation scenario using two ionization units.



PM10 reduction percentage in a semi-enclosed parking garage (garage #2). Percentages mentioned represent the volume-averaged PM10 concentration reduction.

Project Aim

In this research project, we intend to investigate different ways to improve the aerodynamic performance of vertical axis wind turbines (VAWT) for the urban environment. The research has the following objectives:

- Developing guidelines to ensure the accuracy of CFD simulations of VAWTs
- Comprehensively characterizing the aerodynamic performance of VAWTs as a function of various geometrical and operational parameters
- Improving the aerodynamic performance of VAWTs using passive/active flow control methods.

Progress

Minimum requirements for the domain size, convergence criterion and azimuthal increment for different tip speed ratios and solidities have been provided as guidelines for CFD simulations of VAWTs. The impact of geometrical parameters such as pitch angle on the aerodynamic performance of VAWTs has been comprehensively studied. In addition, the effect of the shaft on the turbine power performance has been quantified and an optimal dimensionless roughness height has been proposed to minimize the turbine power loss due to the shaft. The following figure shows vorticity contours around a VAWT with and without shaft.

Dissertations

-

Scientific Publications

1. Rezaeiha A, Kalkman I, and Blocken B, “CFD simulation of a vertical axis wind turbine operating at a moderate tip speed ratio: guidelines for minimum domain size and azimuthal increment,” Renewable Energy, vol. 107, pp. 373-385, 2017.
2. Rezaeiha A, Kalkman I, and Blocken B, “Effect of pitch angle on power performance and aerodynamics of a vertical axis wind turbine,” Applied Energy, vol. 197, pp. 132-150, 2017.
3. Rezaeiha A, Kalkman I, Montazeri H, and Blocken B, “Effect of the shaft on the aerodynamic performance of urban vertical axis wind turbines,” Energy Conversion and Management, vol. 149 (C), pp. 616-630, 2017.

Project Leaders

Prof.dr.ir. Bert Blocken
Dr.ir. Hamid Montazeri

Research Theme

Mathematical and computational methods for fluid flow analysis

Participants

Abdolrahim Rezaeiha

Cooperations

-

Funded By

EU

Funded %

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

Start of the Project

2015

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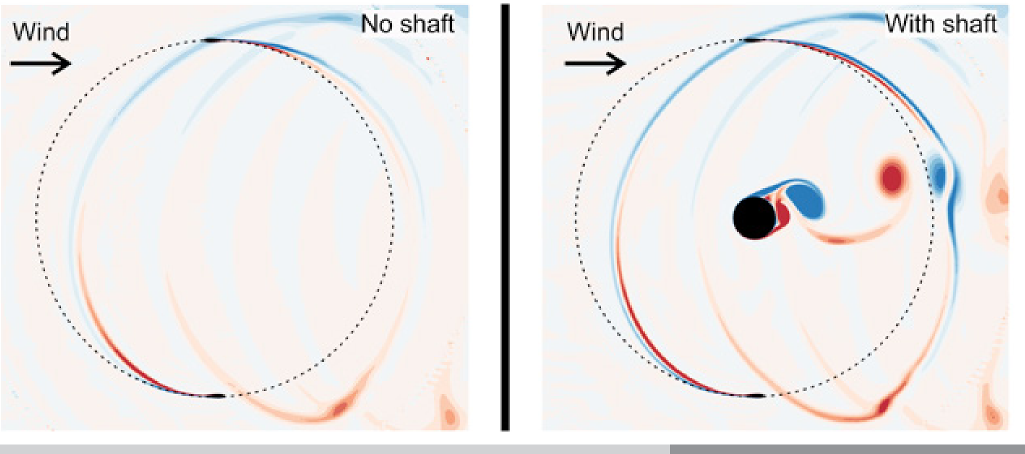

PROJECT LEADERS
Prof.dr.ir. Bert Blocken
Prof.dr.ir. GertJan van Heijst
Dr.ir. Twan van Hooff

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Ir. Jo-Hendrik Thysen

COOPERATIONS
Eindhoven University of Technology
Department of Applied Physics

FUNDED BY
The Research Foundation – Flanders (FWO)

FUNDED %

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

START OF THE PROJECT
2016

INFORMATION
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PROJECT AIM

This project investigates new ventilation concepts which aim at improving the efficiency of mixing ventilation in enclosures. A detailed analysis of the indoor flow patterns, flow structures and their interactions allows to assess the effect of the different ventilation concepts on the mixing ventilation efficiency. The research is performed using computational fluid dynamics (CFD) simulations supported by particle-image velocimetry (PIV) measurements in generic enclosures and aims at transferring the knowledge gained to practical situations such as a room in a building and an airplane cabin.

PROGRESS

Four work packages (WPs) according to four specific objectives are defined. The first three comprise a generic analysis of the jet ventilation concepts (i.e. jet parameters, geometrical details and confluent jets) whereas the last WP aims at evaluating the jet ventilation concepts in realistic situations. CFD simulations to investigate the effect of a variation in supply jet parameters (WP1) on the ventilation efficiency are carried out. In addition, PIV measurements are performed in a reduced-scale water-filled generic set-up that is a simplified model of an airplane cabin.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Thysen J, van Hooff T, Blocken B, van Heijst GJF. Numerical study of time-periodic mixing ventilation: effect of amplitude. In: Proceedings of Healthy Buildings Europe. 2017 July 2-5; Lublin, Poland. [6 p.]

Towards accurate numerical modeling of the thermally stratified atmospheric boundary layer

Project Aim

This project is primarily concerned with including the effect of the thermally stratified atmospheric boundary layer (ABL) into computational fluid dynamics (CFD) simulations of urban wind flow. Both Reynolds-averaged Navier-Stokes (RANS) and large-eddy simulation (LES) approaches will be used. Stratification has an important effect on the profiles of mean velocity and turbulence that approach urban areas, and adding this effect will lead to better predictions of public health related quantities such as pollution dispersion, temperature distributions and also acoustic propagation. Validation of the numerical results will be aided by the collection of dedicated experimental data.

Progress

RANS simulations have been conducted for the neutral ABL, ensuring horizontal homogeneity. The extension to other stratification regimes (stable and unstable) requires modifications to the turbulence model, and are underway. LES simulations are being conducted with the OpenFOAM collection of libraries, and stratification is accounted for using the SOWFA set of solvers. These are being run on the national supercomputing facilities, thus paving the way towards more complex simulations involving urban-like geometries. Furthermore, an experimental campaign with the goal of investigating both the flow field and acoustic propagation is being planned.

Dissertations

-

Scientific Publications

-

Project leaders

Prof. dr. ir Bert Blocken
Dr. ir. Twan van Hooff

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Ir. Gerson Fernandes

Cooperations

-

Funded by

NWO-TTW

Funded %

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

Start of the project

2016

Information

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Optimization of air curtains through spatial and temporal jet excitation

Project leaders
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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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Project Aim

In building applications, air curtains are used to separate a controlled environment, in terms of temperature, pressure or concentration, from an unconditioned environment, while allowing an easy access of people, vehicles and material across 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 air curtains under different operational parameters.

Progress

Validation of Large Eddy Simulations and Reynolds-Averaged Navier-Stokes simulations of turbulent impinging jets using water-tank experiments and field measurements has been performed on verified computational grids. The validated computational parameters have been used in the simulation of a reference air curtain. Preliminary simulations on the influence of environmental parameters indicate the existence of an optimum air curtain separation efficiency determined as a function of the air curtain jet momentum for a given cross-jet temperature or pressure gradient. Further work focuses on different jet excitation techniques to optimize the separation.

Dissertations

-

Scientific Publications

-

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.ir. D van der Meer

Prof.dr.ir. J Snoeijer

Prof.dr. J Harting

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.

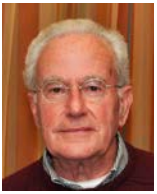
Granular Flow

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.

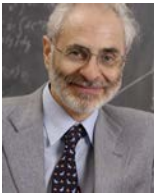
Micro- and Nanofluidics

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. JF Dijksman



Prof.dr.ir. L van Wijngaarden



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
Detlef Lohse, Roberto Verzicco, Richard Stevens, Yantao Yang, Chong Shen Ng, Vamsi Arza, Xiaojue Zhu, Alexander Blass, Pieter Berghout, Martin Assen

COOPERATIONS
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I. Marusic, D. Chung, D. Krug (Melbourne)
R. Ostilla-Monico (Houston)
Z. Wan (Hefei)
K. Xia (Hong Kong)

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 of the respective systems have revealed key mechanisms and flow structures, that contribute to drag and heat transport. One of those structures is a long meandering structure that is seen in Couette flow with unstable stratification, as indicated in the figure below. Also we find a strong interaction between ratchet roughness and the large scale circulation in Rayleigh-Bénard flow and a common mechanism of turbulent transport enhancement through the manipulation of coherent structures. Further work is carried out on the development of a computer code for the two way interaction of deformable interfaces and turbulent flows.

DISSERTATIONS

1. Vamsi Arza - 'Bubbles and drops in turbulent Taylor-Couette flow: numerical modelling and simulations' (July 2017).

SCIENTIFIC PUBLICATIONS

1. X. Zhu, R.J.A.M. Stevens, R. Verzicco, and D. Lohse, Roughness-Facilitated Local 1/2 Scaling Does Not Imply the Onset of the Ultimate Regime of Thermal Convection, Phys. Rev. Lett. 119, 154501 (2017).
2. K.L. Chong, Y. Yang, S.D. Huang, J.Q. Zhong, R.J.A.M. Stevens, R. Verzicco, D. Lohse, and K.Q. Xia, Confined Rayleigh-Bénard Rotating Rayleigh-Bénard, and Double Diffusive Convection: A Unifying View on Turbulent Transport Enhancement through Coherent Structure Manipulation, Phys. Rev. Lett. 119, 064501 (2017).
3. D.J. Krug, X. Yang, C.M. de Silva, R. Ostilla Mónico, R. Verzicco, I. Marusic, and D. Lohse, Statistics of turbulence in the energy-containing range of Taylor–Couette compared to canonical wall-bounded flows, J. Fluid Mech. 830, 797–(2017).
4. C.S. Ng, A. Ooi, D. Lohse, and D. Chung, Changes in the boundary-layer structure at the edge of the ultimate regime in vertical natural convection, J. Fluid Mech. 825, 550–572 (2017).
5. S. Pirozolli, M. Bernardini, R. Verzicco, and P. Orlandi, Mixed convection in turbulent channels with unstable stratification, J. Fluid Mech. 821, 482–516 (2017).
6. X. Zhu, R. Verzicco, and D. Lohse, Disentangling the origins of torque enhancement through wall roughness in Taylor–Couette turbulence, J. Fluid Mech. 812, 279–293 (2017).
7. R. Ostilla Mónico, X. Zhu, V.S. Arza, R. Verzicco, and D. Lohse, Life stages of wall-bounded decay of Taylor-Couette turbulence, Phys. Rev. Fluids 2, 114601 (2017).

8. V.S. Arza, R. Verzicco, and D. Lohse, Deformable ellipsoidal bubbles in Taylor-Couette flow with enhanced Euler-Lagrangian tracking, Phys. Rev. Fluids 2, 104304 (2017).
9. V.S. Arza, V. Meschini, R. Ostilla Mónico, D. Lohse, G. Querzoli, M. de Tullio, and R. Verzicco, A parallel interaction potential approach coupled with the immersed boundary method for fully resolved simulations of deformable interfaces and membranes, J. Comput. Phys. 348, 567 – 590 (2017).

PROJECT LEADERS
Detlef Lohse

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
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FUNDED BY
ERC Advance Grant

FUNDED %

University	-
FOM	-
STW	-
NWO Other	40 %
Industry	-
TNO	-
GTI	-
EU	60 %
Scholarships	-

START OF THE PROJECT
2014

INFORMATION
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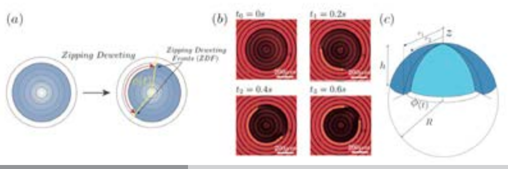
Discovered zipping dewetting mode of droplets (1-pentanol) dewetting concentric ring patterns, as shown below.



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

Discovered the branch-like nanodroplets in 2D confined Ouzu system, and the subsequent local solute concentration gradient drives fast diffusiophoretic movement of colloidal particles.

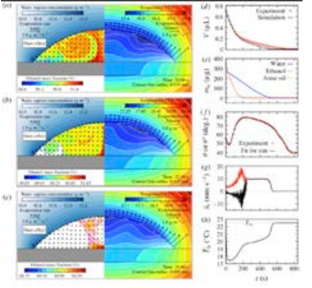
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Lu, Z., Klein Schaarsberg, M. H., Zhu, X., Yeo, L. Y., Lohse, D., & Zhang, X. (2017). Universal nanodroplet branches from confining the Ouzo effect. Proceedings of the National Academy of Sciences of USA, 114(39), 10332-10337.
2. Maheshwari, S., Van Der Hoef, M., Prosperetti, A., & Lohse, D. (2017). Molecular dynamics study of multicomponent droplet dissolution in a sparingly miscible liquid. Journal of Fluid Mechanics, 833, 54-69.
3. Diddens, C., Tan, H., Lv, P., Versluis, M., Kuerten, J. G. M., Zhang, X., & Lohse, D. (2017). Evaporating pure, binary and ternary droplets: thermal effects and axial symmetry breaking. Journal of fluid mechanics, 823, 470-497.
4. Tan, H., Diddens, C., Versluis, M., Butt, H. J., Lohse, D., & Zhang, X. (2017). Self-wrapping of an ouzo drop induced by evaporation on a superamphiphobic surface. Soft matter, 13(15), 2749-2759.
5. Xu, C., Yu, H., Peng, S., Lu, Z., Lei, L., Lohse, D., & Zhang, X. (2017). Collective interactions in the nucleation and growth of surface droplets. Soft matter, 13(5), 937-944.
6. Xiao, Q., Liu, Y., Guo, Z., Liu, Z., Lohse, D., & Zhang, X. (2017). Solvent exchange leading to nanobubble nucleation: A molecular dynamics study. Langmuir, 33(32), 8090-8096.
7. Dević, I., Soligno, G., Dijkstra, M., Roij, R. V., Zhang, X., & Lohse, D. (2017). Sessile nanodroplets on elliptical patches of enhanced lyophilicity. Langmuir, 33(11), 2744-2749.

Studied the behavior of evaporating binary and ternary droplets, and its difference compared with pure droplets. Figure below shows an evaporating ternary Ouzo droplet.



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

Using ultra-high-speed imaging, we reveal the early dynamics of plasmonic bubbles generated on water-immersed, laser irradiated arrays of gold nanoparticles. After some delay time after beginning of the illumination, a giant bubble explosively grows and collapse (life phase 1). After the collapse of the initial giant bubble, much smaller oscillating bubbles form out of the remaining gas nuclei (life phase 2). Then, as was showed by us earlier, vaporization dominated growth phase takes over and the bubble stabilizes (life phase 3). In the final life phase 4 the bubble slowly grows by gas expelling due to heating of the surrounding liquid.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Wang, J., Zaytsev, M., The, H. L., Eijkel, J. C. T., Zandvliet, H. J. W., Zhang, X., Lohse, D. (2017). Vapor and Gas-Bubble Growth Dynamics around Laser-Irradiated, Water-Immersed Plasmonic Nanoparticles. ACS Nano, 11(2), 2045-2051.

PROJECT LEADERS

Detlef Lohse, Harold Zandvliet

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Mikhail Zaytsev

COOPERATIONS

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Yuliang Wang (Beihang University)
Xuehua Zhang (University of Alberta)
Pascal Buskens, TNO

FUNDED BY

NWO, TNO, BASF, Albermarle

FUNDED %

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

START OF THE PROJECT

2014

INFORMATION

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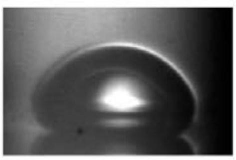
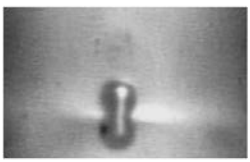
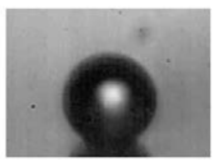


Phase 1: Giant vapor bubble



Phase 2: Oscillating bubbles



Phase 3: Vaporization dominated growth

Phase 4: Slow growth by gas diffusion

Fundamental fluid dynamics challenges of extreme ultraviolet lithography

Project leaders
Gelderblom, Snoeijer, Lohse
Research theme
Complex dynamics of fluids
Participants
M. V. Gielen, A. L. Klein, S.A. Reijers, H. Gelderblom, J. H. Snoeijer, D. Lohse
Cooperations
Villermaux, Université Aix-Marseille
Lhuissier, Université Aix-Marseille
Clanet, Ecole Polytechnique Paris
Versolato, Ubachs & Hoekstra, ARCNL
Toschi, Eindhoven University of Technology
ASML Research
Funded by
NWO and ASML
Funded %

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

Start of the project
2013
Information
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Project Aim

A method to generate Extreme Ultraviolet (EUV) light is to ionize liquid tin drops by a laser pulse. The resulting hot plasma emits EUV radiation. Several of the challenges to make this method operational have their origin in contemporary fluid physics. Here, we focus on two of these fluid dynamics challenges. First, we study the deformation and fragmentation of liquid drops upon impact of a laser pulse. Second, we want to define the criteria for the splashing and bouncing of liquid drops on soft (liquid and elastic) substrates and the role of liquid solidification during impact and spreading.

Progress

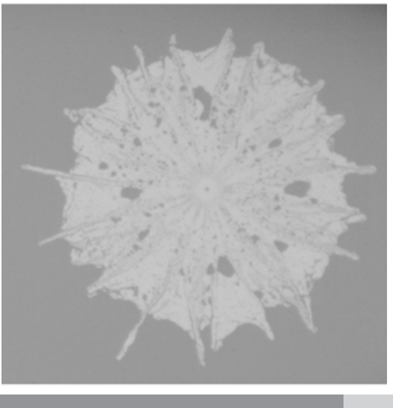
The influence of pulse duration on deformation of a drop after laser impact was studied theoretically. A model was developed to relate droplet deformation and tilt to laser-droplet misalignment. Furthermore, we experimentally studied droplet breakup after laser impact. The impact and splashing of hot tin droplets on both sapphire and tin-coated substrates of various temperatures is investigated. We performed numerical simulations of oblique droplet impact onto a deep pool and found good agreement with experimental results. In addition, we studied the influence of substrate elasticity and deformation on the splashing threshold.

Dissertations

1. Laser impact on flying drops – by Alexander Klein, PhD thesis.
2. Numerical simulation of oblique drop impact onto a liquid pool- by Bo Liu, MSc thesis.

Scientific Publications

1. R. de Ruiter, P. Colinet, P. Brunet, J.H. Snoeijer and H. Gelderblom. Contact line arrest in solidifying spreading drops Phys. Rev. Fluids 2, 043602 (2017).
2. M.V. Gielen, P. Sleutel, J. Benschop, M. Riepen, V. Voronina, D. Lohse, J.H. Snoeijer, M. Versluis and H. Gelderblom. Oblique drop impact onto a deep liquid pool. Phys. Rev. Fluids 2, 083602 (2017).
3. S.A. Reijers, J.H. Snoeijer and H. Gelderblom. Droplet deformation by short laser-induced pressure pulses. J. Fluid Mech. 828 pp. 374-394 (2017).
4. A.L. Klein, D. Lohse, M. Versluis and H. Gelderblom. Apparatus to control and visualize the impact of a high-energy laser pulse on a liquid target, Rev. Sci. Instrum. 88 (2017).
5. H. Gelderblom and O. Versolato. Laserschieten op tindruppels. Nederlands Tijdschrift voor Natuurkunde 83 pp. 26-29 (2017).



Solidified splat formed during the impact of a hot liquid tin drop on a cold (150 deg) sapphire substrate.

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. Research topics include TC turbulence with solid spherical particles, fibers, wall roughness, bubbles and coatings.

Progress

Many experiments have been performed in both the T3C as well as the BTTC setup. A number of manuscripts have been submitted and published in the beginning of 2018: one on measurements on the Taylor-Reynolds number and one on wall roughness, which leads to the so-called asymptotic ultimate regime of turbulence. A MSc. student graduated on a study on periodically driven TC turbulence. Work on two-phase flow included studies on drag reduction using solid particles and solid fibers, and the effects of roughness on bubble drag reduction. Furthermore, we studied air layers in our T3C setup. Recently, we started to study the influence of superhydrophobic membranes and oil-infused coatings on the drag.

A different line of research focusses on boiling in turbulent flow, by heating the inner cylinder in a low-boiling-point liquid.

Project leaders
D. Lohse, C. Sun, S. G. Huisman

Research theme
Complex dynamics of fluids

Participants
Dennis Bakhuis, Ruben Verschoof, Rodrigo Ezeta, Pim Bullee, Sander Huisman

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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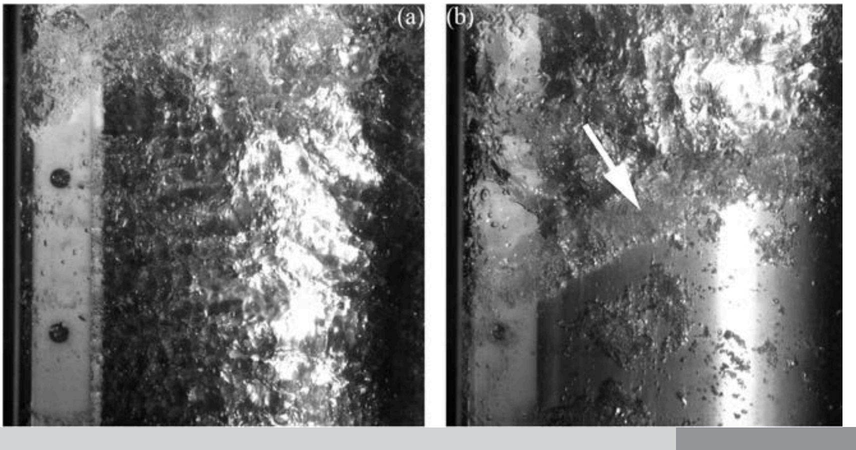
Dissertations

-

Scientific Publications

-



Project leaders
Detlef Lohse, Devaraj van der Meer
Research theme
Complex dynamics of fluids
Participants
Álvaro Moreno Soto
Cooperations
-
Funded by
MCEC - 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

There is a substantial and increasingly important class of processes where a gaseous reaction product is produced on a catalyst surface in a liquid. Wherever a gas bubble forms and covers part of the catalyst surface, the reaction is inhibited and therefore, it is crucial that these gas bubbles are transported away as fast as possible. 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. More specifically, 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. And finally we will address how bubbles nucleate and grow on a photoelectrolytic surface.

Progress

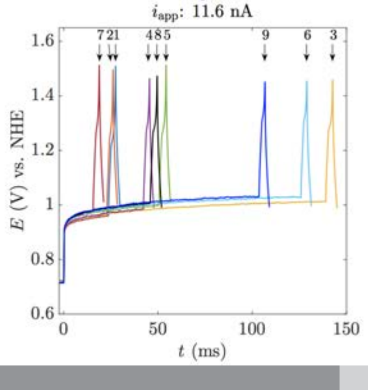
Three manuscripts have been already published regarding bubble nucleation and growth in different conditions and geometries, see below. Another manuscript regarding bubble coalescence has been submitted and a second document about nanobubble nucleation in electrolysis is being prepared for submission. Currently, the participants are involved in the study of bubble growth under confinement and new experiments with bubbles in ultrasound are being prepared. The attached images represent the most updated results on nanobubble nucleation during electrolysis and the non-dimensional growth of bubbles under confinement.

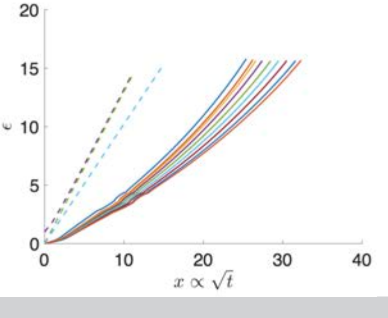
Dissertations

-

Scientific Publications

1. Electrolysis-driven and pressure-controlled diffusive growth of successive bubbles on microstructured surfaces, P. van der Linde, Á. Moreno Soto, P. Peñas-López, J. Rodríguez-Rodríguez, D. Lohse, H. Gardeniers, D. van der Meer and D. Fernández Rivas, Langmuir 2017, 33, 12873-12886.
2. Gas depletion through single gas bubble diffusive growth and its effect on subsequent bubbles, Á. Moreno Soto, A. Prosperetti, D. Lohse and D. van der Meer, J. Fluid Mech. 2017, 831, 474-490.
3. The history effect on bubble growth and dissolution. Part 2. Experiments and simulations of a spherical bubble attached to a horizontal flat plate, P. Peñas-López, Á. Moreno Soto, M. A. Parrales, D. van der Meer, D. Lohse and J. Rodríguez-Rodríguez, J. Fluid Mech. 2017, 820, 479-510.





Understanding the interaction between extended wind-farms and turbulent atmospheric boundary layers

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 wrote an Annual Review of Fluid Mechanics on “Flow Structure and Turbulence in Wind Farms”, in which we present a literature review of field studies, wind tunnel experiments, large eddy simulations, and analytical modeling of the dynamics of extended wind farms. We also investigated the potential of using vertical staggering of wind turbines to improve the overall wind farm power production using detailed large eddy simulations. Surprisingly, in contrast to some analytical predictions, we find that the benefit of vertical staggering compared to the non-staggered case decreases further downstream in the wind farm.

Dissertations

-

Scientific Publications

1. R.J.A.M. Stevens, C. Meneveau, Flow Structure and Turbulence in Wind Farms, Annu. Rev. Fluid Mech. 49, 311-339 (2017),
2. R.J.A.M. Stevens, B. Hobbs, A. Ramos, C. Meneveau, Combining economic and fluid dynamic models to determine the optimal spacing in very large wind-farms, Wind Energy 20 (3), 465-477 (2017)
3. M. Zhang, R.J.A.M. Stevens, Characterizing the coherent structures in large eddy simulations of aligned wind farms, J. Phys.: Conf. Ser. 854, 012052 (2017).

