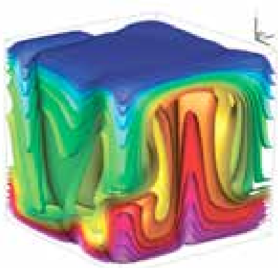
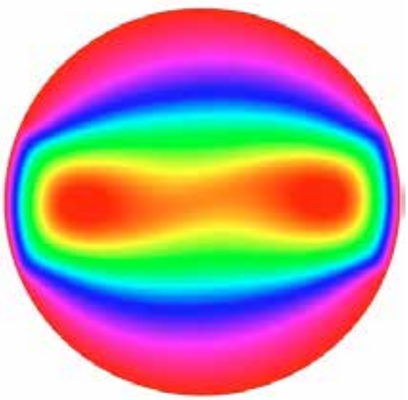
2012

2013





Annual Report & Research Programme

J.M.Burgerscentrum

Research School for Fluid Mechanics

TUD, TUE, UT, RUG, UL, WUR, UU

Annual Report & Research Programme 2012-2013

JM Burgerscentrum
Research School for Fluid Mechanics

TUD, TUE, UT, RUG, UL, WUR, UU

Correspondence for reproduction

JM Burgerscentrum
Attn. Mrs. I Hoekstein
Mekelweg 2
2628 CD Delft
The Netherlands
T 015 278 3216
F 015 278 2979
E jmburgerscentrum@tudelft.nl
www.jmburgerscentrum.nl

Burgers Program for Fluid Dynamics (University of Maryland, USA) www.enme.umd.edu/burgers/

Contributions of the participating groups, Industrial Advisory Board and Contactgroups. Final editing : Prof.dr.ir. G Ooms and Mrs. I Hoekstein of the JM Burgerscentrum.

Design and lay-out : I Hoekstein
Printed by : NIVO, Delft

Preface

Prof.dr.ir. G Lodewijks
Chairman of the JMBC Board

Prof.dr.ir. G Ooms
Scientific Director

As in preceding years this annual report of the J.M. Burgerscentrum provides an overview of the activities of our research school during last year (2012). The core of the report consists of the description of the research projects, carried out by the JMBC groups. In each report the relevant information (title, theme, staff involved, project aim, achievements, publications, funding source, application, etc.) is given. Also some research highlights are presented. It provides also general information about the research school, such as goals, organization, relation with industries and technological institutes.

The number of PhD projects carried out by the JMBC groups is still large (about 300). Although the sponsoring of such projects directly via the universities is almost non-existing, the financing of projects via NWO (in particular 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.

As mentioned last year, the JMBC needs to be re-accredited again in 2013 by the Royal Netherlands Academy of Sciences. To that purpose the application report has been written last year and submitted in December 2012. In the judgment of the research output the existing evaluation reports of the individual JMBC groups will play an important role. These reports are drafted according to the SEP-protocol. From the groups that in their evaluations received a quality score, most scored ‘very good’ to ‘excellent’ and a few scored ‘good’. Overall the productivity of the JMBC-groups is high. The groups are very well connected to industry and work on well-chosen topics that are relevant to important issues, while at the same time succeeding in having an impact on fundamental subjects. In the course of 2013 we will be informed by Royal Netherlands Academy of Sciences about its decision concerning the JMBC re-accreditation.

The activities of the JMBC continue to ensure that the Dutch fluid mechanics field is a tight knit 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 Burgersdag for all scientists involved in the JMBC and for many fluid-mechanics experts from industry, TNO and technological institutes. In January 2013 the Burgersdag attracted a large number of participants (~250).

In 2012 two new groups started their participation in the JMBC: prof. Henk Dijkstra from the group ‘Dynamical Oceanography’ at IMAU, Utrecht University and prof. Harald van Brummelen from the group ‘Multiscale Engineering Fluid Dynamics’ at Mechanical Engineering, Technological University Eindhoven. When a new group wants to participate, the group leader needs to submit a written motivation, a research plan and C.V.’s for the staff members involved. Based on this application the scientific director asks a number of professors in the JMBC for advice. The application and the advice are then sent to the board of the JMBC, who make the final decision.

The PhD-students that started their PhD-project in the years 2004 to 2008 had no problem finding a job after finishing their study. A large percentage found a job in industry and technological institutes. A significant part remained in academia with a post-doc position.