Project leaders

Richard Stevens

Research theme

Complex dynamics of fluids

Participants

Dr. R.J.A.M. Stevens, Dr. M. Zhang
Msc. S. Nagarada Gadde, MSc J. Strickland

Cooperations

Prof. C. Meneveau (Johns Hopkins University, USA)
Prof. D.F. Gayme (Johns Hopkins University, USA)
Dr. M. Wilczek (Max Planck Gottingen, Germany)
Dr. T. Martinez (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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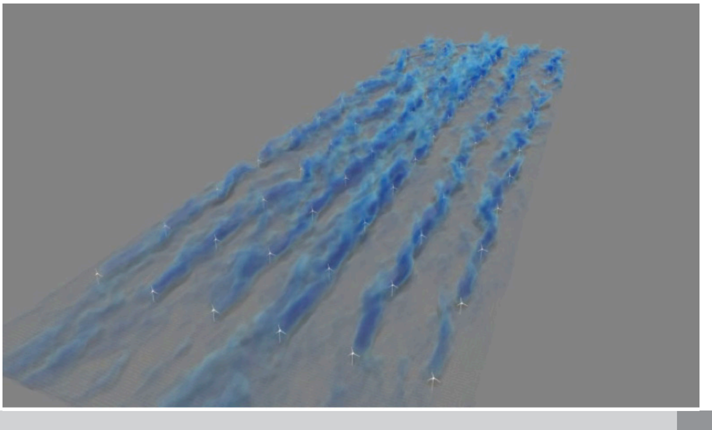
Visualization of the low speed wind regions indicated in blue in a very large wind-farm which shows the creation of turbulent wakes behind the turbines (visualization by David Bock, NCSA Visualization, XSEDE)



Project leaders
Prof. Detlef Lohse, Dr. Martin van der Hoef

Research theme
Complex dynamics of fluids

Participants
Andrea Prosperetti, Xuehua Zhang, Shantanu Maheshwari

Cooperations
-

Funded by
NWO-Shell

Funded %

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

Start of the project
2014

Information
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Project Aim

1) Leakiness of pinned neighboring surface nanobubbles induced by strong gas−surface interaction : To study and identify the reasons for the experimentally observed Ostwald ripening among surface nanobubbles with the help of molecular dynamics simulations.

2) Molecular dynamics study of multicomponent droplet dissolution in a sparingly miscible liquid : Study the dissolution behavior of a multicomponent nanodrop in a sparingly miscible liquid by molecular dynamics simulations.

3) Dynamics of formation of a vapour nanobubble around a heated nanoparticle : To study the role of dissolved gas in formation and growth dynamics of a vapor nanobubble around a heated nanoparticle.

Progress

1) We showed that gas-solid interaction energy plays the crucial role in the stability of surface nanobubbles which has hitherto not been considered in any macroscopic theory.

2) We showed that dissolution of multicomponent nanodrop is different compared to the macroscopic one for lower interaction energy between the drop-components which is due to the very high curvature of the nanodrop.

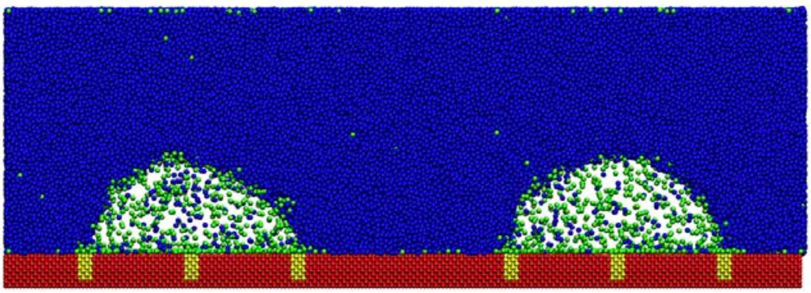
3) We showed that dissolved gas enhances the nucleation of nanobubble around a heated nanoparticle due to two reasons; primary reason is the decrease in the critical temperature of the mixture and secondary reason is the due to the increase in local oversaturation of gas near the nanoparticle surface.

Dissertations

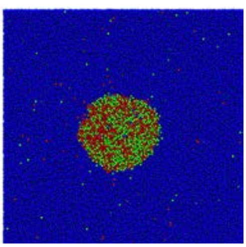
-

Scientific Publications

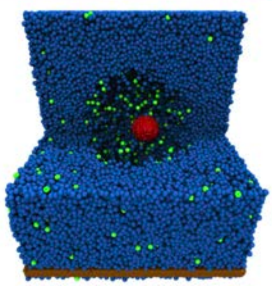
1. S. Maheshwari, M. van der Hoef, A. Prosperetti, & D. Lohse. Molecular dynamics study of multicomponent droplet dissolution in a sparingly miscible liquid. J. Fluid Mech., 833, 54-69 (2017).



Project 1



Project 2



Project 3

PROJECT AIM

The main focus of the project is solid buoyant particles with some form of anisotropy. Initially, we investigated buoyant spheres and air bubbles in turbulence. These particles when moving through a fluid, quiescent or turbulent, will have interesting dynamic behavior. They will also affect the fluid phase, creating complex wake-structures which have been studied. The aim now, is to move towards more complex geometries, introducing features such as anisotropy, chirality, etc. The goal is to track the particles; extracting absolute position and orientation. Additionally, the effects the particles have on the fluid will also be experimentally investigated.

PROGRESS

In the first stage of the work, the dynamics of buoyant isotropic particles in turbulence was investigated. We first addressed the effect of buoyancy on the motion and wakes of spherical particles and air bubbles. Following this, we are extending this problem to the case of ellipsoidal particles (oblate and prolate). The oblate ellipsoids resemble deformable air bubbles. Both free-rise and turbulent measurements are being performed to obtain their trajectories and orientations. Techniques for processing and data extraction are currently being developed.

DISSERTATIONS

1. V. Mathai, PhD Thesis. University of Twente. Buoyant particles and fluid turbulence.

SCIENTIFIC PUBLICATIONS

1. Alméras, E., Mathai, V., Lohse, D., & Sun, C. (2017). Experimental investigation of the turbulence induced by a bubble swarm rising within incident turbulence. J. Fluid Mech., 825, 1091-1112.
2. Mathai, V., Zhu, X., Sun, C., & Lohse, D. (2017). Mass and moment of inertia govern the transition in the dynamics and wakes of freely rising and falling cylinders. Physical Rev. Lett., 119 (5), 054501.
3. Bakhuis, D., Verschoof, R. A., Mathai, V., Huisman, S. G., Lohse, D., & Sun, C. (2017). Finite-sized rigid spheres in turbulent Taylor-Couette flow. arXiv preprint arXiv:1712.02591.

PROJECT LEADERS

Prof. Dr. Chao Sun, Prof. Dr. Detlef Lohse

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Jelle Will, Varghese Mathai

COOPERATIONS

EuHIT, FOM, STW, COST MP1305

FUNDED BY

VIDI grant No. 13477
Max Planck Center

FUNDED %

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

START OF THE PROJECT

2017

INFORMATION

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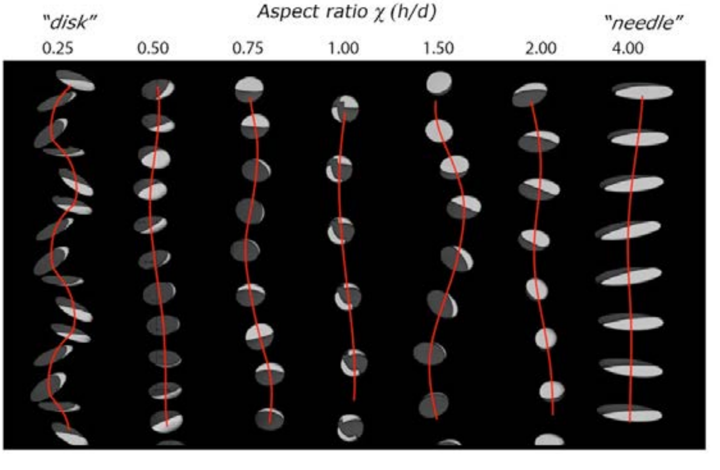

Attached image: Free-rise trajectories of ellipsoidal particles of varying aspect ratio.

PROJECT LEADERS
Prof. Dr. Detlef Lohse,
Prof. Dr. Chao Sun

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Biljana Gvozdic, On Yu Dung,
Sander Huisman

COOPERATIONS
NWO, Netherlands Center for Multiscale Catalytic Energy Conversion
Hans Kuipers, TUE
Shell
Tata Steel
Akzo Nobel
DSM

FUNDED BY
NWO, Netherlands Center for Multiscale Catalytic Energy Conversion
FOM-IPP

FUNDED %

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

START OF THE PROJECT
1) 2015 / 2) 2016

INFORMATION
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PROJECT AIM

1) Fundamentals of heat transport in bubbly flows

2) Chemical reactions and mixing in turbulent multiphase flow with active and passive catalytic particles

1a) To look at the influence of bubble injection on the heat flux in turbulent bubbly flow.

1b) To study the influence of the bubble diameter and gas volume fraction.

1c) To study the influence of the bubble clustering on the local and global heat flux.

2a) Quantitatively characterize the mixing of catalytic reactants and passive scalars in freely rising bubble swarms and swarms with catalytic microparticles.

2b) Measure the mixing of the scalar fields in turbulent flows with bubbles and microparticles.

2c) Search for the optimal parameters for the effective mixing in dispersed multiphase flows.

PROGRESS

1a) We found unique scaling of non-dimensionalised heat flux with the gas volume fraction in homogeneous bubbly flow in the rectangular bubbly column. Through local temperature measurements, we found that the bubbles induce a huge increase in the strength of liquid temperature fluctuations, e.g. by a factor of 200 for $\alpha = 0.9\%$.

1b) Results on the homogeneous injection have been summed in a paper, which is going to be published in 2018.

1c) We characterized the heat transfer in inhomogeneous bubbly flow in the same setup.

2a) The new experimental setup Mass and Heat Transfer Twente Water Tunnel is built (see figure below). Programming and testing of the setup is ongoing.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

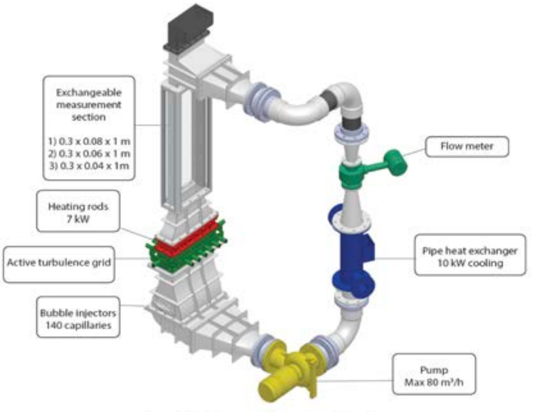

Figure: 3D CAD design of the Twente MHT Tunnel

Project Aim

The main scientific goal of the programme 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 modelling 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 first programme line refers to the fluid dynamics of the printhead including the piezo and the wetting properties at the nozzle, on the droplet formation process and the droplet dynamics. It includes the actuation principles and performances, acoustic ink channel modelling, the meniscus dynamics, air bubble entrainment, wetting properties of the nozzle plate and its coatings, and the droplet formation process. The second programme line refers to the ’paper’ side and includes the dynamics of the droplet impact, its spreading, the droplet merging, the wetting properties of the substrate, the evaporation and drying process, the ink intrusion into the paper, the ink absorption and solidification, and the effect the ink has on the substrate. The programme combines experimental, numerical, and theoretical approaches.

Progress

Since the start of the programme in 2017, 2 group leaders, 2 post-docs and 7 PhD students have been appointed. The appointed persons have become acquainted with the topic and the experimental setup/numerical tools.

Dissertations

-

Scientific Publications

1. 1. Diddens, C. (2017). Detailed finite element method modeling of evaporating multi-component droplets. J. Comput. Phys., 340, 670-687.
2. Diddens, C., Tan, H., Lv, P., Versluis, M., Kuerten, J.G.M., Zhang, X. & Lohse, D. (2017). Evaporating pure, binary and ternary droplets: Thermal effects and axial symmetry breaking. J. Fluid Mech., 823, 470-497.
3. Diddens, C., Kuerten, J.G.M., van der Geld, C.W.M. & Wijshoff, H.M.A (2017). Modeling the evaporation of sessile multi-component droplets. J. Colloid Interface Sci., 487, 426-436.
4. Tan, H., Diddens, C., Versluis, M., Butt, H.J., Lohse, D. & Zhang, X. (2017). Self-wrapping of an ouzo drop induced by evaporation on a superamphiphobic surface. Soft Matter, 13(15), 2749-2759.

Project leaders

Detlef Lohse

Research theme

Complex dynamics of fluids

Participants

Detlef Lohse
Harald van Brummelen
Herman Wijshoff
Michel Versluis
Jacco Snoeijer
Christian Diddens
Tim Segers
Arjan Fraters
Maaike Rump
Michiel Hak
Wojtek Kwiecinski

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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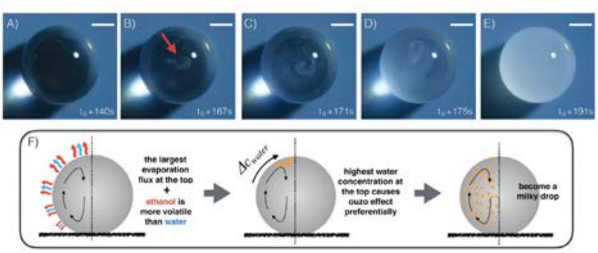
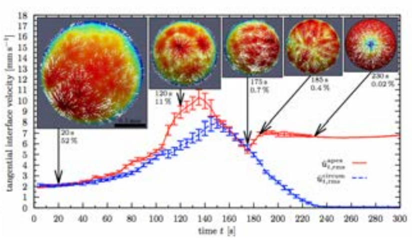
2Phase-separation triggered by selective evaporation of an ouzo droplet on a superamphiphobic substrate





Numerical simulation of an evaporating water-glycerol droplet

Project leaders
Michel Versluis
Research theme
Complex dynamics of fluids
Participants
Michel Versluis
Guillaume Lajoinie
Tim Segers
Benjamin van Elburg
Sophie ten Voorde
Gonzalo Collado
Cooperations
Ine Lentacker
Heleen Dewitte
Silke Roovers
Chris De korte
Bracco Suisse S.A.
Funded by
Bracco Suisse S.A., MIRA
Funded %

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

Start of the project
2015
Information
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Project Aim

This project aims at developing and studying microscale biocompatible agents for contrast and therapy, both in an ultrasound- and in a photoacoustic modality.

Progress

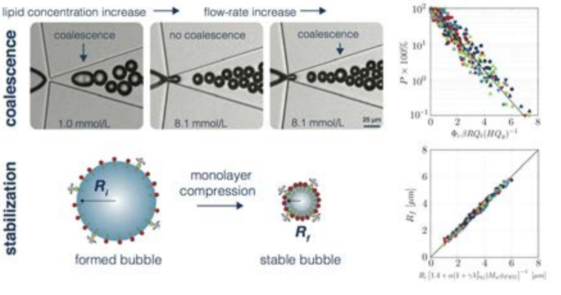
First, microbubbles with a light-absorbing oil layer were developed in order to use the unique bubble resonance not only in acoustics but also in photoacoustics. We have studied the physics of the underlying behavior of such bubbles in response to laser light both experimentally and theoretically1,2. Second, the full parameter space for stable phospholipid monodisperse microbubble formation in a flow-focusing device was characterized and universal scaling laws were derived for bubble stability.1 Additionally, a new, fully automated, microfluidlic platform was developed in collaboration with Bracco Suisse S.A. in order to precisely control microbubble production over long periods of time. Moreover, the microbubble size can be measured and adjusted in real-time. Furthermore, a major step forward was taken in the study of bubble-cell interaction by switching from a 2D cell layer model to a more relevant 3D spheroid model, which is now fully functional. The first in-vitro on-chip results show are promising regarding drug delivery efficiency from drug loaded microbubbles to tumor spheroids. Finally, we have shown that laser-activated microcapsules can be potential photoacoustic agents. We have investigated the effect of these laser-induced, microscale, cavitation events on cells and showed that these agents could be very efficient therapeutic agents.4

Dissertations

-

Scientific Publications

1. T. Segers, D. Lohse, M. Versluis, P. Frinking, 'Universal equations for the coalescence probability and long-term size stability of phospholipid-coated monodisperse microbubbles formed by flow-focussing', Langmuir, 2017, 33 (39), pp 10329–10339.
2. G. Lajoinie, J-Y Lee, J. Owen, P. Kruizinga, N. de Jong, G. van Soest, E. Stride, and M. Versluis, Laser-driven resonance of dye-doped oil-coated microbubbles: experimental study. J. Acoust. Soc. Am. (2017).
3. G. Lajoinie, E. Linnartz, P. Kruizinga, G. van Soest, E. Stride and M. Versluis, Laser-driven resonance of dye-doped oil-coated microbubbles: a theoretical and numerical study. J. Acoust. Soc. Am. (2017).
4. G. Lajoinie, T. van Rooij, I. Skachkov, E. Blazejewski, G. Veldhuis, N. de Jong, K. Kooiman, and M. Versluis, Laser-activated polymer microcapsules for ultrasound imaging and therapy: an in vitro feasibility study. Biophys. J. (2017).



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.

Rock on a Chip II

Project Aim

Understanding the mechanisms underlying low salinity waterflooding enhanced oil recovery by using simplified model systems.

Progress

Published paper on cation-effects on contact angle alterations in model low salinity water flooding systems and submitted a follow-up paper describing the temperature effects.

Dissertations

-

Scientific Publications

1. Salinity-dependent contact angle alteration in oil/brine/silicate systems: the critical role of divalent cations; Martin E. J. Haagh, Igor Siretanu, Michael H.G. Duits, and Frieder Mugele; Langmuir.

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

Information

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Breath figures under electrowetting: Electrically controlled evolution of drop condensation patterns

Project leaders
Dirk van den Ende, Frieder Mugele
Research theme
Complex dynamics of fluids
Participants
Davood Baratian; Ranabir Dey; Harmen Hoek
Cooperations
-
Funded by
Dutch Technology Foundation STW, which is part of the Netherlands Organization for Scientific Research (NWO), and the VICI program (grant 11380).
Funded %

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

Start of the project
2014
Information
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Project Aim

We show that electrowetting (EW) with structured electrodes significantly modifies the distribution of drops condensing onto flat hydrophobic surfaces by aligning the drops and by enhancing coalescence. Numerical calculations demonstrate that drop alignment and coalescence are governed by the drop size-dependent electrostatic energy landscape that is imposed by the electrode pattern and the applied voltage. Such EW-controlled migration and coalescence of condensate drops significantly alter the statistical characteristics of the ensemble of droplets from the classical understanding. The resulting characteristics enhances the associated the net heat transfer.

Progress

We are presently working on the numerical simulations of evolution of condensate droplet pattern under electrowetting. Additionally, we are also working on the associated condensate droplet shedding characteristics under electrowetting.

Dissertations

-

Scientific Publications

1. D. Baratian, R. Dey, H. Hoek, D. van den Ende, F. Mugele, Breath figures under electrowetting: Electrically mediated evolution of condensate droplet pattern, Physical review letters 120 (21), 214502, 2018.

MicroGrease: understanding the relation between the microstructure of lubricating grease and its oil-separation properties

Project Aim

Lubricating grease, the most common lubricant for rolling bearings, consists of a thickener matrix and mobile base oil. This base oil is slowly released from the grease and provides the bearing with a thin film that separates the contacting surfaces, giving the bearing a long operational life. This project aims at understanding the relationship between the material properties/microstructure of the grease, its oil-separation (also called bleeding) properties and the film formation in the bearing contact. A model will be developed to describe the bleeding of grease under static and dynamic conditions.

Progress

A model system is developed, where a cylindrical grease patch with a defined volume is placed on a piece of paper and bleeding of grease is translated into the effective radius of the oil ring in the paper. As shown in figure 1, grease bleeding is much slower than the imbibition of an base oil drop, proving that the grease matrix retains the oil due to the wetting affinity. A Washburn-based model is used to describe the bleeding process and the affinity of grease matrix to the oil is estimated to be around 3.5 kPa. The wetting affinity increases after de-saturation, suggesting that the oil retention increases in the real life where the grease matrix collapses during bleeding.

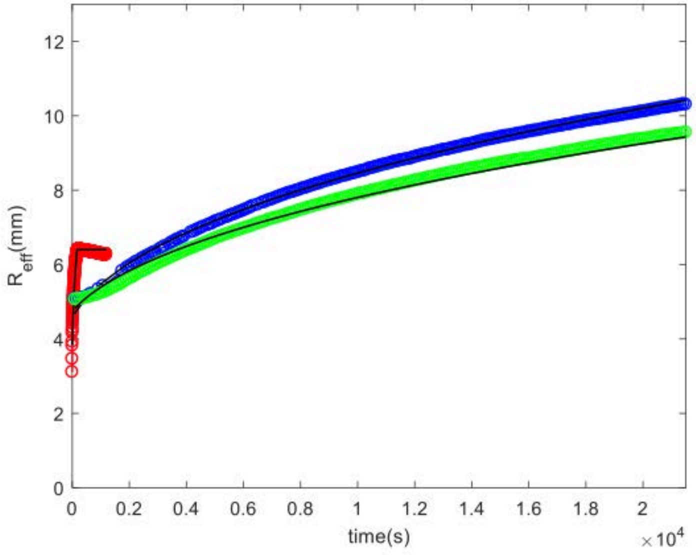
Dissertations

-

Scientific Publications

-

Imbibition of a 10μL oil drop (red) and bleeding of fresh grease (blue) and de-saturated grease (10% less oil, green). Black line indicates the theoretical prediction.



Project leaders

Prof. dr. P.M. Lugt; prof. dr. F. Mugele

Research theme

Complex structures of fluids

Participants

Q. Zhang, dr. D. van den Ende, dr.ir. R. bosman, 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	70 %
Industry	30 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2017

Information

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Distribution of inorganic and organic matter at solid-electrolyte interfaces studied by Confocal Raman Microscopy

Project leaders
Frieder Mugele

Research theme
Complex structures of fluids

Participants
Prof. dr. Frieder Mugele, Sachin Nair, Jun Gao

Cooperations
-

Funded by
NWO, British Petroleum

Funded %

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

Start of the project
2017

Information
Sachin Nair
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Project Aim

To study the adsorption and desorption of organic molecules at solid (clay, rock surfaces) –liquid (water, oil) interfaces for the process of Enhanced Oil Recovery using confocal Raman imaging.

Progress

Basic understanding of Confocal Raman Imaging and its utilization for detection of adsorbing molecules. Feasibility studies were done to see how thin of a particular material can be detected. Normal Raman imaging has so far been unsuccessful at the sub-10 nm level. Preparation for using enhanced Raman for the same, which has been proved successful in previous researches, is being attempted currently.

Dissertations

-

Scientific Publications

-

Project Aim

Detect and investigate the charge trapping phenomenon under the influence of electric field, in amorphous fluoropolymer layers in contact with an aqueous solution, by measuring the contact angle variation with electro-wetting.

Progress

We found an annular formation of trapped charge triggered by an applied voltage at the interface of a screen printed fluoropolymer film and a water droplet. Negative charge with a density of approximately 0.3 mC/m2 was permanently trapped near the three phase contact line (TPL) , while positive trapping charge disappeared after several hours, which was tested by low voltage electro-wetting.

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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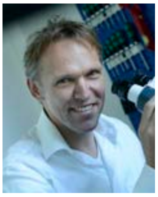
Soft matter, fluidics and interfaces



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.

PROJECT AIM

Boundary layer is a common feature within Solid/Liquid interface that is central to many engineering efforts involving process intensification, regarding chemical conversions and separations, and it acts to limit mass transport , affecting negatively production output, time and energy. This project aims at inducing self-mixing of the boundary layer by electro and diffusio osmotic phenomena, that consequently reduces its thickness and improves the overall process without significantly affecting the bulk or requiring high flow rates. A proof of concept will be realized by studying both experimentally and numerically , the catalytic induced concentration, its potential gradients and generated flow.

PROGRESS

The Bimetallic catalytic system consisting of platinum-gold bi-electrode was fabricated through series of photolithographic processes (fig 1). The Bipolar electrochemical mechanism is currently being studied using various electrochemical techniques. The Induced potential which describes the electric field that serves as body force that induces convective flow was measured directly (Fig 2). Numerical studies are being conducted based on experimental results to extract quantities of interest such as the Ionic strength and flux serving as basis of the catalytically induced convective flow.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Poster presentation at MESA + September 2017.

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

INFORMATION

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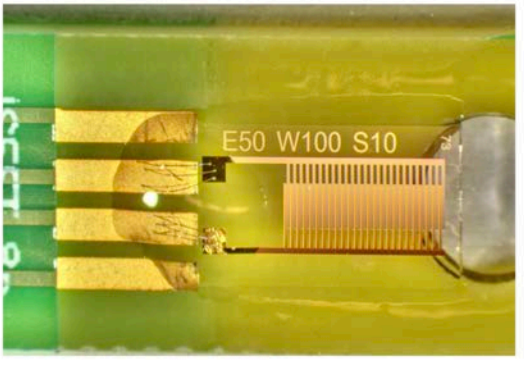
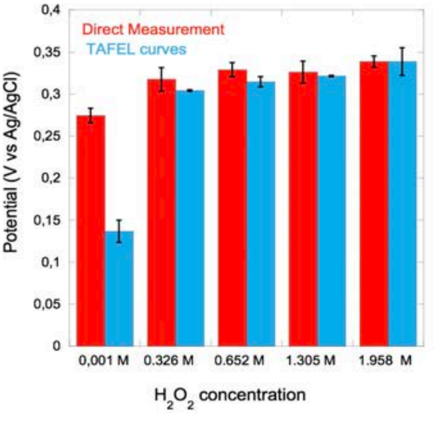
Pt/Au Bimetallic electrodes



Induced potential measuremnt



PROJECT LEADERS
Prof.dr.ir. R.G.H. Lammertink

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Hanieh Bazyar

COOPERATIONS
-

FUNDED BY
-

FUNDED %

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

START OF THE PROJECT
2017

INFORMATION
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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 here is to permeate the dispersed phase (oil droplets) not the continuous phase (water). To achieve this, a process called cross flow electrofiltration (CFEF) will be used. Application of electric field will direct the oil droplets toward the membrane and by setting the proper trans membrane pressure (TMP), oil can be permeated. The electrophoresis of oil droplets will be studied in details.

PROGRESS
Extensive application of SLIMs for filtration processes requires a thorough understanding of the retention of the infusion liquid. We investigated the retention of the infusion liquid in SLIMs via liquid-liquid displacement porometry (LLDP) experiments combined with microscopic observations. LLDP experiments were done cyclic in a flux-controlled mode by pushing pure water through SLIM. The results showed preferential flow path ways for water transport through SLIM with 43% of remaining infusion liquid. The microscopic observations confirmed presence of thin liquid film on the pore wall (liquid-lining) [1].

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
1. Bazyar H., Lv P., Wood J. A., Porada S., Lohse D., Lammertink R. G. H., Liquid-liquid displacement in slippery liquid-infused membranes (SLIMs), Soft Matter (2018) DOI: 10.1039/c7sm02337e.

Project Aim

The proposed experiments include the measurement of fluid flow and ion concentration, both at high precision near a membrane. In electrodialysis, an ion selective membrane is used through which ion transport is driven by an external electric field. Upon increase of the potential, a limiting and overlimiting current regime are observed. The origin of this regime is today still a topic of discussion. Under severe concentration polarization conditions, the occurrence of electroconvection phenomena is predicted. We intend to approach this problem by using controlled microfluidic experiments near ion selective materials.

Progress

Experiments on temperature gradients in macroscale ED systems where done to investigate the ion transport in the limiting current regime. Investigation of ion concentration polarization in microfluidic devices containing positively and negatively charged hydrogels. In-situ concentration profiling adjacent to charged hydrogels using Fluorescent Lifetime Image Microscopy. Finishing up research and final scientific publications, inlcuding the dissertation.

Dissertations

-

Scientific Publications

1. Benneker, A. M., Wendt, H. D., Lammertink, R. G., & Wood, J. A. (2017). Influence of temperature gradients on charge transport in asymmetric nanochannels. Physical Chemistry Chemical Physics, 19(41), 28232-28238.
2. Benneker, A. M., Rijnaarts, T., Lammertink, R. G., & Wood, J. A. (2018). Effect of temperature gradients in (reverse) electrodialysis in the Ohmic regime. Journal of Membrane Science, 548, 421-428.

Project leaders
Prof.dr.ir. R.G.H. Lammertink

Research theme
Complex dynamics of fluids

Participants
Anne Benneker

Cooperations
-

Funded by
ERC

Funded %

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

Start of the project
2013

Information

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Project leaders
Prof.dr.ir. R.G.H. Lammertink
Research theme
Complex dynamics of fluids
Participants
Pim Bullee
Cooperations
-
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

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

Drag reduction (DR) measurements in high turbulent flows have been conducted using a Taylor-Couette (TC) setup. The inner cylinder of the TC was coated with a porous hydrophobic material. Results showed an increase in DR due to the presence of the porous hydrophobic wall for void volume fraction of air present in the working liquid $\alpha > 2\%$. For $\alpha < 2\%$ the drag increased compared to a smooth hydrophilic surface, which is probably the result of the added roughness of the surface. A net drag increase was however found for all values of α when the coating was applied.

Dissertations

-

Scientific Publications

1. Verschoof, R. A., Bakhuis, D., Bullee, P. A., Huisman, S. G., Sun, C. & Lohse, D. 2017 Air cavities at the inner cylinder of turbulent Taylor-Couette flow. ArXiv e-prints, arXiv: 1712.02221.

Project Aim

In this project we study the growth of bacterial biofilms under different flow conditions. For that particle tracking techniques are used to assess the rheological properties and structural heterogeneities of the complex biofilm. The motion of the particles is recorded and used to extract the diffusive and convective dynamics; this gives information about the environment in which the particles are located. We mainly use a technique called Optical Coherence Tomography (OCT), it allows for depth resolved structural imaging with micron level resolutions of biological samples.

Progress

By adding nanoparticles to the sample depth resolved particle dynamics can be obtained in/around the biofilms. The dynamic information is acquired from the autocorrelation function (ACF) at the each detector pixel. The ACF contains both diffusive and convective motions, the ability to differentiate between the two depends on their ratio defined as the Péclet number. For $Pe > 1$ convection dominates, at $Pe < 1$ diffusive motion dominates.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. R.G.H. Lammertink

Research theme

Complex dynamics of fluids

Participants

El Tayeb el Obied, Khalid

Cooperations

-

Funded by

ERC

Funded %

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

Start of the project

2013

Information

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FLAG-ERA - (NU-TEGRAM)

Project leaders
Prof.dr.ir. R.G.H. Lammertink
Research theme
Complex dynamics of fluids
Participants
Mandakranta Ghosh
Cooperations
-
Funded by
FOM (NWO)
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

Nano-pores in graphene are created by ion beam bombardment. We have studied the transport of ions through the nano-pores in graphene by measuring its membrane potential generated due to diffusion of ions from high to low concentration across the membrane. Our study shows that the membrane is selective to cations. This means that the membrane only allows the cations to pass through and blocks the anions. The membrane potential varies with the concentration. At low concentration it is high and at high concentration it decreases to a low value. We have validated our experimental result with theoretical understanding.

Dissertations

-

Scientific Publications

1. L. Madauß, J. Schumacher, M. Ghosh, O. Ocheowski, J. Mayer, H. Lebius, B. Ban-d‘Etat, M. E. Toimil-Molares, C. Trautmann, R. G. H. Lammertink, M. Ulbricht and M. Schleberger (2017), Nanoscale 9: 10487-10493.

Project Aim

This research seeks to provide a novel water treatment method, based on the synergy between membrane separation and photocatalytic oxidation. We aim to combine membrane and catalyst functionality within a single material. Something difference compared to previous reports, as there is a beneficial synergy expected to have these two functions present at a single location. A reactive membrane is expected to reduce the concentration polarization and biofouling layers via the chemical conversion of reactants, which is conceptually innovative. Furthermore, photocatalytic degradation of contaminants in water is considered as a viable method to remove micropollutants.

Progress

Dead-end filtration and catalysis experiments are in progress. Different concentrations of methylene blue solution are filtrated through unique metal 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 concentration after the catalytic oxidation and membrane filtration is represented versus the solution flow.

Dissertations

-

Scientific Publications

-

Project leaders

Prof.dr.ir. R.G.H. Lammertink

Research theme

Complex dynamics of fluids

Participants

Shuyana Heredia

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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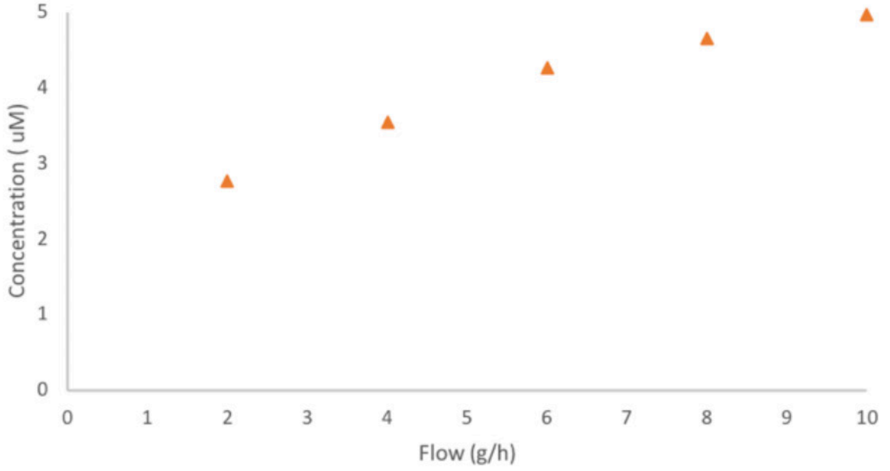
Methylene blue outlet concentration versus flow when using an initial concentration of 5 µM of methylene blue under continues UV light irradiation



PROJECT LEADERS
Prof.dr.ir. R.G.H. Lammertink

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Aura Visan

COOPERATIONS
-

FUNDED BY
MCEC-UT-2-3

FUNDED %

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

START OF THE PROJECT
2014

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PROJECT AIM
Small-scale surface structures, both geometrically as well as chemically, can potentially influence the fluid dynamics and hence the mass transport on a microscopic scale. There is a need to understand these influences in great detail on the nano- and microscopic level, in order to couple them to the largest scales in the flow. The aim is to study catalytic surface heterogeneity with respect to interfacial transport phenomena. To obtain information, the fluid dynamics (momentum transport) and concentration profiles (mass transport) will be experimentally probed on a length scale comparable to the boundary layer.

PROGRESS
The most important progress was made on the numerical modeling of diffusio-osmotic flow induced by catalytic patterning. We studied its impact on mass transfer and conversion enhancement, derived scaling laws to provide guidelines for finding the chemistries and kinetics which could benefit from this approach and determined the optimum catalyst configuration. The paper presenting these findings is being finalized.

DISSERTATIONS
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SCIENTIFIC PUBLICATIONS
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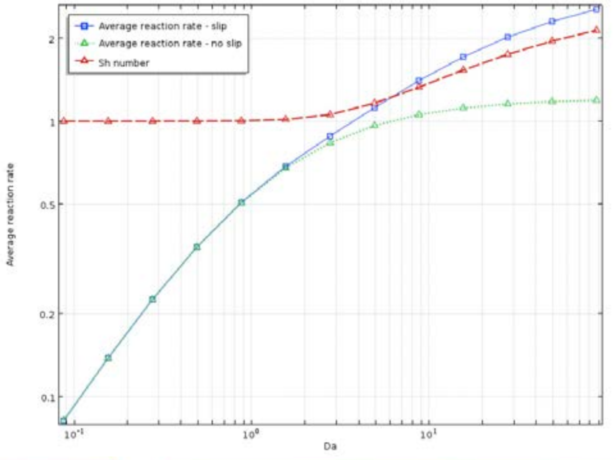
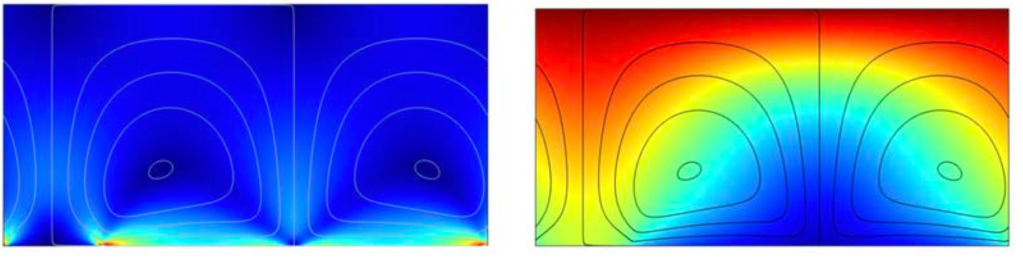


Average reaction rate for diffusion-osmosis and diffusion only and Sh number vs. Da



Velocity and concentration profiles resulting from catalytic induced surface flows

Project Aim

The primary aim is the broad investigation of transport phenomena at the microscale (or millimeter scale). Studies focused last year on two specific types of systems, flow over heterogeneous superhydrophobic surfaces (the so-called bubble mattress) and ion concentration polarization and ion-selective interfaces at the microscale. Fundamental investigations of these systems can yield insights leading to improved performance in application relevant systems such as electrodialysis stacks and lab-on-a-chip based biosensors.

Progress

A number of successful studies were carried out in 2017. Work relating to the role of geometry on ion-transport and related fluid behavior was carried out. Experimental studies relating to the flow of non-Newtonian fluids over superhydrophobic surfaces were performed, as well as on the nature of liquid-liquid displacement in liquid-infused membranes. Experimental and theoretical investigations of ion-transport through a single-atom layer of graphene were carried out. Finally, the effect of temperature gradients in the limiting current regime of electrodialysis was successfully investigated.

Dissertations

-

Scientific Publications

1. Haase, A.S, Wood, J.A., Sprakel, L.M.J and Lammertink, R.G.H. (2017). Inelastic non-Newtonian flow over heterogeneously slippery surfaces. Phys. Rev. E 95(2): 023105.
2. De Valenca, J.C., Kurniawan, A., Wagterveld, R.M., Wood, J.A. and Lammertink, R.G.H. (2017) Influence of Rayleigh-Benard convection in overlimiting current conditions. Phys. Rev. Fluids 2(3): 033701.
3. Benneker, A.M., Wendt, H.D., Lammertink, R.G.H. and Wood, J.A. (2017) Influence of temperature gradients on charge transport in asymmetric nanochannels. Phys. Chem. Chem. Phys. 19(41): 28232-28238.

Project leaders

Prof.dr.ir. R.G.H. Lammertink

Research theme

Complex dynamics of fluids

Participants

Jeff Wood

Cooperations

-

Funded by

ERC

Funded %

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

Start of the project

2014

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PROJECT LEADERS
Prof.dr.ir. R.G.H. Lammertink
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
Arputha Paul
COOPERATIONS
-
FUNDED BY
-
FUNDED %

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

START OF THE PROJECT
2017
INFORMATION
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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 the interface will be explored with the help of surface induced flows that are caused due to voltage and concentration gradients. The different out comes could be utilized in various applications, for instance, in designing of ion exchange membranes with tailored interface structures; and a full-fledged working model could be possibly realised under optimised conditions. This would eventually enhance the tranport of different species within the boudary layer of any system involving interfaces, thereby improving the performance, in a fundamentally different manner.

PROGRESS

Literature survey was done to study the existing methods in determining the surface charge of any solid surface in contact with fluid. A steady experimental set up has been built in order to measure the surface charge. Two different microfluidic chips were fabricated wherein the microchannels were sputtered with titanium dioxide in order to study the surface charge under UV light being turned on and off. Thus, experiments are being carried out in order to quantify the generation and depletion of the various charged species at the surface, as a function of different parameters like the pH of solution, the ionic strength.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

-

ENGINEERING FLUID DYNAMICS

Prof.dr.ir. CH Venner

Modern engineering challenges concern the design and development of processes and equipment with a high performance and minimal environmental impact, i.e. effective use of resources, energy and minimal generation of waste products and noise. The Engineering Fluid Dynamics group aims to contribute to innovative solutions for practically relevant societal, environmental and industrial challenges by bringing "fundamental" physics to actual applications on many scales, ranging from large size high power such as aircraft parts, compressors, and turbines, to small-scale thin-layer free surface flows in lubrication and bearing applications. The research is both experimental and theoretical, including numerical simulations with in house development of accurate numerical codes and multilevel/multigrid computational methodologies. The research focuses on the following themes:

Fluid Mechanics of Rotating Flow Machines

The flow in centrifugal pumps, compressors, and around wind turbine blades. The research involves optimization of the functional aspects (blade/impeller geometry, cavitation characteristics, efficiency, active flow control) as well as the minimization of non-drag related energy losses in the lubrication and transition layers, and minimization of environmental aspects such as the reduction of vibrational and (aeroacoustic) noise. For this purpose, an aero-acoustic test facility is used: A silent closed circuit wind tunnel with a (0.7x0.9 m2) free-jet test-section (maximum velocity 65 m/s) which is enclosed by a 6x6x4m3 anechoic chamber.

Multi-phase flows and wave phenomena

Flows with phase transition occur in many engineering applications such as flow of oil/water/gas mixtures in hydrocarbon transport lines, ice accretion on aircraft wings in flight, flows with cavitation, separation of mixtures, and dense-phase fluid particle flows in dredging applications. The group develops computational methods for specific applications aimed at actual design and prototyping and also carries out fundamental studies, on the mechanisms of e.g. condensation, in multiphase systems. Research is also carried out aimed at identifying the acoustic signature of the flow.

Computational Aerodynamics Algorithm Design

Practical applications in engineering involve the occurrence of phenomena on largely different scales in almost any application. In such cases both high order accuracy as well as computational efficiency are of the utmost importance. The group develops and tests numerical algorithms for simulation and optimization , and validates predictions for actual applications ranging from Navier Stokes and Euler equations to potential flows, and reduced systems such as lubrication flows with combined elasticity on nano-scale. Aspects of development are high order compact schemes, multigrid/multilevel computational methodologies and gradient based adjoint optimization.

Bio-physical flows

This research deals with the flow in (bio)medical and natural systems, Projects include flow in lungs (aerosol deposition), medical sprays, and separation of specific cell rich flows. Research is aimed at developing new (computational) diagnostic and therapeutic tools. Research in nature-inspired flows is aimed at the development of robot-birds and minimizing the impact of technology on the natural environment.

Project Aim

Numerical simulation of ice accretion in the first stages of a compressor of an aircraft engine due to the presence of ice crystals at high altitude. The Eulerian approach for predicting the droplet trajectories will be used, combined with the (modified) Messinger method for the actual ice accretion.

Progress

In 2017 this program was finished by completing and defending the thesis.

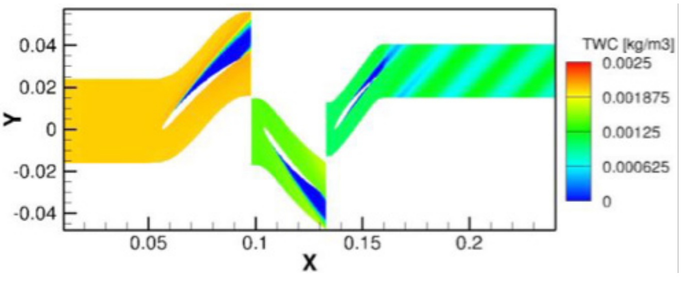
Dissertations

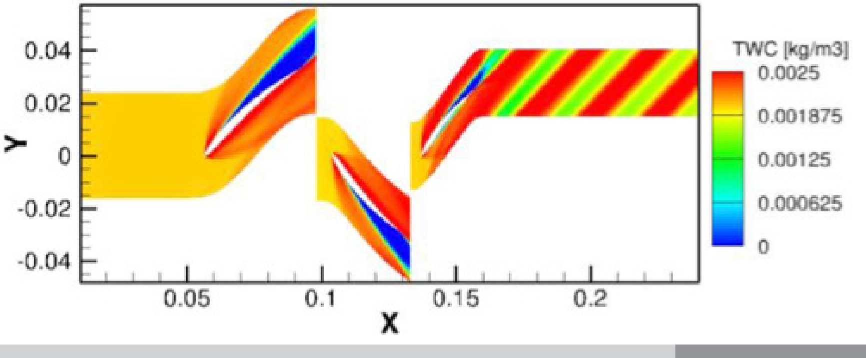
1. E. Norde. Eulerian Method for Ice Crystal Icing in Turbofan Engines.

Scientific Publications

-

Total water content (TWC) field for melting ice crystals with de-activated impact model (top) and activated impact model (bottom). The engine-like geometry is a 1.5-stage stator-rotor-stator linear cascade with aerodynamic conditions: M = 0.25, ptot = 38750 Pa. The particles have an equivalent diameter of 20 μm and a sphericity of 0.7.





Project leaders

H.W.M. Hoeijmakers, C.H. Venner, E.T.A. van der Weide

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

E. Norde (PhD), E.T.A. van der Weide and H.W.M. Hoeijmakers

Cooperations

Onera, CIRA, Airbus Group Innovations, Darmstadt Univ., Braunschweig Univ., TAI, INCAS, TsAGI.

Funded by

EU

Funded %

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

Start of the project

2013

Information

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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. Initial tests for a lid driven cavity were carried out, which show the expected results.

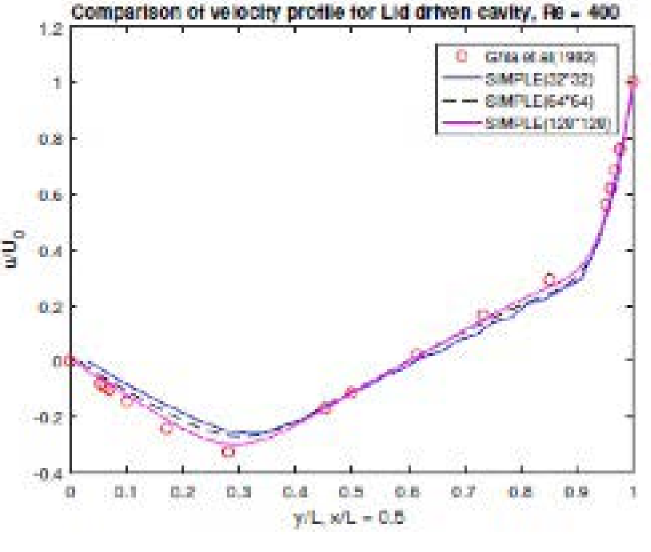
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

The velocity profile at the line x=0.5 for the lid driven cavity using the SIMPLE algorithm. The results of several grids are compared to the reference solution of Ghia et. al (U.Ghia, K.N. Ghia and C. Shin, Journal of Computational Physics, 48, 1982).



Validation and Application of a Multilevel Panel Method for Wind Turbine Rotor Flow Simulations

Project Aim

Validation of a fast multilevel method for wind turbine rotor aerodynamics simulations for unsteady flow cases of the MEXICO wind tunnel experiments. Application of the fast panel method for rotor blade twist optimization.

Progress

Studies have been performed for a recently developed fast panel method for wind turbine rotor aerodynamics simulations. Simulation times are reduced from O(N2) for a conventional approach to O(N). Unsteady test cases from the MEXICO experiment are simulated. The computed rotor blade pressure distributions compare favorably with the experimental data and full Navier Stokes solutions near rotor design conditions. A numerical optimization routine has been written and applied to the case of optimum rotor twist distribution. A result is shown in Figure 2 where the optimized twist distribution gives a power coefficient of 97.17% of the theoretical Betz maximum.

Dissertations

-

Scientific Publications

1. A. van Garrel, C.H. Venner, H.W.M. Hoeijmakers, Fast Multilevel Panel Method for Wind Turbine Rotor Flow Simulations, AIAA 2017-2001, January 2017. https://doi.org/10.2514/6.2017-2001.

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, Prof.dr.ir. H.W.M. Hoeijmakers, H.D.T. Klein, E. Prieto Serratos

Cooperations
-

Funded by
-

Funded %

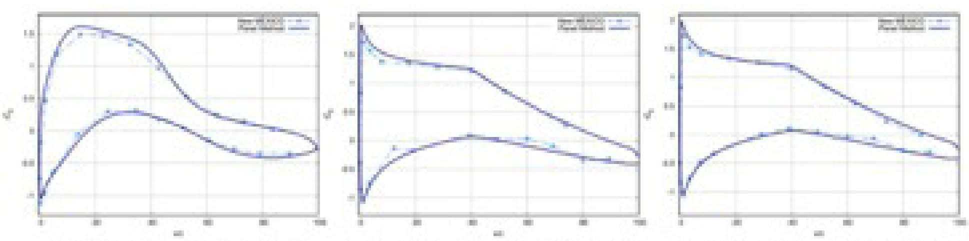
University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2017

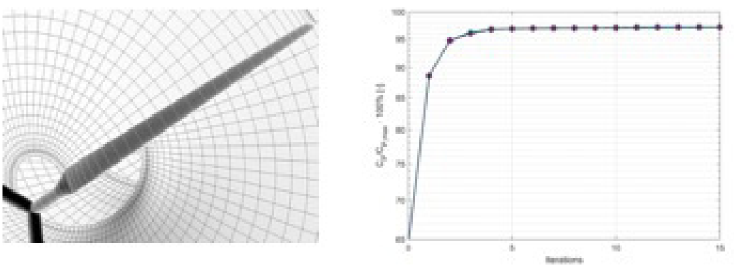
Information

Arne van Garrel
a.vangarrel@utwente.nl

Pressure distributions for rotor in 45° yaw, blade azimuth angle position 240°.



60% Rotor radius, Risø A2-21 — 82% Rotor radius, NACA64-418 — 92% Rotor radius, NACA64-418



Rotor and wake grid and power coefficient optimization test results.

Project leaders
C.H.Venner, H.W.M.Hoeijmakers
Research theme
Complex dynamics of fluids
Participants
L. de Santana, A. Brentjes, 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. Tests with a 7-hole probe with pressure prots distributed over its hemispherical tip have been done. Next a measurement setup has been developed using Particle Imaging Velocimetry. In both cases wind-tunnel experiments have been carried out for a flexible model of the wing of the peregrine bird carrying out a flapping motion similar to the true motion.

Dissertations

-

Scientific Publications

1. Brentjes, A., and Hoeijmakers, H.W.M., 2017, Experimental Investigation into Wake Flapping Wing Robotic Bird", 35th AIAA Applied Aerodynamics Conference, AIAA AVIATION Forum, (AIAA 2017-3409), https://doi.org/10.2514/6.2017-3409.
2. Folkertsma, G.A., Straatman, W., Nijenhuis, N., Venner, C.H., Stramigioli, S. Robird: a robitic bird of prey, IEEE robotics & automation magazine, V. 24, 3, pp. 22-29. (Awarded Best Paper award of 2017).

Model wing of robotic bird in windtunnel setup for PIV measurments. White arrow indicates wing in vertical position. Flow direction from right to left.

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 are now finalized and made ready for production at Apollo Tyres. Competitor solutions, striving cavity reduction, are shown in the figures below.

Dissertations

-

Scientific Publications

-

Project leaders

Prof. C.H. Venner, Dr. ir. Y.H. Wijnant

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Ir. Martin Goossens, Dr. ir. Y.H. Wijnant

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

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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
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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 require advances in current experimental techniques and instrumentation to allow accurate determination of turbulent structures. Aiming to advance the experimental determination of unsteady wall pressure, this research investigates the application of digital MEMS microphones embedded in a 3D printed NACA0012 airfoil at Reynolds number 200,000<Re<700,000. The development of this experimental technique brings challenges regarding the construction since sensors and components must be miniaturized to maximize the sensor's spatial resolution.

Progress

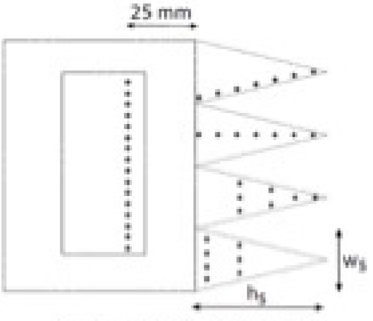
Digital MEMS microphones have been employed in combination with 3D printing techniques for the measurement of unsteady surface pressure fluctuations on a NACA0012 airfoil with 200,000<Re<700,000. Measurements showed that useful information related to the boundary layer characteristics was obtained in 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.

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.

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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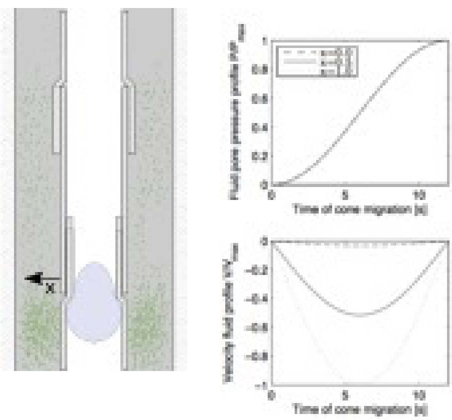
For upward cone migration the cement- and fluid in between the cement along the pipe is compressed. As a result the fluid is displaced towards the interface of cement and oil-pipe, potentially separating the pipeline with its foundation



Thin Layer Flow

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

Droplet on demand lubrication system developed tested based on inkjet technology. First success with thin synthetic oil TT9. Further development towards thicker oil, and steps taken from single contact towards application in bearing. Contribution to various aspects of grease lubrication and theoretical investigations of specific applied problems. Research on composite material analysis using Multigrid methodologies continued. Research into functional grading of subsurface topology continued. Research on viscoelastic layers as lubricant films continued.

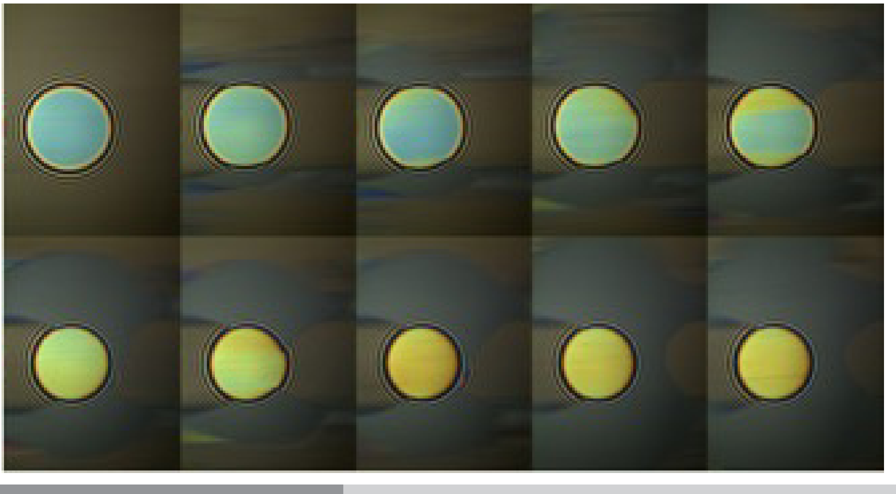
Dissertations

-

Scientific Publications

1. van der Vegte, S., Venner, C.H., (2017) Inkjet based droplet on demand Lubrication system for EHL contacts. 6th World Tribology Congress Beijing, PR of China, sept 2017.
2. Morales-Espejel, G.E., Boffy, H., and Venner, C.H., (2017), Effects of Material Heterogeneity on Surface Fatigue for Rough Lubricated Rolling-Sliding Contacts, accepted, Proceedings ImechE, Part J. Journal of Engineering Tribology. V. 231(2) 274-290. DOI 10.1177/1350650116650126.