Due to the enthusiasm and the combined knowledge, skills and facilities of the participating research groups, the JMBC remains 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 G. Lodewijks	Prof.dr.ir. G. Ooms
Chairman of the JMBC-Board	Scientific Director

Contents

Contents

ORGANISATION

Organisation

The JM Burgerscentrum (JMBC) is the Dutch research school for fluid mechanics. The Delft University of Technology is the coordinating university. The main goals of the JMBC are:

- Stimulation of co-operation of the participating groups with respect to their research efforts. It is the desire to be one of the leading institutes for fluid mechanics in the world.
- Organization of advanced courses for PhD-students. Researchers from industries and technological institutes also attend these courses.
- 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 Dutch fluid mechanics research groups at universities and the international fluid mechanics community.

About 60 professors with their groups participate in the JMBC. These groups are located at the Delft University of Technology, Eindhoven University of Technology, University of Twente, the University of Groningen, Leiden University, Wageningen University and Utrecht University. They are from a number of disciplines; such as Civil Engineering; Mechanical Engineering; Maritime Technology; (Applied) Physics; Aerospace Engineering; Applied Mathematics and Chemical Technology. The professors with their senior staff form the council of project leaders, which meets regularly. There are about 300 PhD-students in the JMBC.

The JMBC has a scientific director who is responsible for the management of the research school; the JMBC secretary assists him. Three times per year he justifies his actions to the Board of the JMBC, and asks the Board for advice with respect to proposed new activities. He is also assisted by the Management Team, which consists of the local directors from the Delft University of Technology (also responsible for the groups at the University of Leiden), Eindhoven University of Technology (also responsible for the groups at the University of Wageningen and Utrecht University) and the University of Twente (also responsible for the groups at the University of Groningen).

The research projects carried out by the JMBC-groups have been ordered in a number of research themes. The reason for this ordering is to present in each theme a combination of projects which have coherence. The themes are:

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

The JM Burgerscentrum has many good contacts with industries and technological institutes in The Netherlands. For that reason there is an Industrial Board, in which Unilever, TataSteel, Philips, AKZO-Nobel, Teijin Aramid, Shell, DOW Benelux, ASML, DSM , Océ , NLR, NMI/VSL, TNO-Science and Industry, TNO-Defence and Safety, TNO-Oil - and Energy Industry, MARIN, Deltares, KEMA, ESTEC, ECN/NRG, FlowServe and Vortech participate. The Industrial Board meets regularly with the scientific director to discuss new activities of relevance to industries and technological institutes.

Each year (also in 2012) there are many scientific contacts with research groups in other countries. For that reason there are often external visitors to the JMBC groups. JMBC staff also regularly visits foreign fluid-mechanics groups, and presents their work at international conferences. The number of publications from JMBC staff in well-known scientific journals is considerable.

Together with Engineering Mechanics (the research school on solid mechanics) the JMBC forms the Centre for Fluid Solid Mechanics. This Centre has been recognized as a centre of excellence in The Netherlands and has received significant funding by the Dutch Government for stimulating new research areas in fluid and solid mechanics.

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 Technological Universities and are financed by the Boards of the Technological Universities or by the Centre for Fluid and 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 (Burgersdag). This year about 250 persons attended the meeting. The theme of the meeting was research by JMBC PhD-students.

Overview of the contribution of the participating groups of the JMBC

University and (sub)faculty	Project leaders	Scientific staff (fte)	Support staff (fte)	PhD students (fte)
TUD				
Mechanical Engineering	J Westerweel, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B Eckhardt	4.4	2.0	19.2
	BJ Boersma	5.7	2.0	12.0
Maritime Engineering	RHM Huijsmans, TJC van Terwisga	1.6	0.0	8.0
	C van Rhee	1.0	0.0	4.0
Applied Mathematics	C Vuik, P Wesseling, AWH Heemink	6.8	0.0	10.4
Chemical Engineering	CR Kleijn, RF Mudde, HEA van den Akker, S Sundaresan	5.7	3.2	14.0
	M Kreutzer	2.1	0.5	6.0
Radiation Science & Techn.	THJJ van der Hagen (M Rohde)	2.6	2.0	1.6
Aerospace Engineering	H Bijl, F Scarano, PG Bakker	4.1	5.0	22.0
Civil Eng. & Geosciences	GS Stelling, WSJ Uijttewaal	6.5	-	11.2
	HJJ Jonker, P Siebesma	2.2	1.0	9.0
TUE				
Applied Physics	AA Darhuber, MEH van Dongen	3.1	0.8	5.6
	HJH Clercx, GJ van Heijst, F Toschi, BJ Geurts	4.6	1.0	9.3
	K Kopinga, OCG Adan	1.2	-	7.2
Mechanical Engineering	LPH de Goey (RJM Bastiaans), B Johansson	1.9	5.0	14.4
	JJH Brouwers	2.0	-	4.0
	DMJ Smeulders, AA van Steenhoven, AH Dietzel HA Zondag	2.1	1.8	10.0
	EH van Brummelen	0.7	-	0.8
Biomedical Engineering	FN van de Vosse	0.2	-	3.2
Mathematics and Computer	B Koren, F Toschi	0.8	0.0	3.2
Science	CJ van Duijn, JJM Slot	2.4	-	3.2
Chemical Eng. & Chemistry	JAM Kuipers, M van Sint Annaland	2.0	1.8	10.8