Interferographic images of lubricated model contact. Flow in contact from left to right. Images from from top left to bottom right: Evolution of fully flooded lubricant film from dry contact by inkjet droplet on demand system. Note the visibility of the lubricant pool in butterfly shape around the contact.



PROJECT AIM

Development of a mixed lubrication model based on physical first principles representing relevant aspects on different scales to predict the behaviour of concentrated contacts as appearing between rolling elements and raceways in rolling element bearings under extreme operating conditions of very limited lubricant supply.

PROGRESS

Development of an dry contact model with an oedometric viscoelastic layer to model effects of the lubricant layer in EHL contacts has been completed. The local nature of the layer opens new physically justified ways to model mixed lubrication. The model has been tested for specific EHL characteristic problems such as start-up and squeeze. Results show that the layer model can quite well predict characteristic effects also observed with fluid lubrication layers. However, also significant differences are noted. Project completed, PhD thesis defended.

DISSERTATIONS

1. Aspects of flow and viscoelasticity in a model elastohydrodynamically lubricated contact, PhD Thesis, University of Twente, Enschede, the Netherlands, DOI:10.3990/1.9789036543347.

SCIENTIFIC PUBLICATIONS

1. Emden, E. van, Venner, C.H., and Morales-Espejel, G.E., 2017, Investigation into the viscoelastic behavior of a thin lubricant layer in an EHL contact, Tribology International V111, pp. 197-210, DOI: 10.1016/j.triboint.2017.03.014.

PROJECT LEADERS

C.H.Venner

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

E. van Emden, C.H.Venner, G.E. Morales Espejel

COOPERATIONS

SKF

FUNDED BY

SKF

FUNDED %

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

START OF THE PROJECT

2009

INFORMATION

C.H.Venner
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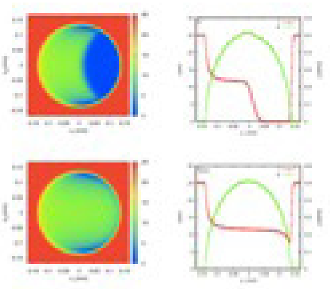
Simulated results of layer thickness contour plot (left) and centerline profile (right) of layer thickness and layer pressure during start-up (top) and achieved steady state (bottom). Viscoelastic oedometric dry contact layer model.



Project leaders
C.H. Venner

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Binbin Zhang, Hugo Boffy

Cooperations
SKF ERC, Nieuwegein, INSA de Lyon, France

Funded by
CSC, SKF

Funded %

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

Start of the project
2016

Information
.C.H.Venner
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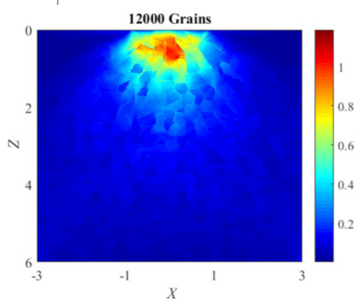
Project Aim
Development of optimally efficient and computational methods for advanced computational diagnostics and optimization of the effect of 3D topology and structural heterogeneity in the subsurface of bearing materials on the service life in contact mechanics and lubrication. The methods will allow "design" of the required local topological mechanical and thermal properties such that fatigue life is maximized, whilst maintaining lubrication life, as well as quick assessment of risk of reduced "lubrication life" from tomographic maps of actual material samples.

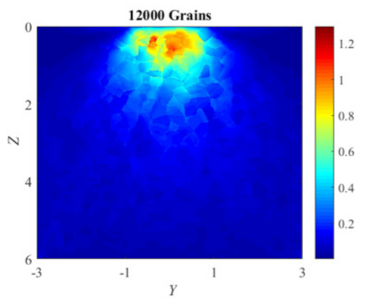
Progress
In 2017, a multigrid based method to simulate 2D and 3D stress fields in anisotropic materials has been realized. The developed method has very high efficiency, owing to fast grid independent convergence. Over 1 billion points can be used in a calculation allowing detailed modeling of grains and topology structures, including crystal orientation. Further work will focus on linking tomographic images and image analysis techniques to the developed programs for computational diagnostics, and, to embed multigrid solvers in material topology optimization. Publications in preparation.

Dissertations
-

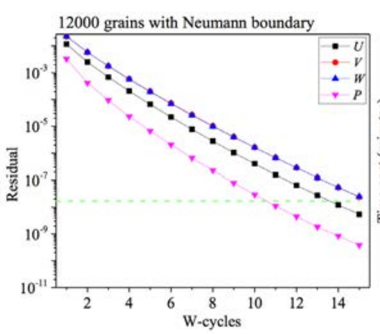
Scientific Publications
-



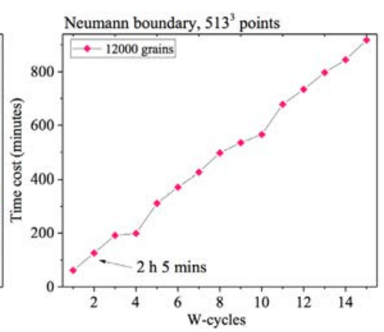
(a) Von Mises stress of XZ plane



(b) Von Mises stress of YZ plane



(C) Functions residual



(d) Time cost

3D Von Mises stress distribution (top), Algorithm performance: Grid independent error reduction (bottom left) and computing time (bottom right) as a function of the number of multigrid iteration cycles.

PROJECT AIM

Development of short time pulse LED 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

A LED driven fast Schlieren system with high speed camera has been further developed electronically and optically and used in studies of a single jet injected in a supersonic cross-flow. In particular it has been used under a specific angle to investigate the possibility of obtaining 3D flow information. Further development towards multiple jets is in process.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Test section and Schlieren system (top left), optical and electronic output LED control (top right): 150 ns and 80A, light output (cyan) and current output (yellow). Bottom left, Schlieren image of jet injection at 0 degree. Bottom right, Schlieren image at angle 10 degrees.

PROJECT LEADERS

C.H.Venner

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

H.W.M. Hoeijmakers, L. de Santana, 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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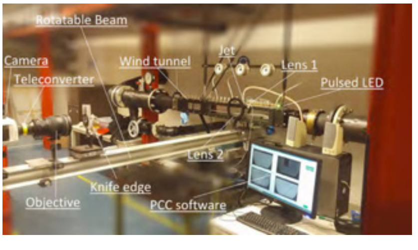

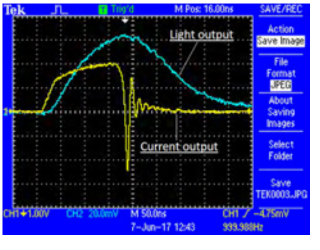

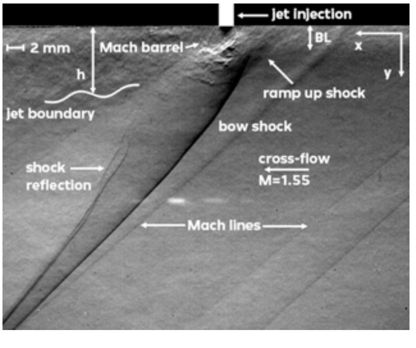

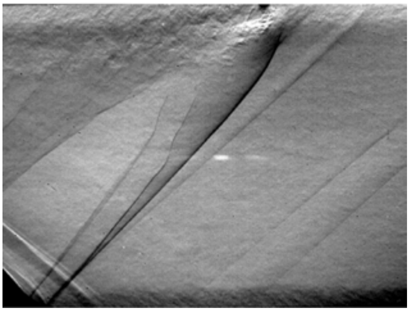

PROJECT LEADERS
R. Hagmeijer, C.H. Venner

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
R. Hagmeijer, V.I. Kalikmanov, E. T. A. van der Weide, H. M. J. Bastiaens, and K.-J. Boller, Y. Tao

COOPERATIONS
-

FUNDED BY
STW (PhDproject), University of Twente (RH & ETAvdW)

FUNDED %

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

START OF THE PROJECT
-

INFORMATION
R. Hagmeijer
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PROJECT AIM

We determine the size of argon clusters generated with a planar nozzle, based on optical measurements in conjunction with theoretical modelling. Using a quasi-one dimensional model for the moments of the cluster size distribution, we determine the influence of critical physical assumptions. We use the calculated value for the liquid mass fraction to retrieve the cluster size from optical measurements, i.e., calibrated Rayleigh scattering and interferometry.

PROGRESS

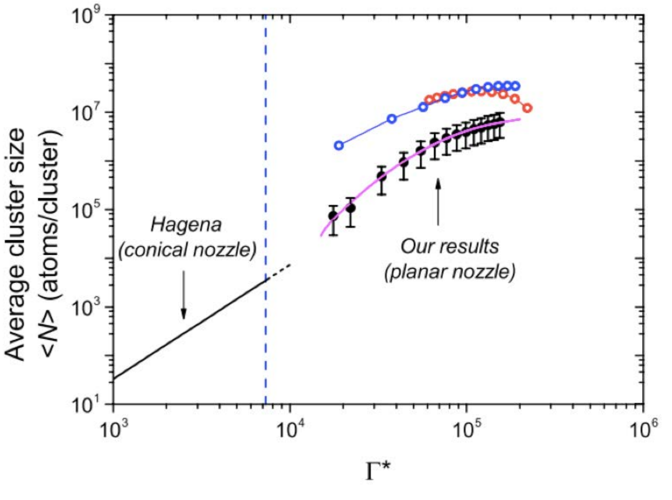
A new power law for higher values of the Hagena parameter Γ□ > 104 has been derived, which is of relevance for experiments on high-intensity laser matter interactions.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Tao, R. Hagmeijer, H.M.J. Bastiaens, S.J. Goh, P.J.M. van der Slot, S.G. Biedron, S.V. Milton and K-J. Boller: Cluster size dependence of high-order harmonic generation. New J. Phys. 19 083017 (2017).



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

Laser ablation of a liquid covered surface is a method by which surface structures may be altered. The ablation efficiency of the process can be optimized by careful variation of the height of the liquid layer. An experimental set-up is proposed which circumvents the issues of a curved free surface. Employing a 7 picosecond, 515nm, pulsed laser the efficiency of laser ablation of stainless steel was studied for a range of liquid layer heights. The result is a more detailed quantification of crater depth as a function of liquid layer.

Dissertations

-

Scientific Publications

1. Liquid covered picosecond pulsed laser ablation of stainless steel: effect of liquid layer thickness on ablation efficiency m on Laser Precision Microfabrication. Sietse VAN DER LINDEN*1, Rob HAGMEIJER*2 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

-

Information

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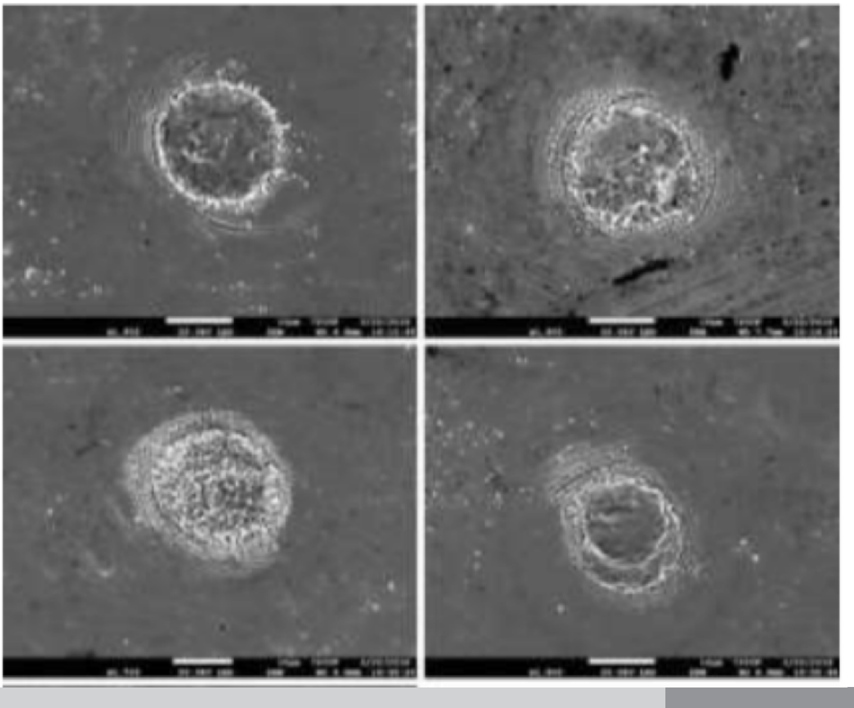

Project leaders
R. Hagmeijer, C.H. Venner
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
R. Hagmeijer (UT), H.C. Venner (UT), M. Pérez Zabalza (UT), B. Thio (MST), J. Goorhuis (MST), S. Klooster, X. Hoppenbrouwer, J. Bors, R. Hebbink.
Cooperations
Medical Spectrum Twente, Thorax Centre Twente
Funded by
ZGT, MST, UT
Funded %

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

Start of the project
2017
Information
R. Hagmeijer
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Project Aim

Severe airway infections in infants are increasingly treated by non-invasive high-flow nasal cannula (HFNC) therapy which provides a flow-rate controlled increase of airway pressure and prevents respiratory insufficiency. However, there is a large uncertainty in the generated pressure level which has received world-wide attention over the last decade. We propose to switch from flow rate control to pressure control, which might lead to increased efficiency and effectiveness, reduced risk, and possibly to reduced costs up to 2.5 - 10 M€ for the Netherlands.

Progress

Data of more than 40 patients have been collected from measurements in the MST-hospital in Enschede, consisting of time-resolved device pressure, heart rate, respiration rate, and saturation. Currently these data are analyzed with the objective to discover or construct parameters that can serve as health monitoring parameters. In addition in-vitro measurements in 3D-printed infant airways have been conducted in order to assess the pressure differences between the cannula-exits and the airway.

Dissertations

-

Scientific Publications

-

Pre-Operative Ring Size Determination in Mitral Valve Plasty

Project Aim

The mitral valve in the human heart regulates the blood flow from the lungs to the heart. In case of malfunctioning, a saddle shaped metal ring can be attached to the annulus. This procedure is called mitral valve plasty. The determination of the ring size is crucial. Based on three projection views from pre-operative three dimensional (3D) echocardiographic data, the circumference of the anterior leaflet is determined, which can be linked to the required ring size.

Progress

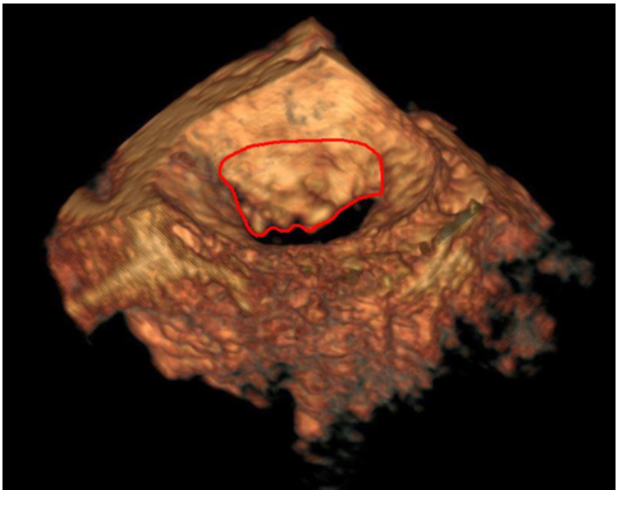
The developed method was tested on 22 patients that had mitral valve plasty recently. The ring sized determined by our method was compared to the ring size implemented, and shows the potential of the method. However, the quality of the 3D echocardiographic data, which is crucial, is insufficient at the moment, and this will be given attention in the coming year.

Dissertations

-

Scientific Publications

-



Project leaders

R. Hagmeijer, C.H. Venner, J. Grandjean

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

R. Hagmeijer, C.H. Venner, J. Grandjean, D.S. van Putten, K. Reinders

Cooperations

Medical Spectrum Twente, Thorax Centre Twente

Funded by

-

Funded %

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

Start of the project

2017

Information

R. Hagmeijer
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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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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.

Dissertations

1. Diaphramatic electromygraphy monitoring in reterm infants J.V.S. Kraaijenga (F. De Jongh co-promotor) 24-05-2017.

Scientific Publications

1. Breath detection by transcutaneous electromyography of the diaphragm and the Graseby capsule in preterm infants. de Waal CG, Kraaijenga JV, Hutten GJ, de Jongh FH, van Kaam AH. Pediatr Pulmonol. 2017 Dec;52(12):1578-1582. doi: 10.1002/ppul.23895. Epub 2017 Oct 24.
2. Exhaled breath profiles in the monitoring of loss of control and clinical recovery in asthma. Brinkman P, van de Pol MA, Gerritsen MG, Bos LD, Dekker T, Smids BS, Sinha A, Majoor CJ, Sneeboer MM, Knobel HH, Vink TJ, de Jongh FH, Lutter R, Sterk PJ, Fens N. Clin Exp Allergy. 2017 Sep;47(9):1159-1169. doi: 10.1111/cea.12965. Epub 2017 Jul 10.
3. ERS technical standard on bronchial challenge testing: general considerations and performance of methacholine challenge tests. Coates AL, Wanger J, Cockcroft DW, Culver BH; and the Bronchoprovocation Testing Task Force: Kai-Håkon Carlsen, Diamant Z, Gauvreau G, Hall GL, Hallstrand TS, Horvath I, de Jongh FHC, Joos G, Kaminsky DA, Laube BL, Leuppi JD, Sterk PJ. Eur Respir J. 2017 May 1;49(5). pii: 1601526. doi: 10.1183/13993003.01526-2016. Print 2017 May.
4. The Mozart study: a relation between dynamic hyperinflation and physical activity in patients with chronic obstructive pulmonary disease? van Leuteren RW, Dijkhuis S, de Jongh FHC, van der Valk PDLPM, Tabak M, Brusse-Keizer MGJ. Clin Physiol Funct Imaging. 2018 May;38(3):409-415. doi: 10.1111/cpf.12430. Epub 2017 Apr 12.
5. Electrical activity of the diaphragm during nCPAP and high flow nasal cannula. de Waal CG, Hutten GJ, Kraaijenga JV, de Jongh FH, van Kaam AH. Arch Dis Child Fetal Neonatal Ed. 2017 Sep;102(5):F434-F438. doi: 10.1136/archdischild-2016-312300. Epub 2017 Mar 14.

The electronic nose project benefits from collaboration with the nanotechnology group of Prof Guus Rijnders (picture: Tubantia 15 Nov 2017)

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 2017 some further work has been carried out. realized. The Rotating Flow facility is being redesigned so that higher rotational speeds become possible. An associated project has been completed that deals with fish-safety of centrifugal pumps.

Dissertations

-

Scientific Publications

-

Project leaders

NP Kruyt, CH Venner

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

RW Westra, NP Kruyt

Cooperations

Flowserve BV

Funded by

Senter, UT

Funded %

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

Start of the project

1998

Information

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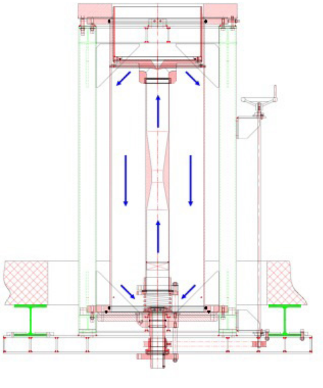

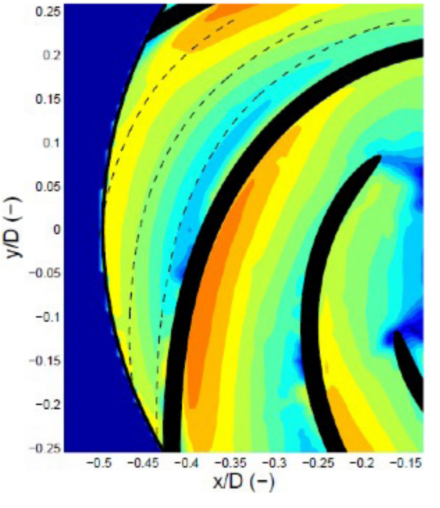

Inverse Design and Optimisation Methods for Centrifugal Pumps and Fans

Project leaders
NP Kruyt, C.H. Venner
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
RW Westra, NP Kruyt, C.H. Venner
Cooperations
Flowserve BV, Urenco Aerospace, Johnson Pump, IHC Parts & Services, NLR, Marin
Funded by
STW,UT
Funded %

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

Start of the project
2003
Information
NP Kruyt
053 489 2528
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Project Aim

Using the augmented potential-flow method developed for the prediction of the hydraulic performance of centrifugal and mixed flow pumps, two types of design methods for three-dimensional configurations are investigated: (i) inverse-design methods and (ii) optimization methods. The validation of the computational methods has been carried out in the newly developed Rotating Flow facility, by PIV-measurements of the relative velocity field.

Progress

A three-dimensional inverse-design method for impellers of centrifugal pumps has been developed, by which an impeller geometry is obtained that meets the prescribed hydraulic characteristics (rotational speed, flow rate, head and loading). Optimisation methods have been developed in which the performance of centrifugal pump impellers is optimised with respect to required head, low losses and optimal cavitation characteristics. The relative velocity field has been measured at various operating conditions using PIV, in the newly developed Rotating Flow facility. Publications have been effected.

Additional work has been done on the development of a semi-analytical inverse design method.

Dissertations

-

Scientific Publications

-

PROJECT 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. Nicot, F. & Kruyt, N.P. & Millet, O. (2017). On Hill's lemma in continuum mechanics. Acta Mechanica 228, 1581–1596.
2. Will, J.B. & Kruyt, N.P. & Venner, C.H. (2017). An experimental study of forced convective heat transfer from smooth, solid spheres. International Journal of Heat and Mass Transfer 109, 1059–1067.
3. Kruyt, N.P. & Millet, O. (2017). An analytical theory for the capillary bridge force between spheres. Journal of Fluid Mechanics 812, 129–151.

PROJECT LEADERS
NP Kruyt

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
NP Kruyt

COOPERATIONS
University of Waterloo, Canada;
Université de La Rochelle, France;
Irstea, Grenoble, France
University of Calgary, Canada

FUNDED BY
UT

FUNDED %

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

START OF THE PROJECT
2003

INFORMATION
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Project leaders
NP Kruyt, C.H. Venner
Research theme
Mathematical and computational methods for fluid flow analysis
Participants
BJ Konijn, NP Kruyt
Cooperations
TUD, IHC
Funded by
Agentschap NL, IHC
Funded %

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

Start of the project
2011
Information
NP Kruyt
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Project Aim

Aim of the project is to develop a CFD method for the modeling of dense-phase fluid-particulate flow. Firstly, experiments have been carried out to determine the dependence of the properties of both liquid and particles on the fluid behavior. With the experimental results, constitutive equations will be constructed. These constitutive relations will be used to develop a CFD method that describes fluid-particulate flow.

Progress

The numerical simulations of mixture flows are continued and expanded. The model is extended with an accurate model for momentum transfer between phases. A specific model has been developed to account for bed formation.

The measurements with the rheometer to characterize the behavior of various suspensions, have been continued by an MSc student. It extends the results obtained so far with measurements of suspensions by the use of other particulate materials and fluid viscosities.

A study has been initiated on the prediction of wear rates of impellers under off-design conditions.

Dissertations

-

Scientific Publications

-

Design for High Efficiency of Low-pressure Axial Fans: Use of Blade Sweep and Vortex Distribution

Project Aim

The effects of blade sweep (in axial and circumferential direction) and of the vortex distribution (i.e. the spanwise variation of the “blade loading” or “mean-swirl distribution”) on the aerodynamic performance of low-pressure axial fans are investigated parametrically by using CFD. Based on these results, optimized design methodologies considering blade sweep and vortex distribution will be formulated for obtaining low-pressure axial fans with high efficiency.

Progress

This project started 6 months ago. The research timeline has been decided. FINE/Turbo, a commercial CFD software, has been studied and tested, which shows good mesh quality and calculation efficiency. UT design method, developed at University of Twente as an inverse-design theory for axial fan design, that focuses on the aerodynamic performance of the impeller, has been studied theoretically. The investigation of the effect of axial forward/ backward sweep on the aerodynamic performance of the impeller forms the next step.

Dissertations

-

Scientific Publications

-

Project leaders

N.P Kruyt, C.H. Venner

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

Jie Wang, N.P Kruyt, C.H. Venner, E.T.A van der Weide, L.D. de Santana

Cooperations

University of Twente and Howden

Funded by

CSC & Howden

Funded %

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

Start of the project

2017

Information

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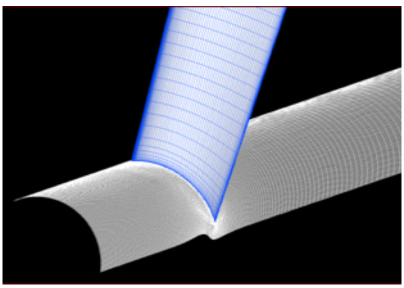

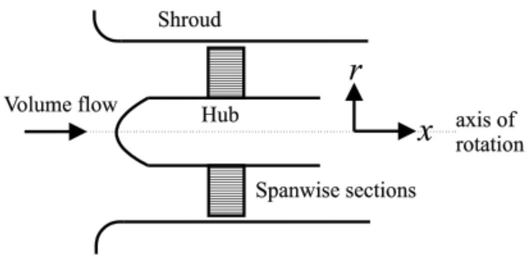

Prof.dr.ir. ThH van der Meer

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.

COPA-GT (Coupled Parallel Simulation of Gas Turbines) Spray Combustion

Project Aim

The numerical simulation of the entire engine with all physics involved is a key element for scientific progress and innovation. Developing numerical tools and methodologies to simulate the entire gas turbine with multiple physical effects is a new challenge and the overall scientific objective of the COPA-GT project. In this task of the project numerical models are developed for spray evolution, evaporation, mixing and turbulent combustion. Targeted is transient behaviour of spray combustion and coupling to acoustics. The models are optimized for large scale parallel computation with embedding in full engine models.

Progress

Numerical simulations were performed with ANSYS on an acoustically forced spray flame. The forcing leads to a considerable speed up of the combustion rate, but the driving mechanisms are different at low and high frequencies. A further investigation has been done to study the influence of the walls on the forced spray flame. A reaction progress variable model with lookup table is developed for ethanol. For this fuel the CSP approach using a 1 D premixed flame as an input failed to recognize the relevant kinetic time scales. This was more fundamental investigated using a Stirred reactor model. An accurate database taking into account detailed chemistry for ethanol was built this way. Simulations were performed of a premixed ethanol jet flame after the fashion of an experiment performed by DLR with a methane jet flame.

The methodology used for tabulation of ethanol chemistry was also applied to NH3 chemistry. This resulted in very accurate formulation of progress variable and tabulation of premixed NH3 chemistry.

Dissertations

1. Aspects of ethanol: laminar, turbulent and dynamic combustion, Virginia Fratalocchi.

Scientific Publications

1. Virginia Fratalocchi & Jim B.W. Kok, Ethanol turbulent spray flame response to gas velocity modulation, Combustion Theory and Modelling Vol. 0 , Iss. 0,0.
2. Virginia Fratalocchi & Jim B.W. Kok , The CSP/PSR approach in reduced chemistry of premixed ethanol combustion, April 2017, • Combustion Science and Technology 189(2), DOI • 10.1080/00102202.2017.1316266.
3. V. Fratalocchi, J.B.W. Kok, The CSP/PSR approach in reduced chemistry of premixed ammonia combustion, 9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK.

Project leaders

J.B.W. Kok

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

V.Fratalocchi, Dr.ir. J.B.W. Kok

Cooperations

CERFACS, RWTH Aachen University, Von Karman Institute, Loughborough University, Turbomeca, Siemens, Barcelona Supercomputing Center, Jülich computational center, Bull, Ansys.

Funded by

European Union Marie Curie ITN

Funded %

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

Start of the project

2012

Information

Dr.ir. J.B.W. Kok
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A novel thermosiphon-like cooling system based on magnetocaloric fluids

Project leaders
Prof.Dr.Ir. T.H. van der Meer
Prof.Dr.Ir. H.J.M. ter Brake
Dr.Ir. Mina Shahi

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Daniel De La Cuesta De Cal
Keerthivasan Rajamani
Amir Mahmoudi

Cooperations
KTH Royal Institute of Technology
Delft University of Technology
Cooll Sustainable Energy Solutions B.V.

Funded by
NWO

Funded %
STW

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

Start of the project
2017

Information
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Project Aim

The main objective of this project is to investigate, design and develop a new magnetocaloric cooling system superior to the existing ones in terms of heat transfer. This is aimed to be done by achieving the highest possible thermal properties of a heat transfer fluid by using magnetic nanofluids.

Progress

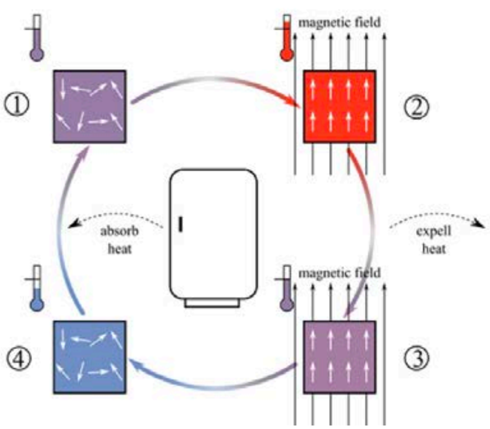
The main tasks have been the initial training of the involved PhD candidates, the literature study of the relevant technologies and the development of a preliminar model able to analyse the viability of the system. The latest task has been performed by and published as the Master Thesis of Evthimios Karaliolios. In fig 1 below, an schematic of the proposed system is presented, including the self-pumping and refrigeration effects created by the interaction between the magnetic field and the nanofluids. In fig 2, a demonstration of the viability of the system is shown using the magnetic field-driven velocity profiles.

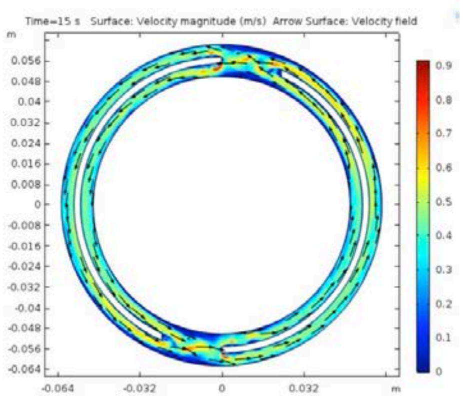
Dissertations

-

Scientific Publications

-





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

To investigate the implementation and performance of a bidirectional turbine in thermoacoustic engines, a CFD model is being developed. Furthermore, several prototypes of bidirectional turbines have been 3D printed to be 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. Finally, a literature study on the conversion of acoustic power to electricity has been completed, which has resulted in a published review article (Feb. 2018).

Dissertations

-

Scientific Publications

-

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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Combustion Modeling of Complex 3D Heat Exchanger Geometries and Systematic Design Optimization

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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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 so that not only the emission characteristics but also performance factors are optimized.

Progress

A 2D model of a pin-fin heat exchanger has been optimized using the discrete adjoint method in ANSYS Fluent 16. The initial heat exchanger shape was modeled as staggered cylinders in a cross-flow. Two observables were monitored during the optimization cycles: the heat transfer and the pressure drop, and the objectives are the maximization of heat transfer and the minimization of pressure drop. However, improving the performance of the heat exchanger poses its own challenges since the heat transfer and pressure drop are usually two contradicting observables. In order to successfully improve both observables, single objective and multi-objective shape optimizations were studied. Both single and multi-objective optimizations were conducted under steady laminar flow conditions at Re = 10 and Re = 100. The single objective optimizations were done for different step sizes of the geometry change, e.g. different changes of pressure drop or heat transfer. The optimized observable behaves linearly, while the other unconstrained observable shows a nonlinear deterioration. The multi-objective optimizations were performed for different weight factors, leading to different end shapes. For the final optimized geometry, we could achieve up to 11% reduction in pressure drop and 11% increase in heat transfer.

Dissertations

-

Scientific Publications

-

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

Powder agglomeration has a wide range of applications in additive manufacturing, pharmaceutics, process and mechanical engineering, geotechnics, and so forth. Due to a lack of efficient and accurate simulation methods, industries largely rely on capital-intensive experiments. The physical processes occurring over a wide-range of spatial and temporal scales in powder agglomeration are still poorly understood. The aim of this project is therefore to provide numerical tools for quantitatively accurate prediction of bulk agglomeration processes involving compression and heating, specifically for applications in tableting and Selective Laser Sintering (SLS).

PROGRESS

A multiscale approach is being undertaken to formulate a continuum model capable of simulating bulk powder agglomeration processes based on information at the particle level. To this end, discrete particle model (DPM) simulations will be used to understand particulate systems under high pressure (tableting) and high temperature (SLS). The knowledge gained will be used to calibrate Granular Solid Hydrodynamics (GSH), a continuum-mechanical theory for granular media. Currently, the continuum model is being parameterized using strain-rate and/or stress controlled DPM simulations.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

S. Luding
T. Weinhart
A.R. Thornton

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

S. Arora
Y. Shaheen
D.R. Tunuguntla

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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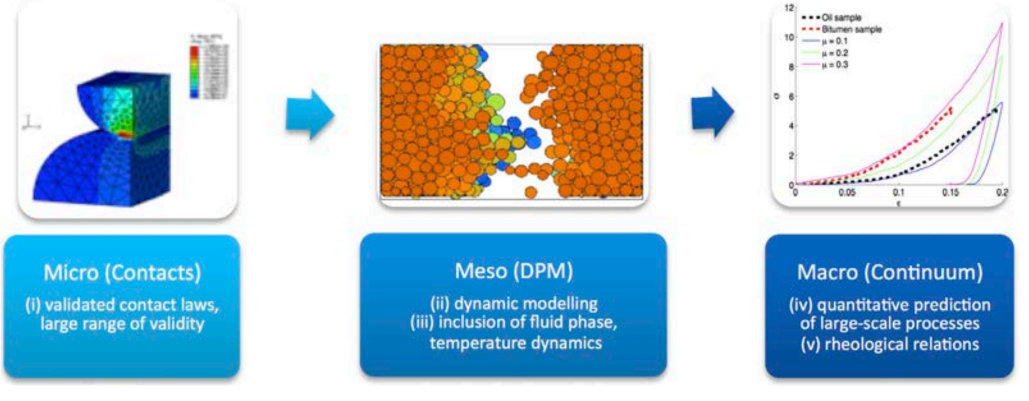
Schematic overview of the multi-scale modelling philosophy: the meso-scale model (center) is based on microscopic contact information (left) to predict macroscopic properties (right).



Project leaders
V. Magnanimo

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
H. Cheng
S. Luding

Cooperations
ENI

Funded by
ENI

Funded %

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

Start of the project
2016

Information
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Project Aim

The project aims to establish the predictive capacity of discrete element simulations for wave propagation in dry and saturated granular soils under generic loading conditions, by proper inference and calibration of micro- and macro-mechanical characteristics through computed tomography imaging and laboratory experiments. Within the framework, hybrid numerical tools will be developed to investigate the effects of pore pressure on the micro-structural and -mechanical characterization of granular soils, which will then be incorporated in a multiscale theoretical formulation.

Progress

The parameters are calibrated through a iterative Bayesian filtering process, which is able to focus increasingly on highly probable parameter subspaces over iterations. Three iterations are needed to obtain excellent agreement between posterior predictions and experimental data as well as accurate approximation of the posterior probability distribution as shown in Fig. 1a. From the posterior probabilities, micro–macro correlations can be obtained with known uncertainties (Fig. 1b). The wave velocities obtained at different pressures quantitatively agree with those measured in experiments, having errors less than 10% for the former and 16% for the latter.

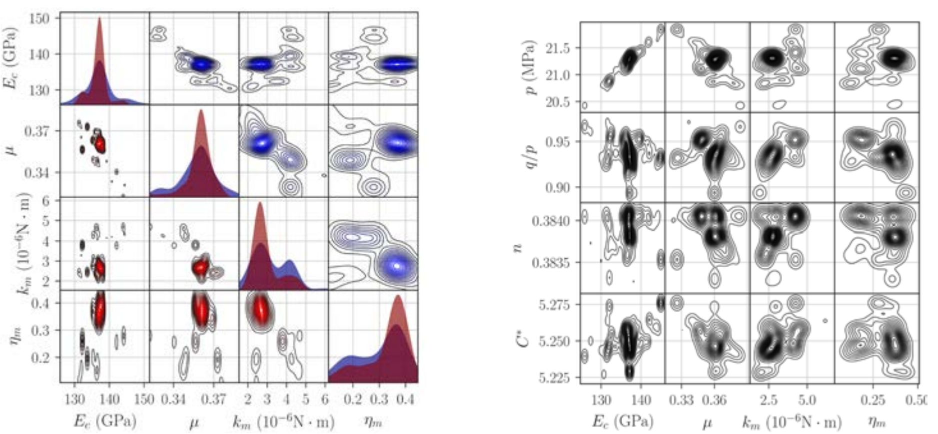
Dissertations

-

Scientific Publications

1. Cheng, H., Pellegrino, A., & Magnanimo, V. (2017). Bayesian calibration of microCT-based DEM simulations for predicting the effective elastic response of granular materials. PARTICLES 2017, Hannover, Germany.
2. Cheng, H., Yamamoto, H., Thoeni, K., & Wu, Y. (2017). An analytical solution for geotextile-wrapped soil based on insights from DEM analysis. Geotextiles and Geomembranes, 45(4), 361-376.
3. Cheng, H., Shuku, T., Thoeni, K., & Yamamoto, H. (2017). Calibration of micromechanical parameters for DEM simulations by using the particle filter. EPJ Web of Conferences , 140, [12011].

(a) Posterior PDF estimated at the beginning (blue) and the end (red) of the sequential Bayesian filtering. (b) Approximated posterior distributions for pairs of micromechanical parameters and macroscopic quantities.



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 particule simulations of small systems, the one-dimensional continuum simulations show that a structure emerges with the front of the flow being thicker than the inflow, see Figure 1. We developed a traveling wave solution for this structure and have shown that the continuum simulations converge to this traveling wave solution. With the approximations being made, the continuum simulations show remarkable good similarity to discrete particle simulations.

Dissertations

-

Scientific Publications

1. T. Weinhart, D.R. Tunuguntla, M.P. van Schrojenstein Lantman, I.F.C Denissen, C.R. Windows-Yule, H. Polman, H., J.M. Tsang, B. Jin, L. Orefice, K. van der Vaart, S. Roy, H. Shi, A. Pagano, W.M. den Breeijen, B.J. Scheper, A. Jarray, S. Luding and A.R. Thornton, MercuryDPM: Fast, flexible particle simulations in complex geometries. Part B: Applications. (Conference Proceeding of Particles 2017, Hannover, Germany).
2. J. Torres-Serra, D.R. Tunuguntla, I.F.C. Denissen, A. Rodríguez-Ferran, A. and E. Romero, Discrete element modelling of granular column collapse tests with industrial applications. (Conference Proceeding of Particles 2017, Hannover, Germany).

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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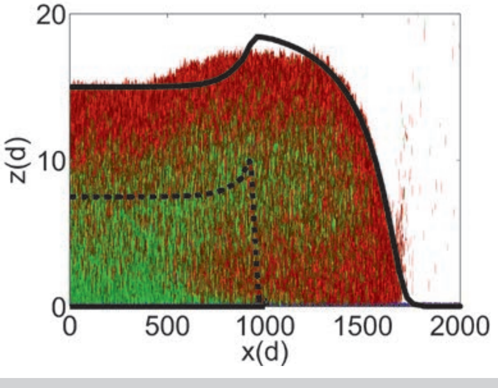
Comparison of a discrete particle simulation of a bidisperse flow down an inclined plane (with large particles in red and small particles in green) with species boundaries by the bidisperse shallow granular continuum model (black lines). Note that the x-axis is 100-fold compressed.



Detection and guidance of nano-particles for enhanced oil recovery

Project leaders
S. Luding (UT)
H. Steeb (U. Stuttgart)
J. Harting (Forschungszentrum Jülich & Helmholtz-Institut Erlangen-Nürnberg)

Research theme
Complex dynamics of fluids

Participants
I. Güven

Cooperations
Shell-FOM IPP

Funded by
Shell-FOM IPP

Funded %

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

Start of the project
2010

Information
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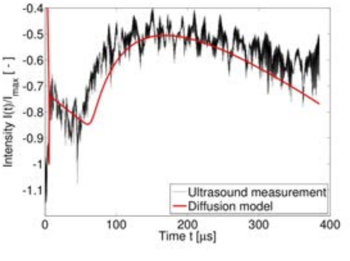
Project Aim
The project aim is to investigate the behavior of water and oil-water mixtures in porous media by means of combined electromagnetic-acoustic wave propagation experiments, where the emulsion will be stabilized by amphiphilic ferro-magnetic nano-particles that allow also to use electromagnetic coupling. The goals are to understand the structure-transport relations in model porous media, the mechanical wave propagation features, and ultimately to find out whether these particles are a suitable alternative to current enhanced oil recovery techniques, and if possibly pulsed electromagnetic fields could be used to guide the particles to regions of interest.

Progress
Model porous media, made by the sintering of glass beads of different sizes, were analyzed using a range of experimental techniques. Essential microscopic and macroscopic features of the sintered samples, such as the structure of the samples and the pore diameters of the channels between the particles, were determined by computer tomography scans (µXRCT). Stationary and oscillatory flows of fluid through the samples were studied by hydraulic experiments (stages I and II). Acoustic measurements were used to determine the saturation of the sample by the fluid, finally also employing magneto-rheological fluids whose properties can be altered by varying the strength of the imposed magnetic field. The PhD project started in January 2012 and has been successful concluded with the defense held on 30.06.2016. Two papers were published in 2017; the first concerned the flow of fluid through sintered glass beads and the correlation between the microstructure and the macroscopic permeability [1]. The second paper concerns an experimental and theoretical study of ultrasonic wave propagation in water-saturated artificial porous samples composed of sintered glass beads. Besides the determination of macroscopic properties, as reflected by the coherent pulse wave propagaton speed, the different microstructures at the contact-level of the beads cause the incoherent “coda” with interesting characterisitcs. Both are reproduced by an effective diffusion model [2].

Dissertations
-

Scientific Publications
1. I. Güven, S. Frijters, J. Harting, S. Luding, and Holger Steeb, Hydraulic properties of porous sintered glass bead systems. Granular Matter 19(2), 28, 2017.
2. I. Güven, S. Luding, and Holger Steeb, Incoherent waves in fluid-saturated sintered granular systems: Scattering phenomena. ASME, J. Vib. Acoust 140(1), 011018, 2017.



Comparison of ultrasound measurements and diffusion model

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 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.

Progress

A literature study suggested Many-body Dissipative Particle Dynamics (MDPD) as a suitable highly coarse-grained simulation method for complex fluids, such as ink. A simulation code is being developed, which is currently being tested and tuned for ink's main component, water, involving surface-tension, viscosity and eventually surface-properties and geometry of paper.

Dissertations

-

Scientific Publications

-

Project leaders

S. Luding
W.K. den Otter

Research theme

Complex dynamics of fluids

Participants

T. Hulikal Chakrapani
A. Jarray

Cooperations

TU/e, Océ Industry B.V.

Funded by

FOM/NWO

Funded %

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

Start of the project

2017

Information

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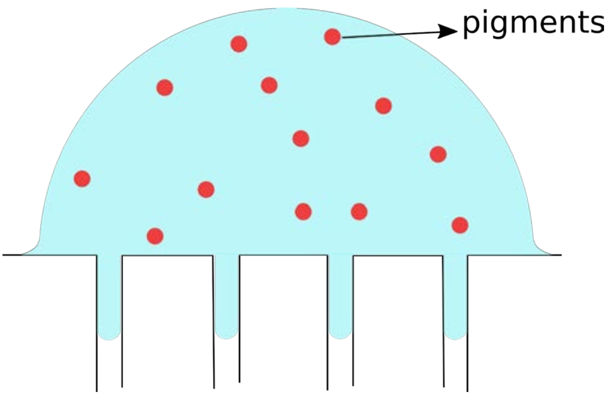
Cartoon of an ink droplet deposited on paper



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 aims of this work are to explore the effects of liquid-induced cohesion on the flow properties of wet granular assemblies of differing particle sizes, to understand the scaling relations, and to establish a methodology allowing control over the flow of wet granular beds 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 the capillary forces between glass beads is significantly reduced by making the beads' surface hydrophobic via 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. The scaling methodology in the flow regimes considered yields invariant bed flow characteristics for differing particle sizes.

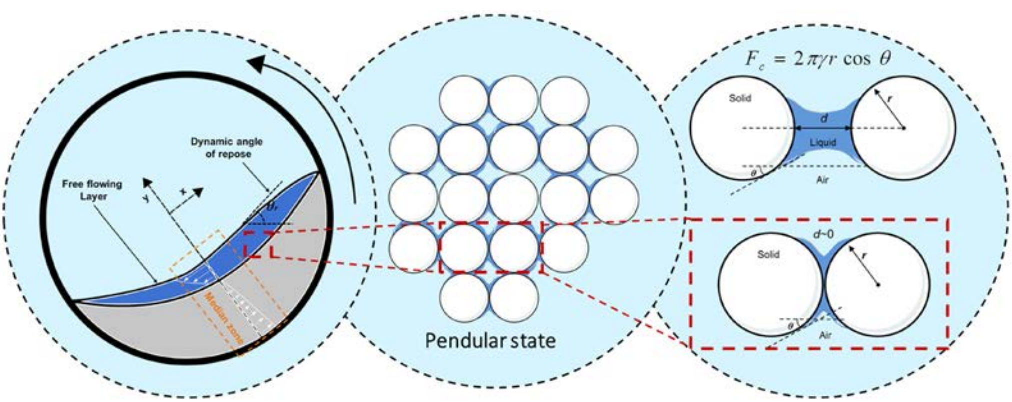
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. A Jarray, V. Magnanimo, M. Ramaioli and S. Luding, Scaling of wet granular flows in a rotating drum, EPJ Web Conf. 140, 03078 (2017).
2. T. Weinhart, D.R. Tunuguntla, M.P. van Schrojenstein Lantman, I.F.C Denissen, C.R. Windows-Yule, H. Polman, H., J.M. Tsang, B. Jin, L. Orefice, K. van der Vaart, S. Roy, H. Shi, A. Pagano, W.M. den Breeijen, B.J. Scheper, A. Jarray, S. Luding and A.R. Thornton, MercuryDPM: Fast, flexible particle simulations in complex geometries. Part B: Applications. (Conference Proceeding of Particles 2017, Hannover, Germany).
3. S. Meuleman, V. Balt, A. Jarray and V. Magnanimo, Investigation of particle properties on the holding force in a granular gripper, (Conference Proceeding of Particles 2017, Hannover, Germany).

Schematic of pendular liquid bridges between two spherical granules (right), the pendular state (middle), and the flow of granules in a rotating drum.



Shaping segregation: advanced modeling of segregation and its application to industrial processes – parallel particle simulation (mercuryDPM.org)

Project Aim

Granular segregation is a major problem to numerous industries, which often rely on empirical rules of thumb to predict non-segregating operating conditions. The aim of this project is to understand the fundamental cause(s) of segregation, particularly in rotating drums, which are investigated using particle simulation tools (MercuryDPM) and particle analysis tools (MercuryCG).

Progress

To investigate segregation, we performed particle simulations of chute flows of similar-sized particles containing one 'intruder' particle of deviant size. The intruder particle is kept at a fixed height normal to the planar chute, to determine the average segregation force acting on the particle. Analysis of the macroscopic field data (density, flow/strain, stress tensor, etc) is currently in progress, using the open source coarse graining tool MercuryCG. Furthermore, MercuryDPM has been adapted to parallel computing. This enables investigation of the extremely slow axial segregation process of bidispere granular beds in rotating long drums.

Dissertations

-

Scientific Publications

1. T. Weinhart, D.R. Tunuguntla, M.P. van Schrojenstein Lantman, I.F.C Denissen, C.R. Windows-Yule, H. Polman, H., J.M. Tsang, B. Jin, L. Orefice, K. van der Vaart, S. Roy, H. Shi, A. Pagano, W.M. den Breeijen, B.J. Scheper, A. Jarray, S. Luding and A.R. Thornton, MercuryDPM: Fast, flexible particle simulations in complex geometries. Part B: Applications. (Conference Proceeding of Particles 2017, Hannover, Germany).

Project leaders

A.R. Thornton

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

M.P. van Schrojenstein Lantman

Cooperations

S. Luding
K. van der Vaart
T. Weinhart

Funded by

STW-NWO VIDI

Funded %

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

Start of the project

2014

Information

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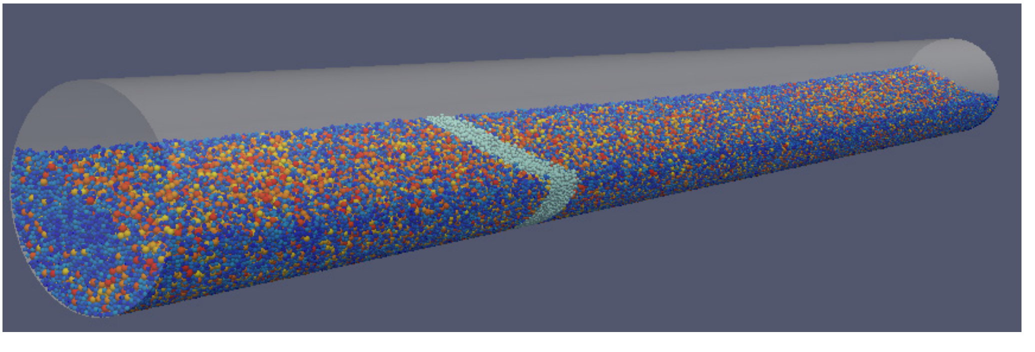

Snapshot of a bed of large (yellow/red) and small (blue) granules in a rotating drum. The simulation runs in parallel, with the white band indicating the workload of one core

Project leaders
W.K. den Otter
Research theme
Complex dynamics of fluids
Participants
D. Palanisamy
Cooperations
-
Funded by
NWO-FOM – Shell CSER project
Funded %

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

Start of the project
2014
Information
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Project Aim

With the increasing number of non-dispatchable sustainable energy sources, electrical energy storage is crucial to maintaining a stable power-grid. The recently proposed 'semi-solid rechargeable flow battery' offers a promising new technique for such energy storage. The aim of this PhD project is to develop a simulation model for the complex physical processes taking place in the (dis)charge cell, in particular i) the flow behavior of sticky colloidal suspensions, ii) the flow of charge between the colloidal aggregates and the walls of the cell, and iii) the interplay between both flows.

Progress

We have developed a 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, and the hydrodynamic interactions between these particles are condensed into a single (11 × 11) grand mobility matrix describing the entire colloid. With this constant matrix, the colloid's dynamics and the stresses it induces in the fluid, are simulated very efficiently. We obtain excellent agreement with e.g. the Jeffery orbits of ellipsoidal colloids under shear.

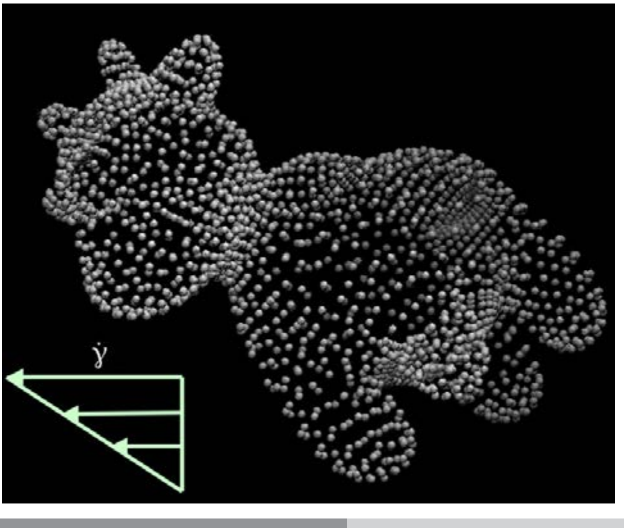
Dissertations

-

Scientific Publications

-

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

-

Scientific Publications

1. S. Roy, S. Luding, and T. Weinhart, A general(ized) local rheology for wet granular materials, New Journal of Physics 19, 043014 (2017).
2. S. Roy, S. Luding, and T. Weinhart, Effect of cohesion on compaction of soft granular materials, EPJ Web Conf. 140, 03065 (2017).
3. T. Weinhart, D.R. Tunuguntla, M.P. van Schrojenstein Lantman, I.F.C Denissen, C.R. Windows-Yule, H. Polman, H., J.M. Tsang, B. Jin, L. Orefice, K. van der Vaart, S. Roy, H. Shi, A. Pagano, W.M. den Breeijen, B.J. Scheper, A. Jarray, S. Luding and A.R. Thornton, MercuryDPM: Fast, flexible particle simulations in complex geometries. Part B: Applications. (Conference Proceeding of Particles 2017, Hannover, Germany)
4. H. Shi, D. Vescovi, A. Singh, S. Roy, V. Magnanimo, S. Luding, Granular flow: from dilute to jammed state, in Granular Materials, edited by M. Sakellariou (InTech, Rijeka, Croatia, 2017).

Project leaders

S. Luding
T. Weinhart

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

S. Roy

Cooperations

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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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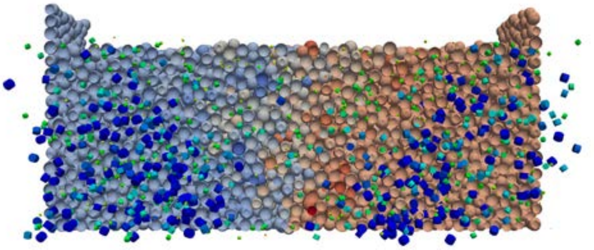

Cross-section of a granular bed in a Cartesian split-bottom shear cell, with rigid arrays of granules as walls. The spherical granules' velocities perpendicular to the cross-section are denoted by a red-blue color scheme, liquid bridges are represented as cylinders (dark blue when large and green when small in volume).