University and (sub)faculty	Project leaders	Scientific staff (fte)	Support staff (fte)	PhD students (fte)
UT				
Applied Physics	WJ Briels	2.4	-	5.6
	D Lohse, D van der Meer, A Prosperetti, JF Dijksman L van Wijngaarden, R Verzicco	9.5	-	22.8
	F Mugele	9.1	3.0	10.0
Chemical Engineering	RGH Lammertink	1.7	0.4	4.0
Mathematical Sciences	EWC van Groesen	0.5	-	3.0
	JJW van der Vegt	1.5	-	5.0
	BJ Geurts, JGM Kuerten, HJH Clercx	1.5	-	5.6
Mechanical Engineering	HWM Hoeijmakers, A Hirschberg	2.0	2.6	7.2
	ThH van der Meer	1.1	0.4	8.8
	S Luding	3.1	-	9.0
Water Engineering & Manag.	SJMH Hulscher	4.0	-	6.0
RUG				
Mathematics	AEP Veldman	1.9	-	5.6
UL				
Math. and Natural Sciences	M van Hecke	1.3	-	2.4
WUR				
Experimental Zoology	JL van Leeuwen	0.5	-	0.9
UU				
Physics and Astronomy	LRM Maas	0.2	-	0.8
	H Dijkstra	0.3	-	0.8

The calculation of fte's is based on:
Professor 0,3 fte | Part-time professor 0.1 fte | Associated professor and assistent professor 0,4 fte | post-doc 1,0 fte | Support Staff 1.0 | PhD-student 0,8 fte

Overview of university participants

University	Scientific staff (fte)	Support staff (fte)	PhD-students (fte)
TUD	42.7	15.7	117.4
TUE	21.0	10.4	71.7
UT	36.4	6.4	87.0
RUG	1.9	-	5.6
UL	1.3	-	2.4
WUR	0.5	-	0.9
UU	0.5	-	1.6
Total	104.3	32.5	286.6

Industrial Board

It is a privilege to contribute a few words to the Annual Report of the J.M. Burgers Centre, the research school for fluid dynamics in The Netherlands. In the time I have been member of the Industrial Advisory Board of the J.M. Burgers Centre I have witnessed a continuous increase of the industrial participants, with presently Shell, Unilever, TataSteel, Philips, AKZO-Nobel, Teijin Aramid, and DOW. This illustrates the present position of the well recognised research school.

The interest of the Dutch Industry for the use of OpenFOAM was noted some years ago. The response from the assembled industries during the first sounding meetings underpinned a surprising interest in the initiative. The list of industries is:

Benelux, ASML, DSM , Océ , NLR, NMI/VSL, TNO-Science and Industry, TNO-Defence and Safety, TNO-Oil - and Energy Industry, MARIN, Deltares, KEMA, ESTEC, ECN/NRG and FlowServe.

The idea is that OpenFOAM is an ideal platform for knowledge transfer from Universities and institutions to the participating industries. To achieve this, the initiative group prepared an application of the OpenMIND programme for STW support. The supporting industries were convinced of the good application perspective, but the application was judgment as insufficient. Looking backward, all involved in the initiative remain very supportive. The number of collaborative industrially supported projects which use OpenFOAM continues to grow, which illustrates the continued support of industry. Note that the continued support of our scientific director Prof. Gijs Ooms and the support of Ilse Hoekstein-Philips within the Burgers Centre has been an essential contribution to the collaborations.