Multi-scale modeling of agglomeration – application to Selective Laser Sintering and tableting

Project leaders
T. Weinhart
S. Luding
A.R. Thornton

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
M.Y. Shaheen
S. Arora
D.R. Tunuguntla

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

Our aim is a multi-scale model of powder agglomeration to predict, and eventually to steer in real-time, bulk processes in Selective Laser Sintering (SLS) and tableting. A novel two-scale coupled (micro-meso / meso-macro) approach is to be developed, by combining

1. at the micro-scale: pressure and temperature dependent contact models for granules,
2. at the meso-scale: particles representing ensembles of granules,
3. at the macro-scale: a continuum model,
4. between micro-meso and meso-macro scales: matching and transition between the respective two adjacent regimes.

Progress

Industry currently relies on experimental trials to obtain optimum process parameters for Selective Laser Sintering (SLS) in 3D-printers. To reduce manufacturing costs, a model with predictive capabilities is called for.

First particle simulations of powder spreading have been performed.

A contact model to simulate sintering of granules is under development.

A desktop SLS unit has been built to manufacture samples under varying process conditions, to perform tensile tests on, with the goal to validate the multi-scale simulation model.

Dissertations

-

Scientific Publications

-

Discrete Element Method simulations and experimental validation of tableting processes

Project Aim

• Identify the non-cohesive and cohesive regimes of granular systems.

• Identify DEM contact models for dry/cohesive systems and calibrate by laboratory experiments.

• Apply the selected, calibrated 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 spectrum of sizes, and thus cohesivity, with various shear testers. These tests are currently being explored in more detail for the particle and continuum model calibrations as the second objective. The results from this second objective will be used as starting point for the third objective, where much larger stresses have to be considered. In addition, an investigation of dilute to dense granular rheology is being conducted, and the development of an extended, generally valid model hereof is in progress.

Dissertations

-

Scientific Publications

1. H. Shi, S. Luding and V. Magnanimo, Steady state rheology from homogeneous and locally averaged simple shear simulations, EPJ Web Conf. 140, 03070 (2017).
2. T. Weinhart, D.R. Tunuguntla, M.P. van Schrojenstein Lantman, I.F.C Denissen, C.R. Windows-Yule, H. Polman, H., J.M. Tsang, B. Jin, L. Orefice, K. van der Vaart, S. Roy, H. Shi, A. Pagano, W.M. den Breeijen, B.J. Scheper, A. Jarray, S. Luding and A.R. Thornton, MercuryDPM: Fast, flexible particle simulations in complex geometries. Part B: Applications. (Conference Proceeding of Particles 2017, Hannover, Germany).
3. H. Shi, D. Vescovi, A. Singh, S. Roy, V. Magnanimo and S. Luding, Granular flow: from dilute to jammed state, in Granular Materials, edited by M. Sakellariou (InTech, Rijeka, Croatia, 2017).

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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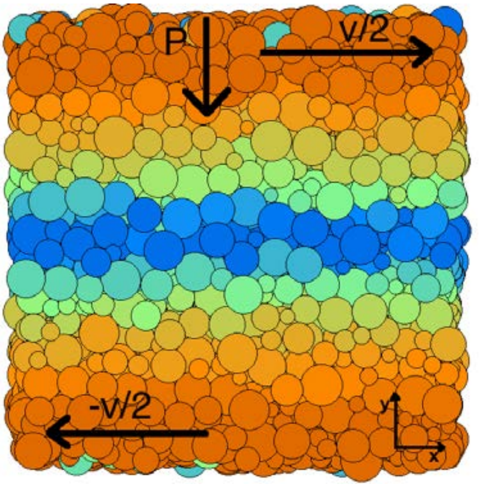
Sheared powder under pressure-controlled simple shear



PROJECT LEADERS
S. Luding
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
R.K. Shrivastava
COOPERATIONS
Shell Netherlands
FUNDED BY
NWO-FOM-Shell CSER Project
FUNDED %

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

START OF THE PROJECT
2014
INFORMATION
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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

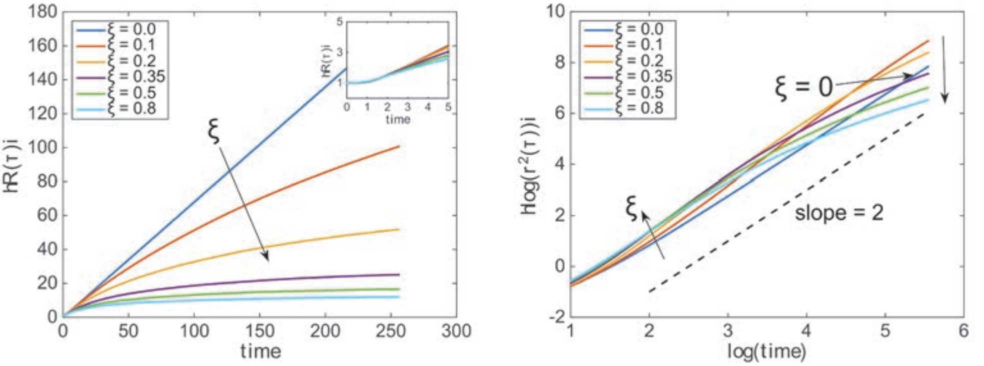
Simulations of wave propagation through three-dimensional disordered poly-disperse packings of frictional spheres show that structure anisotropy leads to frequency filtering effects. Energy contained in uniaxial translational motion (P-wave) is quickly scattered to shear and rotational modes. To isolate the P-wave from shear and rotational modes and study the effect of mass disorder (quantified by ξ) on energy transmission and frequency propagation, we use a mass-disordered granular chain. Whereas ordered granular chains show ballistic propagation of energy, disordered granular chains exhibit more diffusive-like propagation.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. R.K. Shrivastava and S. Luding, Effect of disorder on bulk sound wave speed: a multiscale spectral analysis, Nonlin. Processes Geophys. 24, 435 (2017).
2. R.K. Shrivastava and S. Luding, Wave propagation of spectral energy content in a granular chain EPJ Web Conf. 140, 02023 (2017).
3. R.K. Shrivastava, A. Thomas, N. Vriend, and S. Luding, Long Wavelength Coherent Pulse of Sound Propagating in Granular Media, WASET Int. J. Mech. Aerospace Mech. Eng. 11 1694 (2017).



Propagation of the center of energy R (left) and the width of the propagating distribution r (right) in disordered granular chains of disorder ξ.

PROJECT AIM

The objective of this project is to develop a unified continuum model for predicting particle segregation – using state-of-the-art experimental techniques and particle simulations – which is capable of simulating realistic particles and complex system geometries. The model will also be able to handle flows of irregularly shaped polydisperse particles with evolving size-distributions.

PROGRESS

A granular mixture in a rotating drum is both flowing and experiencing a solid body rotation. Mixing (or all too often: segregation) of granules differing in size, mass, density, etc, occurs in the flowing region, which strongly resembles flow over an inclined chute. The literature reports several models for chute-flows of disperse mixtures. We are using discrete particles simulations of chute flows and a highly effective micro-macro mapping technique (coarse-graining) to test and improve these theories. The theory performing best will be used to developing an improved continuum segregation theory applicable to rotating drums.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. C.R.K. Windows-Yule, A.J. van der Horn, D.R. Tunuguntla, D.J. Parker, A.R. Thornton, Inducing axial banding in bidisperse-by-density granular systems using noncylindrical tumbler geometries, Phys. Rev. Applied 8, 024010 (2017).
2. D.R. Tunuguntla, T. Weinhart and A.R. Thornton, Comparing and contrasting size-based particle segregation models, Comput. Part. Mech. 4, 387 (2017).
3. T. Weinhart, D.R. Tunuguntla, M.P. van Schrojenstein Lantman, I.F.C Denissen, C.R. Windows-Yule, H. Polman, H., J.M. Tsang, B. Jin, L. Orefice, K. van der Vaart, S. Roy, H. Shi, A. Pagano, W.M. den Breeijen, B.J. Scheper, A. Jarray, S. Luding and A.R. Thornton, MercuryDPM: Fast, flexible particle simulations in complex geometries. Part B: Applications. (Conference Proceeding of Particles 2017, Hannover, Germany).
4. J. Torres-Serra, D.R. Tunuguntla, I.F.C. Denissen, A. Rodríguez-Ferran, A. and E. Romero, Discrete element modelling of granular column collapse tests with industrial applications. (Conference Proceeding of Particles 2017, Hannover, Germany).

PROJECT LEADERS
A.R. Thornton

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
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COOPERATIONS
T. Weinhart (UT)
S. Luding (UT)
D. van der Meer (UT)
C. Ancey (EPFL)
N. Gray (Univ. Manchester)
N. Vriend (Univ. Cambridge)
M Ramaoili (Univ. Surrey)
Friesland Campina B.V.
Blue Steel (Australia)

FUNDED BY
STW

FUNDED %

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

START OF THE PROJECT
2015

INFORMATION
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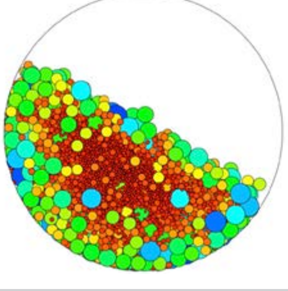
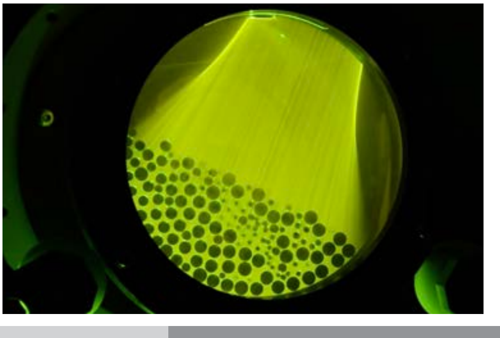
Snapshots using the Refractive Index Matching technique (left, experiment) and particle simulations (right, see mercurydpm.org) to understand the dynamics of a partially filled rotating drum.





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.

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.

Dissertations

-

Scientific Publications

1. Cortes Arevalo, V.J., den Haan, R.J., Leung, N., Berends, K.D., Augustijn, D.C.M. & Hulscher, S.J.M.H., 2017, RiverCare communication workshop: a strategy to reach beyond with sustainable river management, International Water Week 2017.
3. Ji, .U., Penning, E., Berends, K.D., Cho, M., Ahn, M. (2017). Stream-scale experiment and numerical modelling for vegetated flows. 14-14. 15th Annual Joint Seminar between Japan & Korea, Aomori, Japan.
4. Berends, K.D., Fujisaki, A., Warmink, J.J., Hulscher, S.J.M.H. (2017). Automatic cross-section estimation from 2D model results. 66-67, NCR Days 2017 Wageningen, The Netherlands.
5. Ji, U., Berends, K.D., Cho, M., Penning, E.W. (2017). Numerical model calibration for partially submerged condition of vegetation flow in a stream-scale channel. Green & Smart Technology 2017, Jeju National University, Republic of Korea. Best paper award.
6. Verbrugge, L.N.H., Ganzevoort, W., Fliervoet, J.M., Panten, K., van den Born, R.J.G. (2017) Implementing participatory monitoring in river management: The role of stakeholders' perspectives and incentives. Journal of Environmental Management 195: 62-69.
7. Verbrugge, L.N.H., W. Ganzevoort & R.J.G. van den Born (2017). Belevingsonderzoek langsdammen Waal: meting 2016 onder bewoners, sportvissers, recreatievaarders en binnenvaartschippers. Rapportage in opdracht van Rijkswaterstaat Oost-Nederland, Radboud Universiteit, Nijmegen.
8. Verbrugge, L.N.H. (2017). Vissen langs de dam 2017 - Jaarverslag. Rapportage in opdracht van Rijkswaterstaat Oost-Nederland, Radboud Universiteit, Nijmegen.
9. Cortes, J.A., Verbrugge, L.N.H., den Haan, R.J., Baart, F., Hulscher, S.J.M.H., van der Voort, M.C. (2017). Storylines as an alternative method to communicate river research via a knowledge platform. European Geosciences Union (EGU) General Assembly 2017, April 2017 in Vienna, Austria.

Project leaders
prof. dr. S.J.M.H. Hulscher
dr. J.J. Warmink
dr. D. Augustijn

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
ir. K.D. Berends
dr. L.N.H. Verbrugge

Cooperations
Deltares, Rijkswaterstaat, Witteveen+Bos, HKV, Waterbouwkundig Laboratorium (Flanders Hydraulics Research)

Funded by
NWO STW (Perspectief)

Funded %

STW	-
University	-
FOM	-
STW	75 %
NWO Other	-
Industry	20 %
TNO	-
GTI	5 %
EU	-
Scholarships	-

Start of the project
2015

Information
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Modelling 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

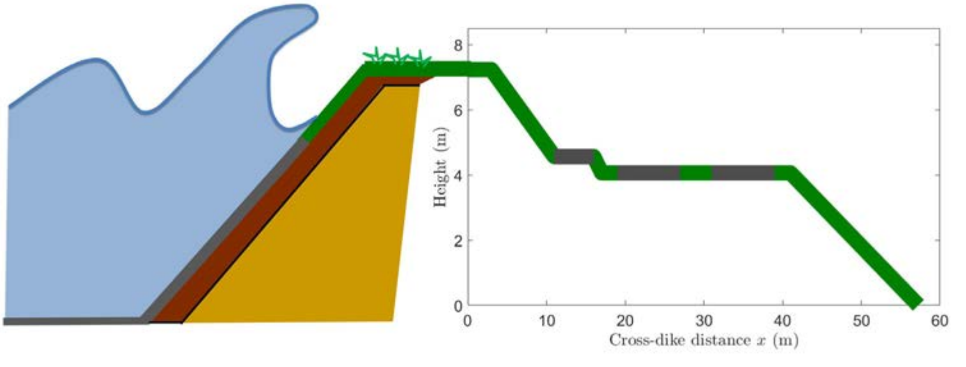
The PhD student started in October 2017 and wrote a research proposal and a literature review.

Dissertations

-

Scientific Publications

-



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, the 1926 river Rhine flood was reconstructed with the use of a 1D-2D coupled model. The maximum discharge at Lobith was determined as well as its uncertainty. A paper was written and submitted to Environmental Modelling and Software. Also, a paper about the effect of grid shape and size on model output was written.

Besides, the methodology of how to determine the flow patterns in the embanked areas caused by wave overtopping and dike breaches was developed. With this it will be possible to study the change in discharge partitioning along the Dutch river Rhine branches as a result of upstream inundations.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Bomers, A., Schielen, R. M. J., & Hulscher, S. J. M. H. (2017). Benchmark study of numerical model grids to study historic floods of the river Rhine. 1-3. Abstract from 4th International Symposium on Shallow Flows, ISSF 2017, Eindhoven, Netherlands.
2. Bomers, A., Schielen, R. M. J., & Hulscher, S. J. M. H. (2017). Modelling historic floods to validate present and future design discharges: the 1926 case. 68-69. Abstract from NCR days 2017, Wageningen, 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)

ForeShore: Soft solutions – certain safety

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. Borsje, B. W., de Vries, S., Janssen, S., Luijendijk, A. P., & Vuik, V. (2017). Building with nature as coastal protection strategy in the Netherlands. In D. M. Bilkovic, M. M. Mitchell, M. K. La Peyre, & J. D. Toft (Eds.), Living shorelines: The science and management of nature-based coastal protection (pp. 137). New York: CRC Press.
2. Poppema, D. W., Willemsen, P. W. J. M., de Vries, M., Zhu, Z., Borsje, B. W., & Hulscher, S. J. M. H. (2017). Experimentsupported modeling of salt marsh establishment: Applying the Windows of opportunity concept to the Marconi pioneer salt marsh design. 19-19. Abstract from ECSA Focus Meeting 2017, Shanghai, China.
3. Best, Ü. S. N., van der Wegen, M., Dijkstra, J., Borsje, B. W., Roelvink, D., & Willemsen, P. W. J. M. (2017). Modelling sea level rise impact on salt marsh/ mangrove-mudflat morphodynamics. 36-36. Abstract from NCK-days 2017, Den Helder, Netherlands.
4. Willemsen, P. W. J. M., Borsje, B. W., Zhu, Z., Oteman, B., van der Wal, D., Bouma, T. J., & Hulscher, S. J. M. H. (2017). Seasonality in morphological behaviour at the interface of salt marshes and tidal flats using high temporal resolution field data. 35-35. Abstract from NCK-days 2017, Den Helder, Netherlands.
5. Vuik, V., Suh Heo, H. Y., Zhu, Z., Borsje, B. W., & Jonkman, S. N. (2017). Stem breakage of salt marsh vegetation under wave forcing: A field and model study. Estuarine, coastal and shelf science. DOI: 10.1016/j.ecss.2017.09.028.

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

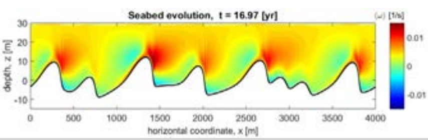
Subproject 1 (G.H.P. Campmans): A non-linear sand wave model has been developed which is able to model finite amplitude sand wave dynamics. Using this model the effect of wind waves and wind-driven flow on sand wave dynamics has been investigated. This resulted in an submitted second journal paper. Subproject 2 (J.M. Damen): A method for data analysis of static (i.e., instantaneous) sand wave properties has been completed for the entire NCS. These properties have been related to processes on the seabed. The method and the results resulted in a submitted journal paper.

Dissertations

-

Scientific Publications

1. Campmans, G.H.P., P.C. Roos, H.J. de Vriend & S.J.M.H. Hulscher (2017). Modeling the influence of storms on sand wave formation: A linear stability approach, Cont. Shelf Res. 137, 103-116, doi: 10.1016/j.csr.2017.02.002.
2. Campmans, G.H.P., P.C. Roos, H.J. de Vriend & S.J.M.H. Hulscher (2017). The influence of storms on finite amplitude sand wave dynamics: an idealized nonlinear model, oral presentation at ISSF2017 conference, 26-28 June, 2017, Eindhoven, Netherlands.
3. Damen, J.M., Dijk, T.A.G.P. van & Hulscher, S.J.M.H. (2017). Analysis of variation in sand wave shapes. In M. Baptist, A. de Groot & M. Baart (Eds.), Book of abstracts NCK-days 2017, 15–17 March 2017, Den Helder (pp. 64–64). Den Helder: Imares.
4. Hulscher, S.J.M.H., P.C. Roos & B.W. Borsje (2017), Dredging offshore sandwaves for navigation: a numerical modelling approach, ECSA-conference, 16-20 October 2017, Shanghai, China.
5. Campmans, G.H.P., P.C. Roos, R. Bijker& S.J.M.H. Hulscher (2017). Nonlinear modeling of tidal sand waves: application to a pipeline location in the North Sea, ECSA-conference, 16-20 October 2017, Shanghai, China.
6. Campmans, G.H.P., P.C. Roos & S.J.M.H. Hulscher (2017). The influence of wave and wind climate on sand wave dynamics: A North Sea case study with a linear stability model, ECSA-conference, 16-20 October 2017, Shanghai, China.
7. Roos, P.C., Campmans, G.H.P., & Hulscher, S.J.M.H. (2017). The influence of wave and wind climate on sand wave dynamics: A North Sea case study with a linear stability model. 86-86. Abstract from ECSA Focus Meeting 2017, Shanghai, China.



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
In the first half of 2017 Johan Damveld worked developing a two-way coupled idealized model of sand waves and benthic organisms. Next the model was analyzed and a paper was written to be submitted in 2018. Also, together with a MSc student, a numerical model has been developed to study the interaction of fully grown sand waves with benthos.

In June, a project wide field campaign was conducted in the North Sea, where sand wave and biological data was gathered, which can be used as validation for the developed models. Also, work has been done for a data analysis paper in collaboration with the DISCLOSE project.

Dissertations
-

Scientific Publications
1. Damveld, J. H., Roos, P. C., Borsje, B. W., & Hulscher, S. J. M. H. (2017). Exploring the two-way coupling between sand wave dynamics and benthic species: an idealised modelling approach.. 1-3. Abstract from 4th International Symposium on Shallow Flows, ISSF 2017, Eindhoven, Netherlands.

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

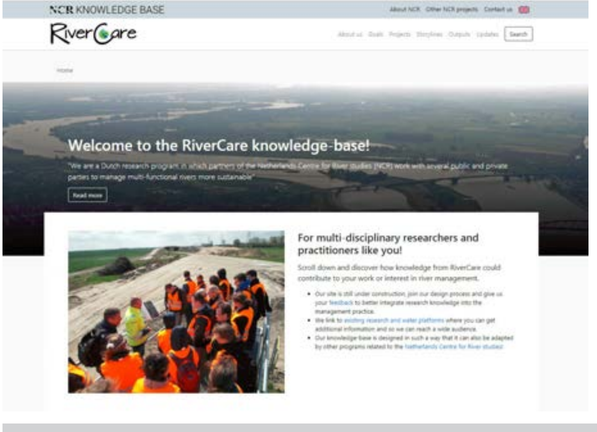
For subproject G2, based on the interview study, two journal publications are worked out about users’ perspectives for the storyline and knowledge-base design. The first publication about storylines was written and submitted to the journal of Environmental Communication. The second publication was split into two one about outputs of the interview study for the design criteria and the second one about the development process of the knowledge-base. The development started by creating 1) personas from the interviews and carrying out first usability tests and 2) evaluating the storylines in workshops with students and researchers at the NCR days. The working prototype (https://kbase.ncr-web.org/rivercare/) will be made available online from April/2018 onwards and a second round of workshops and usability tests will be carried out in April to July/2018.

Dissertations

-

Scientific Publications

1. Ottevanger, W., Haan, R.J. den, Baart, F., Visser, P., De Jong, J., Van de Pas, B., Van de Vries, C., Swinkels, C., Luijendijk, A. (2017). SandBox-FM: Augmented reality CFD. Hydro 2017. Retrievable from https://hydro17.com/papers/PYwHMyoZruAfCsjQvOTbVgbwDL5u8EFvTSGafkyX.pdf.
2. Cortes Arevalo, V. J., den Haan, R-J. J., Berends, K. D., Leung, N., Augustijn, D. C. M., & Hulscher, S. J. M. H. (2017). RiverCare communication strategy for reaching beyond. Abstract from EGU General Assembly 2017, Vienna, Austria. Retrievable from https://ris.utwente.nl/ws/portalfiles/portal/18883274/EGU2017_8126.pdf.
3. Cortes Arevalo, V. J., Verbrugge, L. N. H., den Haan, R-J. J., Baart, F., Hulscher, S. J. M. H., & van der Voort, M. C. (2017). Storylines as an alternative method to communicate river research via a knowledge platform. Abstract from EGU General Assembly 2017, Vienna, Austria. Retrievable from https://ris.utwente.nl/ws/portalfiles/portal/20606479/EGU2017_5768_Session_IE4.3NH9.12.pdf.



Working prototype of the knowledge-base

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
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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 a field experiment was carried out with the aim to test and compare five aeolian sand transport measuring devices. As a result of this field experiment one article was submitted to a peer-reviewed scientific journal (Aeolian Research). This paper was developed in collaboration with KU Leuven, Wageningen University and Desert Research Institute (USA).

Additionally, a conference abstract was presented (Oral presentation) in Estuarine Coastal Sciences Association Focus Meeting, Shanghai, 2017.

Dissertations

-

Scientific Publications

1. Duarte Campos, L.A., Wijnberg, K.M., Oyarte Galvez, L.A. & Hulscher, S.J.M.H. (2017). Laser particle counter validation for sand transport measurements using a high speed camera. Aeolian Research, Volume 25 (2017), pp. 37-44.
2. Duarte Campos, L.A., Wijnberg, K.M. & Hulscher, S.J.M.H. (2017). Estimating aeolian sand supply from the intertidal beach using video imagery. pp. 68-68. Abstract from ECSA Focus Meeting 2017, Shanghai, China.

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. One paper on the topic has been submitted and one is in preparation. Numerical modelling using the model XBeach has also been performed, with results being gather for further analysis.

DISSERTATIONS

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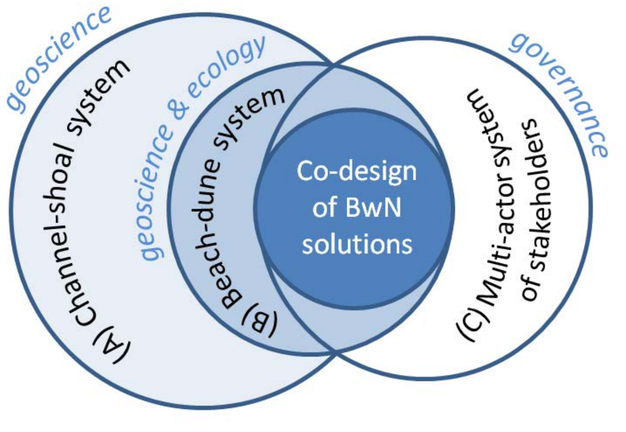
SCIENTIFIC PUBLICATIONS

1. de Groot, A., de Vries, S., Arens, B., Bodde, W., de Winter, W., Donker, J., ... Williams, I. A. (2017). State of the art of aeolian and dune research on the Dutch and Belgian coast. 65-65. Abstract from NCK-days 2017, Den Helder, Netherlands.
2. Galiforni Silva, F., Wijnberg, K. M., de Groot, A. V., & Hulscher, S. J. M. H. (2017). On the importance of tidal inlet processes for coastal dune development. In T. Aagaard, R. Deigaard, & D. Fuhrman (Eds.), Proceedings Coastal Dynamics 2017 (pp. 1131-1141).
3. Galiforni Silva, F., Wijnberg, K. M., & Hulscher, S. J. M. H. (2017). Observation of storm surge flooding on dune topography in inlets. 97-97. Abstract from NCK-days 2017, Den Helder, Netherlands.
4. Wijnberg, K., van der Spek, A., Galiforni Silva, F., Elias, E., van der Wegen, M., & Slinger, J. (2017). Connecting subtidal and subaerial sand transport pathways in the Texel inlet system. In T. Aagaard, R. Deigaard, & D. Fuhrman (Eds.), Proceedings Coastal Dynamics 2017 (pp. 323-332)



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, Natuumonumenten, Hollands Noorderkwartier, Noorderzijlvest, It Fryske Gea, Vechtstromen

FUNDED BY
NWO-TTW

FUNDED %

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

START OF THE PROJECT
2017

INFORMATION
Matthijs Gensen
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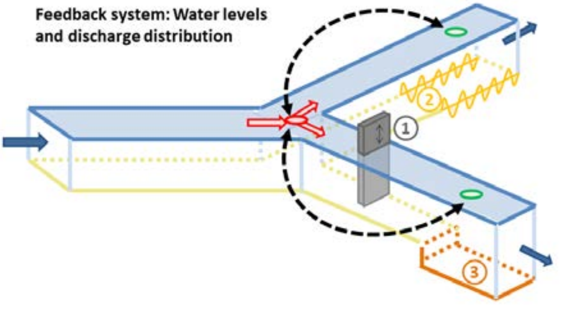
PROJECT AIM
The goal of this project is to quantify and possibly reduce river water level uncertainties in a bifurcating river system. In this very complex and interactive system uncertainties are propagated throughout the entire system. Dominant sources of water level uncertainties are regulation structures at bifurcation points, river bed forms and large-scale river interventions. In this project these uncertainty sources are studied in a model with dimensions similar to the river Rhine. This work will give insight into the combined effect of natural processes and human river interventions to improve river maintenance strategies.