One example of a well recognised event is the Burgers Day where PhD's were demonstrating and sharing their developments. The sustained huge number of visitors of the Burgers Day illustrate that the community is living and developing well. I thank the Scientific Director of the Burgers Centre and the Office for leading this living community to the volume is has nowadays.

The present state of the economy in The Netherlands, and in Europe did not directly impact the collaborative projects. However, the Industrial Board will consider the possibility of new collaborations which might fit better in the present industrial climate.

Dr. RPJ Duursma
Tatasteel
Chairman of the Industrial Advisory Board

Prof.dr.ir. AE Mynett
UNESCO-IHE
Chairman of the Industrial Advisory Board

Prof.dr.ir. RAWM Henkes
Delft University of Technology

Dr.ir. NG Deen
Eindhoven University of Technology

Prof.dr.ir. AEP Veldman
University of Groningen

Prof.dr. DJEM Roekaerts
Delft University of Technology

Contactgroup "Multiphase Flow"

The objective of the Contactgroup 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, multiphase flow measurements and innovation with multiphase flow. On 22nd May 2012 a one-day meeting was held at the Multiphase Reactors Group of Eindhoven University of Technology. The theme of that day was "Multiphase Flow with Heat and Mass Transfer at Interfaces".

Contactgroup "Computational Fluid Dynamics (CFD)"

The aim of the contactgroup "Computational Fluid Dynamics" is to exchange knowledge and experience in developing and applying CFD methods.

It is accompanied by a series of succesfull JMBC courses on designing CFD methods (CFD 1, 2 and 3). There were no meetings in 2012, but plans are being made for a series of thematic meetings in 2013/2014.

Contactgroup "Combustion"

The JMBC has groups active in combustion research at the universities of Delft, Eindhoven, Groningen, and Twente. The contactgroup combustion is an informal network between these groups. The groups play an important role in the organization of the symposia of the Dutch section of the Combustion Institute, which is part of the international Combustion Institute, an international forum for scientific combustion research. These groups also have formed the STW-platform 'Clean and Efficient Combustion' to enhance the mutual collaboration between the different groups and to interest more industrial parties for the fundamental research on combustion.

The COMBURA symposium was organized for the 11th time. It took place in Maastricht on October 3 and 4. This symposium is the major annual event in The Netherlands for exchange of information on combustion research and its applications. It is a joint initiative of the Technology Foundation STW, the Nederlandse Vlam Vereniging NVV (Dutch section of the International Flame Research Foundation IFRF) and the Dutch section of the Combustion Institute. The first day was devoted to the eight research projects within the STW program on Clean Combustion Concepts (CCC), all of which are executed by research groups of the JM Burgers Centre.

On the second day a keynote lectures were presented by Dr. Werner Krebs (Siemens) on “Combustion technologies for future gas turbines: design methodology and validation” and by Prof. Dr. Luc Vervisch (INSA/CORIA, Rouen) on “Combustion, flames and burner design: challenges and computing tools”. Sessions were held on “Gas Turbines”, “Engines”, “Experiments/ Radiation” and on “Modeling/Explosions”.

Contactgroup “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. The contact group promotes the organisation of educational and research events.

Prof.dr. F Toschi
Eindhoven University of Technology

Prof.dr.ir. BJ Boersma
Delft University of Technology

Dr.ir. WP Breugem
Delft University of Technology

Prof.dr.ir. J Westerweel
Delft University of Technology

Dr. M Versluis
University of Twente

Contactgroup “Turbulence”

The contactgroup “Turbulence” organizes (half-)yearly 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. Researchers that are not affiliated to the JM Burgerscentrum are also welcome to participate in our meetings. If you want to be invited for our meetings, please send an email to Wim-Paul Breugem at w.p.breugem@tudelft.nl with subject “jmbc turbulence mailing list”. Past meetings of our contactgroup were held in Groningen (April 2012), Eindhoven (April 2011) and Delft (June 2010). The next meeting will presumably be held in May 2013. More information on our meetings is available at www.pe.tudelft.nl/~wim/jmbc_turb_contactgroup

Contactgroup “Experimental Techniques”

The Contact Group Experimental Techniques forms a platform where experiments and experimental techniques can be discussed and evaluated. The main function of the contact group is to organize meetings in which the practice of experimenting can be discussed. 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 next course will be held 2-6 June 2014 at the University of Twente.