PROGRESS
The project started in September 2017. Since then a research proposal and a literature review was written. Courses have been followed to increase academic skills.

DISSERTATIONS
-

SCIENTIFIC PUBLICATIONS
-



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

Field and labwork is ongoing. First paper is submitted. Model development ongoing

Dissertations

-

Scientific Publications

1. Harezlak, V., Augustijn, D.C.M., Geerling, G.W., and Leuven, R.S.E.W. (2017). Seeking functional plant traits in 3 Dutch floodplains. In Hoitink, A.J.F., de Ruijsscher, T.V., Geertsema, T.J., Makaske, B., Wallinga, J., Candel, J.H.J., and Poelman, J. (Eds). NCR days 2017, Book of abstracts. NCR publication 41-2017.
2. Harezlak, V., and Augustijn, D.C.M. (2017). Unravelling processes steering vegetation development in Dutch floodplains: combining fieldwork, theoretical trait frameworks and models. Book of abstracts NAEM 2017, not yet available online.
3. Harezlak, V., Augustijn, D.C.M., Geerling, G.W., and Leuven, R.S.E.W. (2017): “Plant traits as a floodplain management aid?”, in Pinfield-Well, H., S. Lennon and J. Brooke (2017): “39th New Phytologist Symposium – Trait covariation: Structural and functional relationships in plant ecology”,Exeter, 83 pp.

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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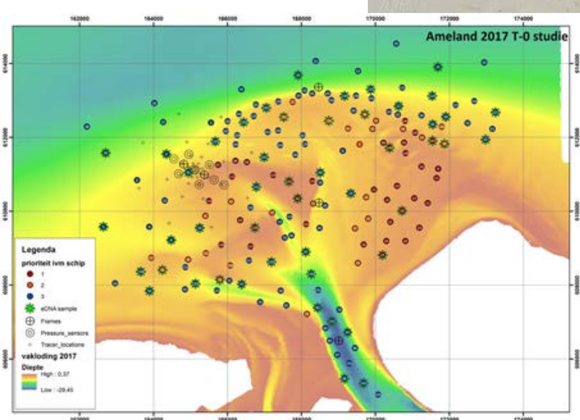
Project Aim
To ensure ecological sustainability of the Dutch coast, human activities in the coastal zone need to be managed. This requires knowledge and models to assess and predict changes in the coastal ecosystem in response to changes in environmental conditions. Within this research we focus on the 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 large field campaign
First data analysis

Dissertations
-

Scientific Publications
-



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

The focus of the study in the previous year (first year of the PhD.), was on writing a research proposal and executing the first part of the research. The proposal was assessed and approved by a committee from the University of Twente. The first part of the research focusses on determining the dominant processes for the wave attenuating capacity of the coupled system. The long-term (~50 years) temporal and spatial variability is/will be assessed on various locations. A method is developed to assess (incomplete) historical data as well. Field data on morphological changes around the vegetation edge of multiple salt marshes is measured using SED-sensors (recently developed for measuring bed-levels). An autonomous script is developed and tested for converting raw data into bed level data. Last year a manuscript on the obtained field data was written and will be submitted soon. For this manuscript and further understanding of biophysical and bio-geomorphological processes at tidal flats and salt marshes more field data was obtained and analysed. Finally an existing cross-shore line model was set-up and extended to predict the morphological development of tidal flats and salt marshes (under climate change).

Dissertations

-

Scientific Publications

1. Willemsen, Pim, Borsje, Bas, Bouma, Tjeerd J., Van der Wal, Daphne, Hulscher, Suzanne (2017). Assessing salt marsh stability for flood risk reduction: characterizing salt-marsh mudflat transitions. CERF 2017, Providence, Rhode Island, USA.
2. Willemsen, P.W.J.M., Borsje, B.W., Zhu, Z., Otemans, B., Van der Wal, D., Bouma, T.J., Hulscher, S.J.M.H., 2017. Seasonality in morphological behaviour at the interface of salt marshes and tidal flats using high temporal resolution field data. NCK-days 2017, Den Helder, The Netherlands, pp. 35.

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
STW, Regional Water Authorities, Province of Overijssel, Deltares

Funded %

University	-
FOM	-
STW	85 %
NWO Other	-
Industry	15 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2015

Information
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www.utwente.nl/en/et/wem/staff/pezij/

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

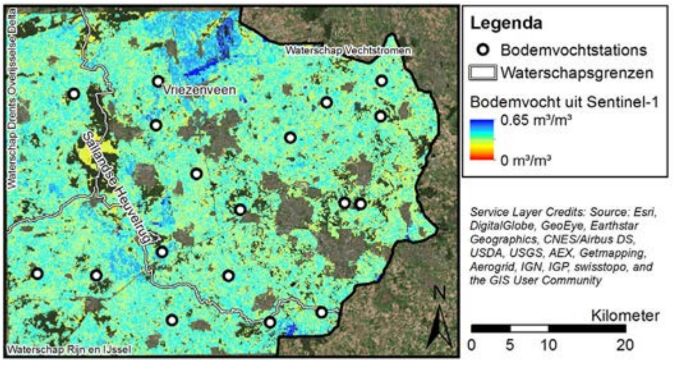
Together with the OWAS1S project team, a data paper was written concerning the installed soil moisture monitoring network in the Raam region. The paper is published in Earth System Science data, while two datasets obtained from the network are published by the 4TU.Datacentre. In addition, M. Pezij wrote and submitted a research paper about the application of hydrological models in Dutch regional operational water management. These results were obtained in interviews with Dutch regional operational water managers. Furthermore, M. Pezij developed an OpenDA-wrapper for the MetaSWAP model together with Deltares and HKV. This wrapper will be used in a data-assimilation procedure to merge soil moisture observations with model estimates.

Dissertations

-

Scientific Publications

1. Benninga, H. F., Carranza, C. D. U., Pezij, M., van der Ploeg, M. J., Augustijn, D. C. M., & van der Velde, R. Regional soil moisture monitoring network in the Raam catchment in the Netherlands. Dataset. DOI: 10.4121/uuid:2411bbb8-2161-4f31-985f-7b65b8448bc9.
2. Benninga, H. F., Carranza, C. D. U., Pezij, M., van der Ploeg, M. J., Augustijn, D. C. M., & van der Velde, R. Regional soil moisture monitoring network in the Raam catchment in the Netherlands - 2016-04 / 2017-04. Dataset. DOI: 10.4121/uuid:dc364e97-d44a-403f-82a7-121902deeb56.



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 research proposal was written and approved. Furthermore, new models were developed to study the effects of a non-uniform basin width and storm-induced breaches on the evolution of barrier coasts. We found that a non-uniform basin width results in a clustering of tidal inlets in the wider part of the basin. This result has been presented at the ECSA conference in Shanghai. Preliminary results on the effect of storm-induced breaches show that if a new inlet remains open, its neighbors becomes smaller, confirming observations.

DISSERTATIONS

SCIENTIFIC PUBLICATIONS

1. Reef, K.R.G. (2017). Exploratory modelling of mesotidal barrier coasts. ConcepTueel, 26(4), 16-19.
2. Reef, K.R.G., Roos, P.C., Schuttelaars, H.M., Hulscher, S.J.M.H. (2017). Exploratory modelling of mesotidal barrier coasts: the influence of basin geometry on equilibrium configurations. In: book of abstracts ECSA 2017. Where land meets ocean: the vulnerable interface. 16-20 October 2017, Shanghai, China.

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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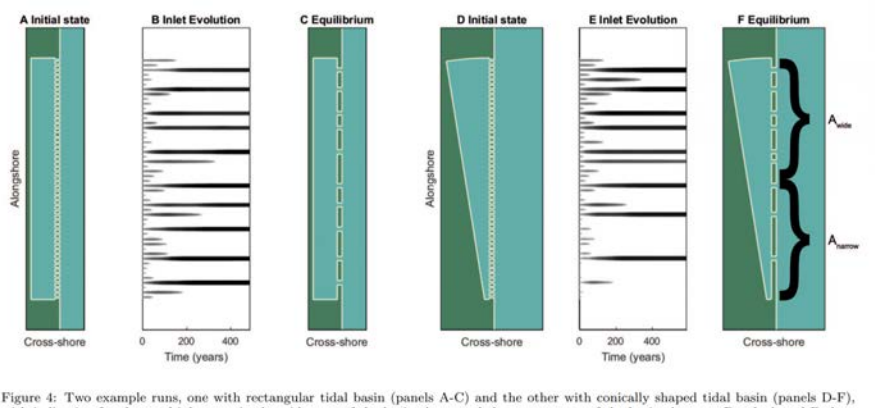

Figure 4: Two example runs, one with rectangular tidal basin (panels A-C) and the other with conically shaped tidal basin (panels D-F), with indication for the total inlet area in the wide part of the basin A_{wide} and the narrow part of the basin A_{narrow}. Panels A and D show a saturated coast in 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 several measurements in a Dutch side channel system. We mainly looked at morphodynamic changes and sediment characteristics in this side channel system. Using this data we are able to identify the main mechanisms for aggradation of the side channels and compare this with the development of other Dutch side channel systems. In addition, we use a 2D morphodynamic model to study the effects of grain size sorting at the bifurcation of a side channel system. Using this model we can estimate the development and the corresponding time scale of side channel development.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Van Denderen, R. P., Schielen, R. M. J., Blom, A., Hulscher, S. J. M. H., & Kleinhans, M. G. (2017). Morphodynamic assessment of side channel systems using a simple one-dimensional bifurcation model and a comparison with aerial images. Earth surface processes and landforms. DOI: 10.1002/esp.4267.
2. van Denderen, R. P., Schielen, R. M. J., & Hulscher, S. J. M. H. (2017). Mechanisms for sediment fining in a side channel system. 252-252.
3. van Denderen, R. P., Schielen, R. M. J., & Hulscher, S. J. M. H. (2017). Sediment sorting at a side channel system. 79-79. Abstract from NCR days 2017, Wageningen, Netherlands.

Sand transport under irregular and breaking wave conditions (SINBAD)

Project Aim

The research has two main aims: (1) to improve understanding of the near-bed hydrodynamics and sand transport processes occurring under real-scale irregular non-breaking and regular breaking wave conditions and (2) to develop a new practical model for predicting sand transport under waves, accounting for wave irregularity and wave breaking in a way that is well founded on experimental data and understanding of the fundamental processes. The research is based on a combination of fixed and mobile-bed laboratory experiments (incl. PhD-project J.van der Zanden) and process-based numerical modeling (incl. post-doc A. Fernández Mora).

Progress

The final project meeting was in November 2016. Several peer-reviewed scientific publications have appeared in 2017. The experimental data have been uploaded to the online server of the 4TU Data Centre.

Dissertations

-

Scientific Publications

1. van der A, D. A., van der Zanden, J., O'Donoghue, T., Hurther, D., Cáceres, I., McLelland, S. J., & Ribberink, J. S. (2017). Large-scale laboratory study of breaking wave hydrodynamics over a fixed bar. Journal of Geophysical Research: Oceans, 122(4), 3287-3310. doi:10.1002/2016jc012072.
2. van der Zanden, J., van der A, D. A., Hurther, D., Cáceres, I., O'Donoghue, T., Hulscher, S. J. M. H., & Ribberink, J. S. (2017). Bedload and suspended load contributions to breaker bar morphodynamics. Coastal Engineering, 129, 74-92. doi:10.1016/j.coastaleng.2017.09.005.
3. van der Zanden, J., van der A, D. A., Hurther, D., Cáceres, I., O'Donoghue, T., & Ribberink, J. S. (2017). Suspended sediment transport around a large-scale laboratory breaker bar. Coastal Engineering, 125, 51-69. doi:10.1016/j.coastaleng.2017.03.007.
4. Zheng, P., Li, M., van der A, D. A., van der Zanden, J., Wolf, J., Chen, X., & Wang, C. (2017). A 3D unstructured grid nearshore hydrodynamic model based on the vortex force formalism. Ocean Modelling, 116, 48-69. doi:10.1016/j.ocemod.2017.06.003.

Project leaders

dr.ir. J.S. Ribberink
prof.dr. S.J.M.H. Hulscher

Research theme

Complex dynamics of fluids

Participants

dr. ir. J. van der Zanden
dr. ir. A. Fernández Mora
dr. ir. J.J. van der Werf

Cooperations

Deltares
University of Aberdeen, UK
University of Liverpool, UK
Bangor University, UK
Universitat Politècnica de Catalunya
LEGI, Grenoble, Fr
National Oceanography Centre, UK

Funded by

SINBAD (STW/EPSRC)
Hydralab IV-WISE (EU)

Funded %

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

Start of the project

2012

Information

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PROJECT LEADERS
Prof. Dr. S.J.M.H. Hulscher
Dr. J.J. Warmink

RESEARCH THEME
Complex dynamics of fluids

PARTICIPANTS
Weiqiu Chen

COOPERATIONS
Deltares, Rijkswaterstaat,
Ministerie van Infrastructuur en Water,
HKV, Royal Haskoning DHV, Arcadis,
Witteveen + Bos, HillBlocks,
Vechtstromen

FUNDED BY
China Scholarship Council
University of Twente

FUNDED %

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

START OF THE PROJECT
2017

INFORMATION
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PROJECT AIM

(This research project focuses on the wave overtopping and wave-overtopping erosion of flooddefences, which is affiliated with Project D3 of All-Risk program. (a) The Erosion of grass cover on the seaward slope and inner slope of dikes taking the effect of transitions into account will be studied. (b) To research the grass erosion, flow parameters including layer thickness, flow velocity, turbulence and shear stress will also be investigated based on the existing data or experiments. (c) Physical model experiments will be conducted to study the effect of roughness of different types of armour units combined as the revetment on the seaward slope on the wave overtopping discharge.)

PROGRESS

Writing the literature report and research proposal

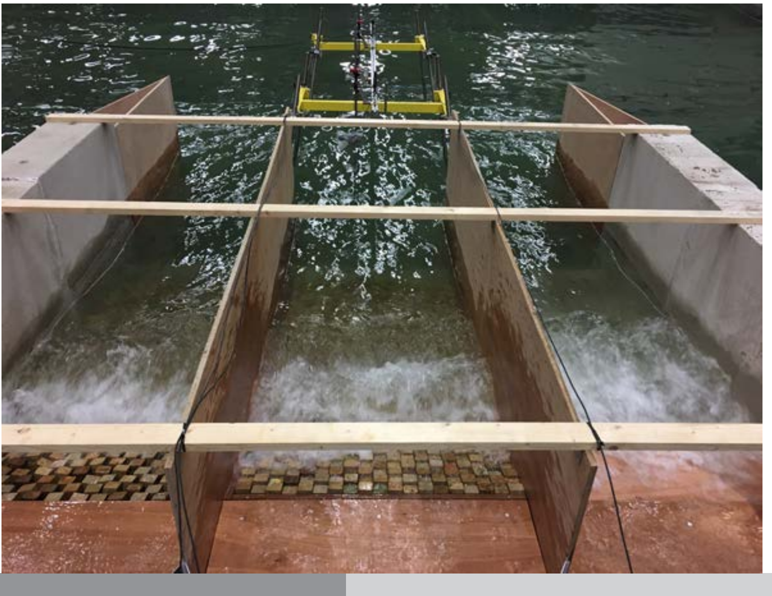
Finished the experimental plan about the effect of roughness on the overtopping discharge.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



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 developed methodology is currently being written up into a paper.

Dissertations

-

Scientific Publications

-

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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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. Extensions to fully nonlinear Finite Element VBM code, and 2HD pseudo-spectral AB-code, with applications for waves in harbours and Jakarta bay. Force calculations on fixed and moving ships. Methods for wave reconstruction and future prediction from radar images of (multi-modal) seas have been extended.

Dissertations

1. Andreas Parama Wijaya, Reconstruction and deterministic prediction of ocean waves from synthetic radar images, 6 July 2017 UTwente.
2. P. Naaijen, Deterministic prediction of waves and wave induced vessel motions, 6 October 2017, TUDelft.

Scientific Publications

1. E. van Groesen, P. Turnip, R. Kurnia, High waves in Draupner seas Part 1: Numerical simulations and characterization of the seas, Journal of Ocean Engineering and Marine Energy 2017 3:233–245.
2. E. van Groesen, A.P. Wijaya, High waves in Draupner seas Part 2: Observation and prediction from radar images, Journal of Ocean Engineering and Marine Energy (2017) 3:325–332.
3. M.R. Badriana, H. Bachtiar, D. Adytia, L. Sembiring , Andonowati, and E. van Groesen, Wave Run-up of a Possible Anak-Krakatau Tsunami on Planned and Optimized Jakarta Sea Dike, AIP Conference Proceedings 1857, 090004 (2017);
4. E. van Groesen & Andonowati, Hamiltonian Boussinesq formulation of Wave-Ship-Interactions, Applied Mathematical Modelling 42 (2017) 133–144.
5. R. Kurnia & E. van Groesen, Localization for spatial-spectral implementations of 1D Analytic Boussinesq equations, Wave Motion 72 (2017) 113-132.
6. Latifah, A. L. & van Groesen, E. Freak Wave Formation from Phase Coherence, Journal of physics: Conference series. 822, 1, 012067 2017.

Project leaders

E. van Groesen

Research theme

Mathematical and computational methods for fluid flow analysis

Participants

R. Kurnia (PhD-UT)
D. Adytia (PD-UT/LMI)
A. P. Wijaya (PhD-UT/LMI)
Lawrence (LMI)
P. Turnip (LMI)
Dr. Andonowati (LMI & ITB);

Cooperations

LabMath-Indonesia, Bandung Indonesia (LMI)
TUD Ship hydromechanics & structures

Funded by

STW, Labmath-Indonesia

Funded %

STW	-
University	-
FOM	-
STW	30 %
NWO Other	-
Industry	70 %
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.

FastFem: Behaviour of Fast Ships in Waves

Project Aim

This project aims at developing new simulation tools to compute the dynamics of fast ships and the surrounding wave field. The waves are modeled using the potential flow water wave equation. A key element in the development of the numerical algorithm is the preservation of the underlying Hamiltonian structure after numerical discretization using a finite element method. An important challenge is to include the ship motion and induced wave field in the simulation model.

Progress

A novel discrete variational formulation for nonlinear potential flow water waves was derived for general domains. The mathematical formulation includes both a wave maker and now also a moving ship. The coupling of the ship and wave motion is accomplished without the need to compute the time-derivative of the potential, which results in a more robust numerical discretization. The algorithms have been implemented and tested in the DGWave code, using the MACS finite element toolkit hpGEM. In 2017 the simulation model was extended to include a ship and a numerical wave tank was constructed that includes a beach. The code is fully parallelized and works efficiently on a parallel cluster.

Dissertations

-

Scientific Publications

1. F Brink, F Izsák, JJW van der Vegt, Hamiltonian Finite Element Discretization for Nonlinear Free Surface Water Waves, Journal of Scientific Computing 73 (1), 366-394 (2017).

Project leaders
JJW van der Vegt

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
F. Brink, J.J.W. van der Vegt

Cooperations
R.H.M. Huijsmans, TU Delft, Damen Ship Yards, MARIN, Royal Netherlands Navy, Bureau Veritas, Lloyds Register, Royal Netherlands Rescue Organization

Funded by
STW (TTW)

Funded %

STW	-
University	-
FOM	-
STW	66 %
NWO Other	-
Industry	33 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2014

Information
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Prof.dr.ir. BJ Geurts

Multiscale modeling & simulation

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.

PROJECT AIM

We aim to develop an efficient numerical method for direct numerical simulations of Rayleigh-Bénard convection. Turbulent flows at high Rayleigh numbers are challenging to solve numerically and require long computing times, even on today's large supercomputers. Current numerical solvers are limited in the number of processors that can be used efficiently. By parallelizing the problem in time, in addition to a traditional parallelization in space, we may deploy many more processors in parallel and reduce the computing time significantly.

PROGRESS

We analyzed the performance and accuracy of the open-source spectral element method Nek5000 for simulations of Rayleigh-Bénard convection and compared this with AFID and GoldFish. The basis extension for the ParaExp method was formulated and published.

DISSERTATIONS

1. G.L. Kooij, Towards parallel-in-time simulations of turbulent Rayleigh-Benard convection, University of Twente.

SCIENTIFIC PUBLICATIONS

1. A block Krylov subspace implementation of the time-parallel Paraexp method and its extension for nonlinear partial differential equations GL Kooij, MA Botchev, BJ Geurts Journal of computational and applied mathematics 316, 229-246, 2017.

PROJECT LEADERS
Prof. B.J. Geurts

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Gijs Kooij, Mike Botchev

COOPERATIONS
Dr. Rudie Kunnen (TUE)

FUNDED BY
FOM

FUNDED %

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

START OF THE PROJECT
2013

INFORMATION
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PROJECT LEADERS
Prof. B.J. Geurts
RESEARCH THEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
M. Koenrades, C. Slump
COOPERATIONS
-
FUNDED BY
UT, Vascutek Ltd.
FUNDED %

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

START OF THE PROJECT
2016
INFORMATION
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PROJECT AIM

The objective of this research is to validate motion estimation algorithms applied to dynamic CT scans and to investigate motion and conformational changes of aortic vessels and implanted stent grafts during patient follow-up. With this research, we aim to identify parameters that aid the prediction of stent graft failure. This would allow for patient specific follow-up schemes and early identification of problems. In addition, stent graft manufacturers may optimize their designs based on this knowledge.

PROGRESS

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., Struijs, E. M., Klein, A., Kuipers, H., Geelkerken, R. H., & Slump, C. H. (2017). Validation of an image registration and segmentation method to measure stent graft motion on ECG-gated CT using a physical dynamic stent graft model. In Medical Imaging 2017: Computer-Aided Diagnosis (Vol. 10134). [1013418] SPIE. DOI: 10.1117/12.2254262.

PROJECT AIM

For the design of evaporator tubes used in various types of conventional power plants, medium-size boilers and waste incinerators, knowledge of flow pattern changes under the influence of external heating is of utmost importance to warrant safe operation. The project is focused on the development and validation of a numerical method based on a multi-scale approach to boiling flows. The proposed research will produce a validated, reliable and versatile prediction tool as well as a set of practical flow pattern maps for heated two-phase flows.

PROGRESS

A two-phase flow model with phase-change was successfully implemented in the open source CFD tool OpenFOAM. A kinetic-based mass transfer rate was adopted and compared to a balance model. As a main result, several simulations of a rising bubble with mass and heat transfer in a viscous liquid were carried out. Extensions to vapor bubbles in turbulent flow are constructed in an in-house opensource code, capable of high performance simulation of deformable bubble columns. This work was awarded the Wim Nieuwpoort price in 2017.

DISSERTATIONS

1. P. Cifani, DNS OF TURBULENT BUBBLE-LADEN CHANNEL FLOWS, University of Twente, ISBN : 978-90-365-4416-0.

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS
Prof. B.J. Geurts

RESEARCH THEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
P Cifani, JGM Kuerten

COOPERATIONS
G.J.M. Priem, W.R. Michalek, C.W.M. van der Geld (TUE)

FUNDED BY
STW

FUNDED %

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

START OF THE PROJECT
2013

INFORMATION
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REPORTS OF INDIVIDUAL RESEARCH GROUPS

university of groningen

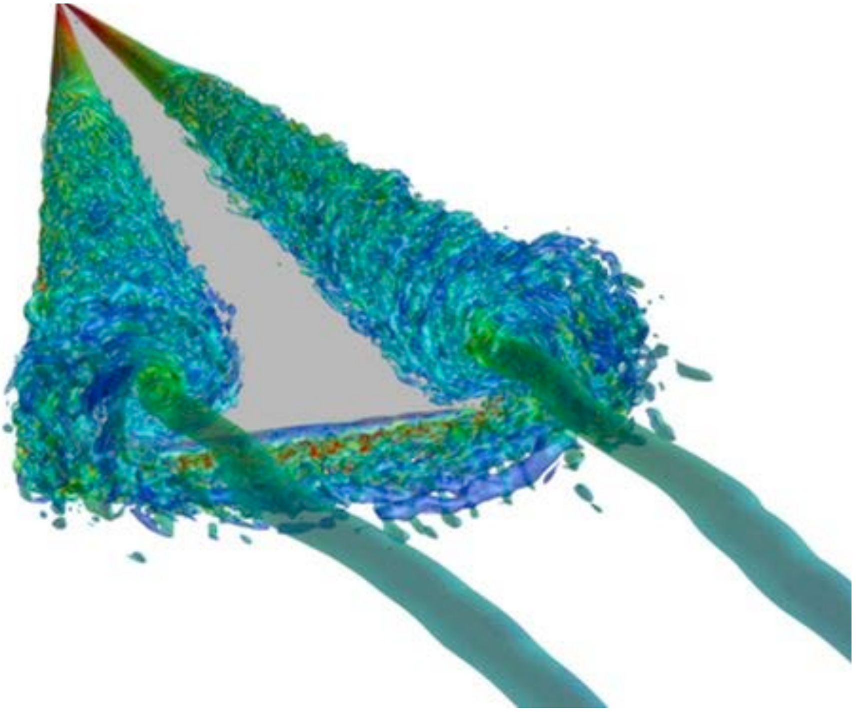
COMPUTATIONAL MECHANICS AND NUMERICAL MATHEMATICS (CMNM)

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. Applications are free-fall life boats (with validation tests at MARIN), CALM buoys and elastically deforming objects. Adaptive local grid refinement has been further developed. Software design and user-friendliness get much attention. Most parts of the code are now parallel (combined MPI and OpenMP).

Dissertations

1. P. van der Plas, Local grid refinement for free-surface flow simulations. Promotor: A.E.P. Veldman; co-promotor: R. Luppes. PhD thesis, University of Groningen, March 24, 2017.