Contactgroup "Biological Fluid Mechanics"

More and more research is conducted at the border 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 flight). However, all deal with the interaction between fluids and a complex, changing geometry. One of the main challenges is to bridge the gaps between physics (esp. fluid mechanics) and medical and health sciences. To stimulate this relatively young field of research and bring together researchers, a new contact group was started in 2006. While the contactgroup is formally a part of the J.M. Burgerscentrum, the participation from researchers from non-affiliated universities, medical centers and institutes is encouraged. Recent activities include mini-symposia in Wageningen (Experimental Zoology Group) and Eindhoven (in combination with the JMBC course on Bio-fluid Mechanics).

The Bio-Fluid Mechanics course (March 2009: about 40 participants) was jointly supported by the JM Burgers Centre and the ERCOFTAC organization by advertising the course amongst their members, via the website and by some financial means.Topics included: a recap of basics of fluid mechanics, external flows (swimming and flying, interaction of plankton and turbulence), internal flows (microcirculation, hemodynamics in large arteries, flow in flexible tubes, respiratory system, etc.). Examples of relevant experimental techniques, as well as simulation techniques were discussed.

Finally, members of the contactgroup are active in the definition of a new FOM-program in the bio-fluid mechanics field. A new course is planned in the autumn of 2013.

Prof.dr.ir. F van de Vosse
Eindhoven University of Technology

Dr.ir. C Poelma
Delft University of Technology

Prof.dr. F Mugele
University of Twente

Prof.dr. J den Toonder
Philips Research
Eindhoven University of Technology

Prof.dr.ir. J Westerweel
Delft University of Technology

Prof.dr. JM Wallace
University of Maryland

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. Topics of interest include wetting and capillarity-driven flows, two-phase flow, drop generation, emulsification, contact line dynamics, flow visualization and measurement techniques. During the 2012 spring meeting of the contact group on May 31st in Eindhoven, 10 PhD students presented their recent progress and discussed their results with colleagues from other groups of the Tu/e, TUD, and UT. The next meeting is planned for late spring in Delft and will be announced to all members of the contact group in due time. Students and researchers who are interested in the activities of the group are invited to contact the organizers of the contact group and have their name added to the mailing list. On April 15-19, members of the contact group organize the JMBC course "Capillarity-driven flows in microfluidics", which will take place in De Lutte, close to Twente. Participants are invited to apply for the course as usual via the JMBC website.

Burgers Program for Fluid Dynamics at the University of Maryland

Inspired by the intellectual heritage of Johannes M. Burgers, who had a second career at the University of Maryland (1955 - 1981) after his retirement at the Technical University of Delft as Professor of Aero and Hydrodynamics, 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) in The Netherlands. 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 for Fluid Dynamics was celebrated with an inaugural symposium at the University of Maryland in November 2004. Gijs Ooms, Scientific Director of the JMBC gave a lecture on the life and legacy Burgers on this occasion. At the second Burgers Symposium in 2005, James Wallace gave a talk celebrating the contributions of Frans T. M. Nieuwstadt, recently deceased Director of the Laboratory for Aero and Hydrodynamics of the Technical University of Delft and a founder of the JMBC.

The interdisciplinary Burgers Program encompasses over 70 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/.

Burgers Visiting Faculty and Student Exchanges - In 2003 the Burgers Program created a Burgers Visiting Professorship in fluid dynamics. We have been able to attract a number of distinguished professors from universities abroad to spend up to a year at the University of Maryland working with our faculty and their graduate students and post-doctoral fellows. The first (2004-2005) Burgers Visiting Professor was Bruno Eckhardt of the Phillips Universität in Marburg. In 2005-2006 our Burgers Associate Professors were Dr. Sasa Kenjeres of TU Delft and Dr. Serge Simoëns of the Ecole Centrale de Lyon. Since then, our Burgers Visiting Professors have been Jerry Westerweel of TU Delft for three months in 2007, Willem van de Water of the Eindhoven University of Technology for 2 ½ months in 2008, W. van Saarloos of Leiden University for two weeks, also in 2008, W. J. Briels of Twente University for two months in 2010, Marie Farge of the Ecole Normale Supérieure, Paris for one month in 2011, Henk Dijkstra of Utrecht University for two months in 2012 and Ulrike Feudel of the University of Oldenburg for six months in 2013. In addition, quite a number of graduate students from JMBC have had visits of several months at Maryland with our faculty. Faculty from the University of Maryland are encouraged to spend a sabbatical at one of the Dutch Universities associated with JMBC. Kenneth Kiger, who was a speaker at the Burgersdag 2006, earlier had spent a sabbatical year with the JMBC research group in Delft.

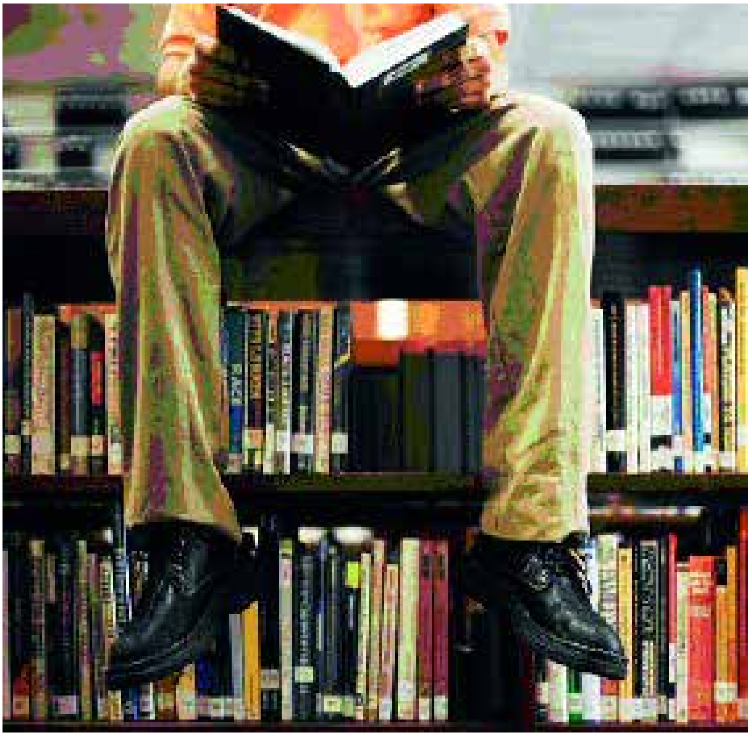
Burgers Lectureship - We have also initiated an annual Burgers Lecture which is given by a distinguished visitor who comes to the campus for several days or even weeks in November. This is always the keynote lecture at our annual Burgers Symposium, which takes place in the week before the annual Division of Fluid Dynamics meeting of the American Physical Society. In 2003 Frans Nieuwstadt, was our lecturer. Since then, Bruno Eckhardt , Charles Meneveau of Johns Hopkins University, Gijs Ooms, Detlef Lohse of Twente University, Wim van Saarloos, Kees Vuik of TU Delft, Prof. Wim Briels, Marie Farge and Henk Dijkstra have been our Burgers Lecturers.

Annual Graduate Student/Post-Doctoral Fellow Showcase Symposium with Johns Hopkins University - In collaboration with the Center for Applied and Environmental Fluid Mechanics of Johns Hopkins University, the Burgers Program has put on an annual graduate student/post-doctoral fellow showcase symposium in the spring of each year, beginning in April, 2005. The venue for the symposium alternates between sites each year. After a keynote address by a faculty member from the visiting institution, students and research associates give short presentations on their research. Members of the fluid dynamics community from around the region are invited to attend the symposium with the hope that the presentations will interest these attendees and create employment opportunities for the presenters. Beginning in 2012, faculty, graduate students and post-doctoral fellows at the George Washington University in Washington, D.C. have also participated in the symposium.

Tutorial School on Fluid Dynamics - This initiative was inaugurated in late May 2010, with plans to try to offer it every year. The level of instructions for these schools is aimed somewhat beyond that of a first graduate course in the subject area. The subject of the first School was Turbulence. Almost 40 graduate student and post-doc participants from the U.S. and other countries, including nine from JMBC, attended. Subsequently, another very successful Tutorial School on Granular Flows - From Simulations to Astrophysical Applications was held in June of 2011. In June 2013 a Tutorial School on Data Assimilation in Geoscience will be held and one on Regional Climate is planned for the summer of 2014.