Scientific Publications

1. X. Chang, I. Akkerman, A.E.P. Veldman. R.H.M. Huijsmans, Towards non-reflecting boundary conditions for wave simulations in offshore applications. IWWWFB32, 23-26 April 2017, Dalian (China) 4 pages.
2. B. Duz, M.J.A. Borsboom, P.R. Wellens, A.E.P. Veldman, R.H.M. Huijsmans. An absorbing boundary condition for free-surface water waves. Comp. & Fluids 156 (2017) 562-578, DOI: 10.1016/j.compfluid.2017.05.018.
3. S.M. Hosseini Zahraei, A.E.P. Veldman, P.R. Wellens, I. Akkerman, R.H.M. Huijsmans. The role of a structural mode-shape based interaction law to suppress added mass instabilities in partitioned strongly coupled elastic structure-fluid systems. OMAE2017, 26-29 June, Trondheim (Norway), paper OMAE2017-62075, 10 pages.
4. Matin Hosseini Zahraei, Peter Wellens and Arthur Veldman. Stabilization of a fluid-deforming structure partitioned coupling. NUTTS, 1-3 October 2017, Wageningen, 4 pages.
5. Peter van der Plas, Arthur Veldman, Joop Helder and Ka-Wing Lam. Adaptive grid refinement for two-phase flow applications. NUTTS, 1-3 October 2017, Wageningen, 5 pages.
6. Henk Seubers and Arthur Veldman. Controlling the added-mass instability in fluid-solid coupling. NUTTS, 1-3 October 2017, Wageningen, 5 pages.
7. Arthur E.P. Veldman. Entrainment and boundary-layer separation: a modeling history. J. Eng. Math. 107:5-17 (2017). DOI: 10.1007/s10665-017-9930-x.
8. A.E.P. Veldman, H. Seubers, P. van der Plas, J. Helder. Accelerated free-surface flow simulations with interactively moving bodies. In: Michel Visonneau, Patrick Queutey and David Le Touzé (eds) Computational Methods in Marine Engineering MARINE 2017, 15-17 May, Nantes (France), pp. 604-615.
9. A.E.P. Veldman, H. Seubers, P. van der Plas, J. Helder, Free-surface flow simulations with interactively moving bodies. OMAE2017, 26-29 June, Trondheim (Norway), paper OMAE2017-61175, 8 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

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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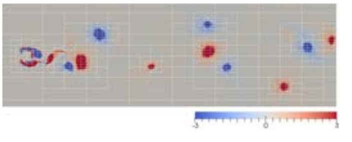

Snapshot of the wake behind a square cylinder (Re=1000), with an adaptively-refined grid following the vortical structures.

SLING: Liquid sloshing in LNG tanks

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. Therefore, as a first step, the occurrence of spurious velocities has been suppressed; the decay rates towards equilibrium could be investigated. Thereafter, the Kelvin-Helmholtz instability has been studied in the presence of surface tension, both theoretically and by means of simulation.

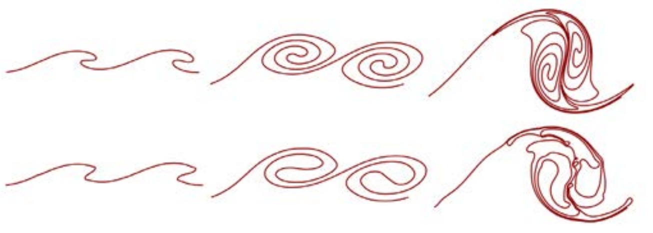
Dissertations

-

Scientific Publications

-

Influence of capillarity on a Kelvin-Helmholtz instability.
Top: without surface tension; bottom: with surface tension.



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).

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.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECT LEADERS

Cristóbal Bertoglio

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

David Nolte, Hugo Carrillo

COOPERATIONS

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, HJ Bandringa, RA Remmerswaal, AEP Veldman, FX Trias (UPC), A Oliva (UPC), HJ Bae (CTR), P Moin (CTR) M Abkar (Aarhus Univ) A Gorobets
Cooperations
Polytechnica University of Catalunya (UPC), Stanford University (CTR), Aarhus University, Keldysh Institute for Applied Math
Funded by
NWO
Funded %

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

Start of the project
1998
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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

-

Scientific Publications

1. M.H. Silvis, R.A. Remmerswaal, R.W.C.P. Verstappen, Physical consistency of subgrid-scale models for large-eddy simulation of incompressible turbulent flows, Physics of Fluids 29 (1) 015105, 2017.
2. F.X.Trias, A. Gorobets, M.H. Silvis, R. Verstappen, A. Oliva, A new subgrid characteristic length for turbulence simulations on anisotropic grids, Physics of Fluids 29 (11), 115109, 2017.
3. M.H. Silvis, R.A. Remmerswaal, R. Verstappen, A framework for the assessment and creation of subgrid-scale models for large-eddy simulation. Progress in Turbulence VII, \Orlu et al (eds.), Springer Proceedings in Physics, 133-139, 2017.
4. M.H. Silvis R. Verstappen, Nonlinear subgrid-scale models for large-eddy simulation of rotating turbulent flows Proceedings 11th Workshop on Direct and Large Eddy simulation DLES 11, 29-31 May, Pisa, Italy, 2017.
5. M.H. Silvis, H.J. Bae, F.X. Trias, M. Akbar, R. Verstappen, Subgrid-scale models for large-eddy simulation of rotating turbulent channel flows. Proceedings 68th Meeting APS Division Fluid Dynamics, 19-21 November 2017, Denver, also in Bulletin of the American Physical Society 62.

Numerical Methods for the Incompressible Navier-Stokes Equations

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

The developed solver for generalized Lyapunov equations has been applied to study stochastic marine ice sheet variability. A paper has been finalized and has been accepted for publication. The corresponding software RAILS has been made available on GITHUB. The parallel implementation of the dynamical orthogonal field method (DO method) for general systems of PDEs has been completed and is currently tested on a quasi-geostrophic (QG) model. In this method, higher moments of probability distributions can be computed than what is possible with the Lyapunov solver. A paper on pattern formation in a 2D and 3D Turing problem has been written and has been accepted for publication. A long-standing problem in our solver for CFD problems HYMLS has been resolved. Performance results are underway.

Dissertations

-

Scientific Publications

1. Baars, S., Viebahn, J. P., Mulder, T., Kuehn, C., Wubs, F. & Dijkstra, H. A., Continuation of Probability Density Functions using a Generalized Lyapunov Approach, Journal of computational physics. 336, p. 627-643 31 p., 2017.
2. Mulder, TE, MLJ Baatsen, FW Wubs, HA Dijkstra, Efficient computation of past global ocean circulation patterns using continuation in paleobathymetry, Ocean Modelling, 2017.
3. Baars, S,. RAILS: Residual Approximation-based Iterative Lyapunov, https://github.com/Sbte/RAILS.

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), TUE, 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

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

Mosquitos fly at an exceptionally high wingbeat frequency, 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 an extensive parametric study using computational fluid dynamics (CFD) simulations of flapping insect wings (mosquito and fruit flies) and idealized equivalent wings with an elliptical shape. The parametric space consisted of wing stroke angular rate, wing pitch rate and various geometrical parameters of the wings. These parameters were systematically varied, in order to estimate their effect on aerodynamic force production. For this analysis, we adapted and validated the open-source immersed boundary method solver IBAMR. The CFD results were used to correct and extend current quasi-steady aerodynamic models of flapping wings of flying insects.

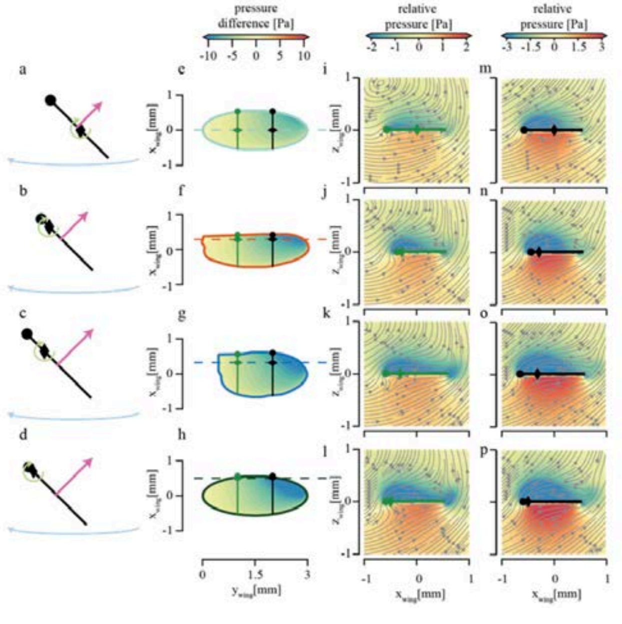
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

The aerodynamic forces (pink arrow) on airfoils (a-d), pressure difference across wing surfaces (e-h), and pressure and streamlines around the wings (i-p), for four different wings with a combined stroke-rate (blue arrow) and pitch-rate (green arrow) of both 1000 rad/s. The wings are from top to bottom: an elliptic wing pitching around its chordwise centreline, a mosquito wing, a fruit fly wing, and an elliptic wing pitching about its leading edge.



PROJECT LEADERS

FT Muijres

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

W 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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PROJECT LEADERS
JL van Leeuwen
RESEARCH THEME
Complex dynamics of fluids
PARTICIPANTS
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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
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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

An invited review paper on the 'biomechanics of swimming in larval fish' was written and submitted to the Journal of Experimental Biology. We continued our work on the reconstruction of bending moments in free-swimming larval zebrafish, and showed that a full solution of the Navier Stokes equation is required to obtain a reliable solution of the external forces on larval fish which serves to derive the bending moments along the body. The open-source immersed-boundary-method CFD code IBAMR was adapted and validated for this purpose. An extensive 3D kinematic data set of free-swimming larval fish was acquired and used as input for the computations of the bending moments. A set-up was built for the recording of the muscle activity in larval zebrafish using highly sensitive fluorescent techniques. In collaboration with G Li and H Liu (Tokyo), we made a numerical optimization study of swimming in larval fish. Finally, a three-dimensional analysis of the fast-start escape response of the least killifish, Heterandria formosa was completed (in collaboration with M Fleuren and BJA Pollux), using our previously developed automated software approach for reconstructing 3D swimming kinematics of swimming. This work was submitted to the Journal of Experimental Biology.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

How to catch a flying mosquito? The flight response of mosquitoes to odours and air gusts produced by odour-baited traps

Project Aim

We study the flight dynamics of the malaria mosquito (Anopheles coluzzii) with the applied goal to improve current and/or develop novel mosquito trap systems for vector control. We aim to reach this goal by quantifying mosquito flight dynamics during host searching with diverse attractive cues and mosquito escape manoeuvres near wind gusts. These should provide novel insights into mosquito flight behaviour and the mechanisms involved for odour and wind gust detection and response.

Progress

The flight of malaria mosquitoes around odour-baited traps has been studied, which shed new light on their behaviour during host seeking and their response to the airflow generated by the trap. An article has been written about the results of our study. It shows that mosquito flight dynamics around odour baited traps correlate with the orientation of the trap (hanging or standing) which induce distinct capture efficiencies of the traps. This work was orally presented at the 2017 JMBC symposium in Lunteren and the 2017 annual conference of the Society for Experimental Biology, Gothenburg, Sweden. Following this study, another experimental setup is currently being built with the aim to unravel how mosquitoes detect and react to looming stimuli and wind gusts in various light conditions.

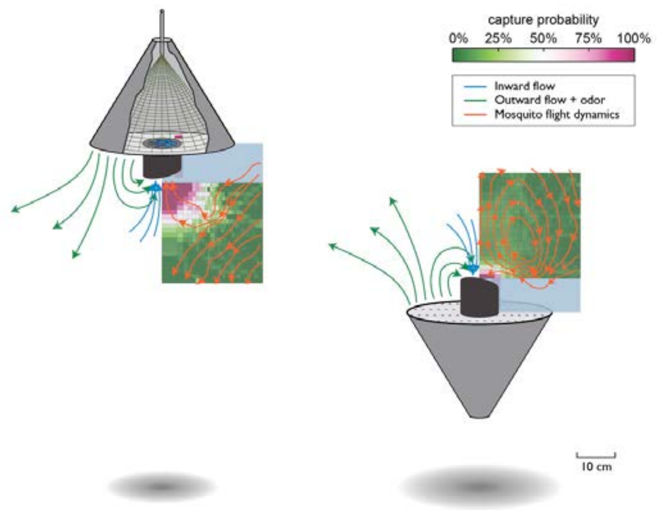
Dissertations

-

Scientific Publications

-

The average flight tracks and capture percentage of mosquitoes around the two traps, and an artist impression of airflow induced by the traps. The mean flight tracks (in red) are determined from the streamlines of mosquito flight dynamics.



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

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
Funded %

University	-
FOM	-
STW	100 %
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 navigate through complex environments in the presence of wind gusts very easily. The aim of this project is to study and understand the gust rejection capabilities of insects. We aim to reach this goal by exposing insects (bumblebees and blowflies) to known wind gusts and record their response using a high-speed videography system. This will provide innovative insights into interaction of different sensory systems and their control architecture involved in gust mitigation.

Progress

We have designed, built, and tested a insect flight wind tunnel, including gust generator apparatus for the first set of experiments. In these experiments, we will attach a hive of bumblebees to the wind tunnel and train the bumblebees to forage food from the food source placed at the other end (Figure 1). In mid-air, we will expose the bumblebees to various types of wind gusts, and record their resulting position and orientation. We aim to find out ways in which the effect of wind gusts can be mitigated and model the closed loop response by exciting both longitudinal and lateral dynamics over different frequencies.

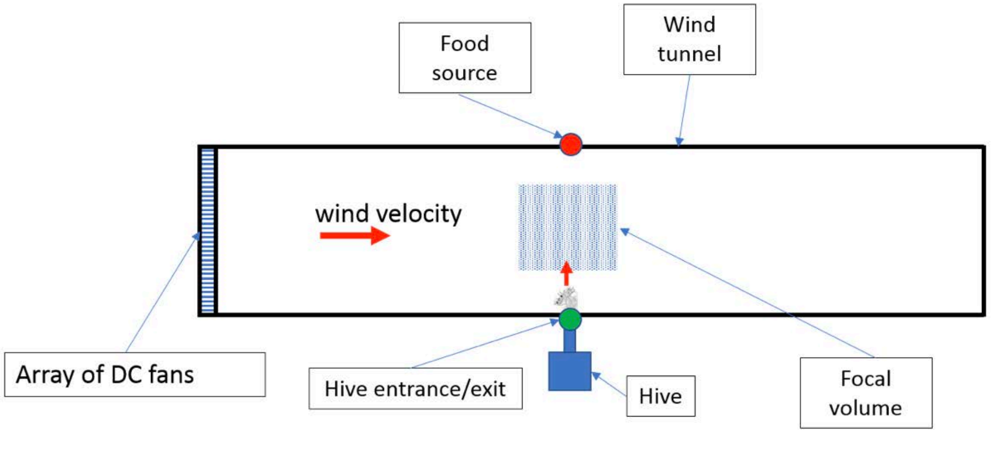
Dissertations

-

Scientific Publications

-

Schematic of the experimental set-up (top view of the wind tunnel), bumblebees flying from hive to food source will be exposed to different gusts in mid-air and its response will be captured by cameras



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 rapidly blood-fed mosquitoes escape their human host without being detected [1]. Using high-speed stereoscopic videos of mosquitoes taking off from a platform, and by modelling aerodynamics force based on the wingbeat kinematics measured throughout the take-off, we showed that mosquitoes produce push-off forces that are below the detection threshold of the mechanosensory hairs on mammalian skin. This showed that blood-fed mosquitoes use a highly specialized take-off maneuver in order to minimize detection. We studied how wing molt in passerine birds affects their escape performance, and consequently their breeding success [2]. Using a high-speed stereoscopic videography system, we recorded vertical escape flights of molting and non-molting birds. Based on these videos, we measured the body and wingbeat kinematics of these flying animal, allowing us to quantify the reduction in escape performance as a result of molt, and how molting birds adjust their flight dynamics in order to negate these detrimental effects.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Muijres, F. T., Chang, S. W., van Veen, W. G., Spitzen, J., Biemans, B. T., Koehl, M. A. R. & Dudley, R. 2017 Escaping blood-fed malaria mosquitoes minimize tactile detection without compromising on take-off speed. J. Exp. Biol. 220, 3751–3762. (doi:10.1242/jeb.163402).
2. Tomotani, B. M., Muijres, F. T., Koelman, J., Casagrande, S. & Visser, M. E. 2017 Simulated moult reduces flight performance but overlap with breeding does not affect breeding success in a long-distance migrant. Funct. Ecol. (doi:10.1111/1365-2435.12974).

PROJECT LEADERS

Dr. Ir. FT Muijres

RESEARCH THEME

Complex dynamics of fluids

PARTICIPANTS

Ir. W van Veen (PhD candidate)
Prof. JL van Leeuwen

COOPERATIONS

Prof. MH Dickinson (Caltech, USA)
Prof. R Dudley (UC Berkeley, USA)
Prof. Marcel Visser (NIOO)

FUNDED BY

NWO ALW Veni
Wageningen University (WUR)

FUNDED %

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

START OF THE PROJECT

2012

INFORMATION

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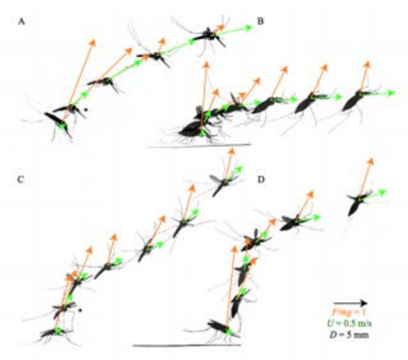
Photomontages of mosquitoes taking off. (A,C) Two unfed mosquitoes; (B,D) two blood-fed mosquitoes. From [1]



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

Setting up a computational fluid dynamics (CFD) model that describes flow segregation of suspensions as a result of shear induced diffusion that drives large particles faster toward the middle of a channel. In first instance, the flow of particles in a closed channel is validated, and the effect of process parameters charted. As a next step, pores through which liquid can be removed are added to the computational model, which in turn allows elucidation of pore design and its' effects on separation efficiency. The final aim is to combine all previously mentioned effects, and design a novel energy efficient separation technology based on these findings.

Progress

The closed channel model has been set up and validated and the result is published (see figure, reference: I. Drijer, T.X. van de Laar, H.M. Vollebregt, K. Schroen, From highly specialised to generally available modelling of shear induced particle migration for facilitated microfiltration, Sep. Purif. Technol. 192 (2018) 99–109. doi:10.1016/j.seppur.2017.10.001).

We are currently working on the different parameter studies described above, and expect to finish this soon. Simultaneously, we are doing an experimental study with a food product to showcase the practical relevance of the designed system.

Dissertations

-

Scientific Publications

1. I. Drijer, T.X. van de Laar, H.M. Vollebregt, K. Schroen, From highly specialised to generally available modelling of shear induced particle migration for facilitated microfiltration, Sep. Purif. Technol. 192 (2018) 99–109. doi:10.1016/j.seppur.2017.10.001).

Project leaders
K Schroen

Research theme
Mathematical and computational methods for fluid flow analysis

Participants
Ivon Drijer

Cooperations
NanoNextNl consortium (water cluster)

Funded by
NanoNextNl

Funded %

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

Start of the project
2012

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Reports of Individual Research Groups

Utrecht University

Institute for Marine and Atmospheric Research Utrecht (IMAU)

Prof.dr. LRM Maas

Prof.dr.ir. HA Dijkstra

The research of this Institute concerns transport processes in the ocean and in the atmosphere. Some sections of IMAU participate in the research school Buys Ballot. However, the section Dynamical Oceanography also participates in the JM Burgerscentrum.

One of the main topics is the role of the ocean circulation in the variability of the climate system and the processes controlling the large-scale ocean circulation. In particular, attention is focused on the path changes of the oceanic western boundary currents (such as the Gulf Stream in the Atlantic Ocean, the Kuroshio in the Pacific Ocean, and the Agulhas Current near South Africa), the El Nino / Southern Oscillation phenomenon in the Pacific, and the North Atlantic Multidecadal variability. Both theory development and (high-resolution) model simulation are used to better understand these phenomena and our favourite framework to analyse the complex behaviour of ocean flows is that provided by stochastic dynamical systems theory.

Another line of research focuses on ocean wave dynamics. Due to temperature and salinity differences, the ocean is stratified in density. This supports internal gravity waves, that have their maxima below the surface of the ocean. These waves are especially generated by surface tidal motions over topographic irregularities, like the continental shelf edge or Mid-Atlantic Ridge. When subject to friction at ocean boundaries, Reynolds-stresses induced by internal gravity waves are found to also drive horizontal mean flows. Another type of large-scale ocean wave is related to the rotation of the earth: the Rossby wave. This wave type exists due to variations in background potential vorticity, which represents the ratio of planetary vorticity (equal to twice the rotation rate of the fluid) and water depth. An explicit expression for the Green's function, describing the response to an impulsive point source is uncovered.

PROJECT AIM

The Atlantic Ocean circulation, in particular its Meridional Overturning Circulation (MOC), is sensitive to freshwater anomalies. A tipping point may exist such that the present-day MOC will collapse if the northern North Atlantic freshwater forcing is gradually increased. In addition, if the MOC is in a multiple equilibrium regime it may undergo transitions due to the impact of noise. The aim of this project is to determine the probability of transitions of the MOC in a hierarchy of stochastic ocean-climate models. Both noise in the surface forcing as well as in the representation of turbulent mixing processes will be considered.

PROGRESS

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.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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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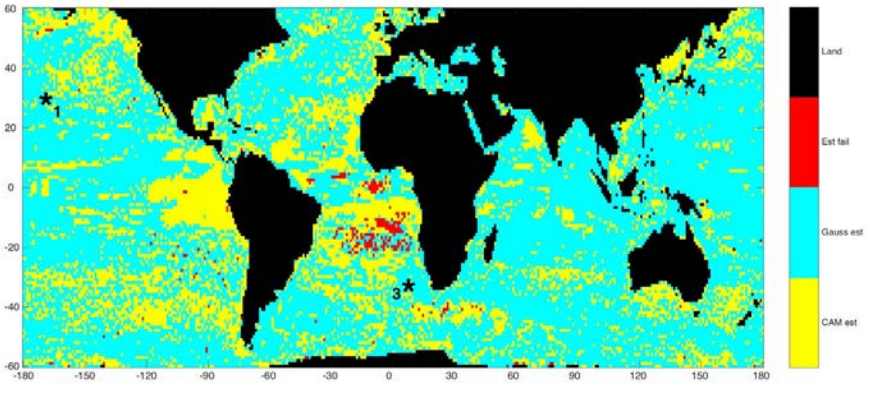
Overview of locations over the global ocean where Gaussian (blue) or CAM (yellow) noise better represent sea surface height variability as observed by satellite observations.



PROJECT LEADERS
Jason Frank and Leo 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

The aim is to better understand non-linear energy transfer from internal gravity waves to an induced mean vortex flow. Understanding these processes is important for a better understanding of vertical mixing induced by internal waves.

PROGRESS

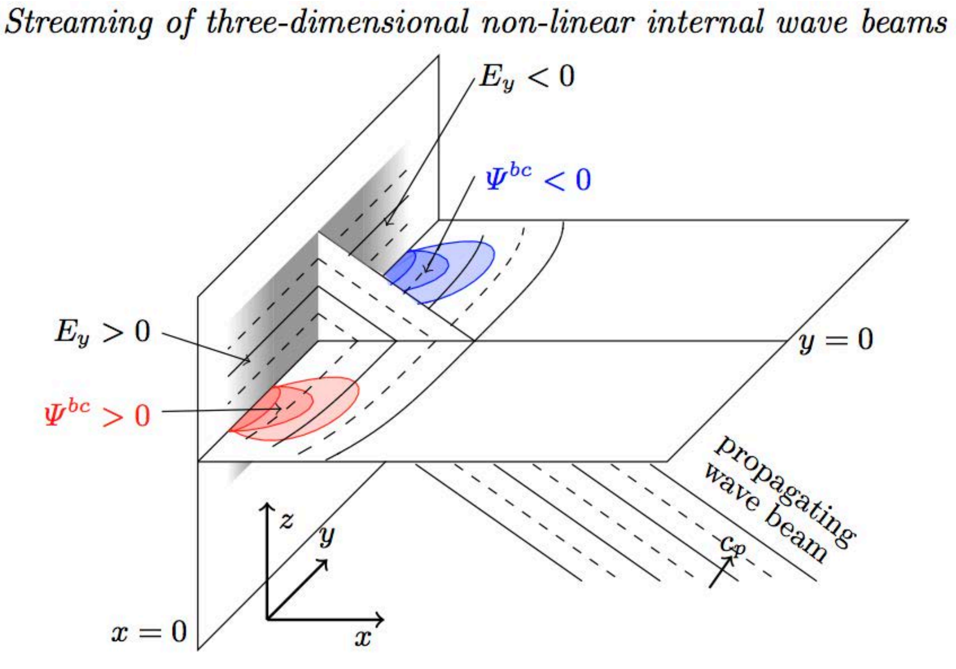
Internal gravity waves can induce mean flow through non-linear advection terms, a process known as streaming. With a perturbation expansion, we construct solutions for 3D diffracting internal waves beams, generated by an energy flux through a rigid wall, as sketched below. Such energy input also generates localized curl-free and divergence-free horizontal oscillations, which interact with the wave beam to generate a mean flow. This is a novel streaming mechanism, which has not yet been discussed in literature.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



PROJECT AIM

To construct impulse response functions on the geophysical beta-plane to both instantaneous as well as maintained point torques of wind stress.

PROGRESS

Previously unmanageable integral expressions have been solved explicitly in terms of products of Besselfunctions of complex conjugate arguments. The problem is in essence a 'one-liner':

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Kloosterziel, R., & Maas, L.R.M. (2017). Green's functions for Rossby waves. Journal of Fluid Mechanics, 830, 387-407. doi:10.1017/jfm.2017.601.

PROJECT LEADERS

Leo Maas

RESEARCH THEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

R.C. Kloosterziel, L.RM. Maas

COOPERATIONS

-

FUNDED BY

-

FUNDED %

STW

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

START OF THE PROJECT

-

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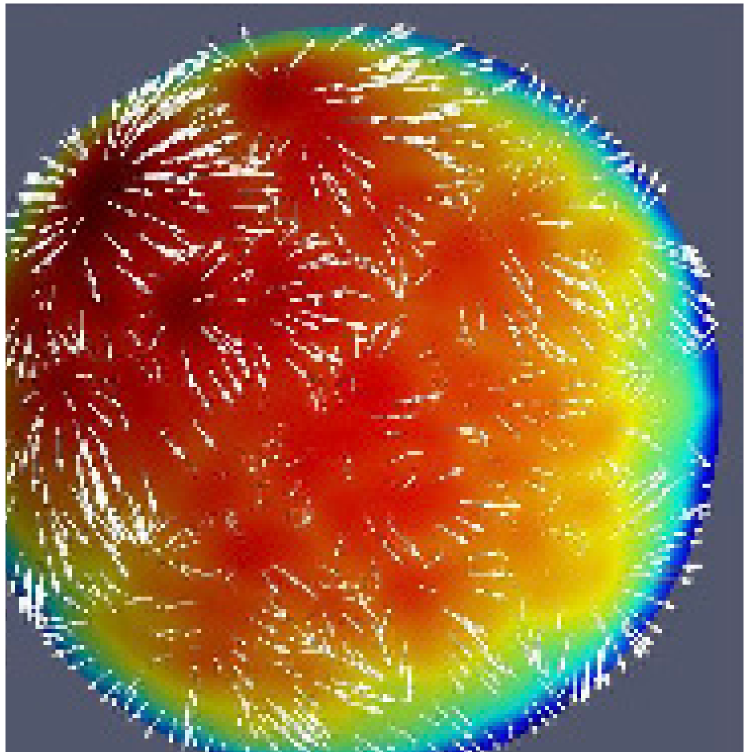
$$\nabla^2\psi_t + \psi_x = \delta(t)\delta(x)\delta(y) \;\rightarrow\; \psi = \frac{1}{4}\left(J_0(z_+)Y_0(z_-) + J_0(z_-)Y_0(z_+)\right), \quad z_\pm = \sqrt{t(x \pm i\,y)}$$

Who & Where



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