Fluid Dynamics Reviews seminars - This seminar series, which has continued for almost fifty years at the University of Maryland, has been incorporated into the Burgers Program. It is supported by the Minta Martin research fund. The format allows for faculty and their students and post-docs from the Burgers Program as well as for visitors to give presentations five or six times per semester. The seminar series has sponsored the visits of a long list of very distinguished speakers over the many years it has been a part of the campus' intellectual life.

HIGHLIGHTS



Thermo-chemical heat storage in salt hydrates

OCG Adan, L Pel, PAJ Donkers, TU/e

Effective integration and full use of the potential yield of renewable energy is required to realize an energy neutral society. A compact solution for thermal energy storage in the existing building stock is a key priority to make such a step. Potential solutions are thermo chemical materials, with very high energy densities, hence giving the possibility for small “heat batteries”. The seasonal heat needed for one household could be stored in not more than several cubic meters of such high energy density materials. One option for storing heat is the hydration/dehydration reaction of salt crystals[1]. Such reactions are reversible and hence, like a battery, the process can be repeated. Moreover the process can be fine tuned on the basis of the vapor pressure of the hydrating solvent. As the reaction only takes place by a hydrating solvent these batteries could store heat almost loss-free, unlike other systems in use nowadays (like phase change materials or water baskets[2]). A schematic diagram of a heat battery is given in figure 1.

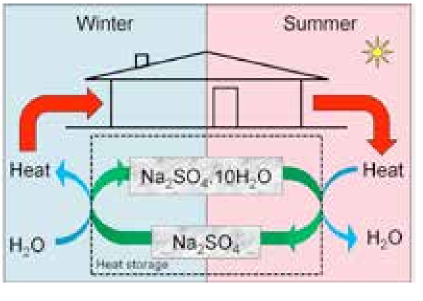
Like any electric battery, the reversibility of the heat exchange process in such a heat battery by hydration declines in time, and at this moment the degradation is not understood well[3]. Nowadays solutions show an additional disadvantage i.e. the slow hydration/dehydration rate of crystals[4]. Heat is released to slow in response to the demand. Here we have chosen to look at a well known salt: sodium sulfate (Na2SO4). The anhydrous salt is called Thenardite (Na2SO4 (s)) where the hydrated salt with 10 water molecules Na2SO4.10H2O is called Mirabilite.

In this study we are focusing on two main questions:

- How is water transport through the crystal in the hydration/dehydration process?
- What are the changes in crystal structure in relation to the decline of the storage process?

We use specially adapted Nuclear Magnetic Resonance (NMR) to measure hydrogen distributions in salt crystals during de-/hydration experiments. As an example figure 2 shows the dehydration process as measured for a large single crystal. In this case, the sample is isolated and water can only be exchanged at the top of the crystal, where dry air with a relative humidity of 0% is flowing. As can be seen from the start, the dehydration process is almost homogeneous throughout the sample, which is about 30 mm in length in this case. This homogeneous drying indicates extremely fast water redistribution throughout the crystal. In this case the process, and hence the heat released, is limited by the boundary conditions.

In order to get a better understanding of the dehydration process throughout the crystal we performed additional Rontgen diffraction (XRD) experiments in order to study the crystal structure changes during dehydration.

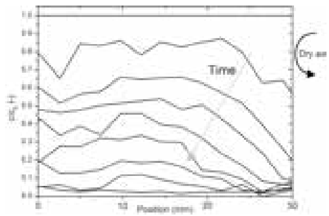


A schematic diagram of a heat battery for storing energy by the cyclic hydration/dehydration process using Na2SO4. In the summer the heat is stored by dehydrating the salts, whereas in the winter the heat is released again in a controlled way by hydrating the salt.

As an example the signal contribution of the Mirabilite phase is plotted against the Thenardite phase as a function of the dehydration process (figure 3).

An almost linear relation is found, i.e., the transition of Mirabilite into Thenardite is one-to-one. Complementary information of the process is found using another technique, Raman spectroscopy, which gives information on the vibration of the sulphate in a crystal structure. When the results of Raman measurements are plotted in the same figure 3, a different picture emerges. The Raman measurements show that the Mirabilite phase disappears first and, subsequently, the Thenardite phase comes up slowly. Obviously, at intermolecular scale the transition is direct (XRD), but at intramolecular scale the transition occurs through an intermediate state (Raman). Most probably during the Mirabilite-Thenardite transition the vibrations are affected as related to the degree of hydration. This may introduce a route to understand the decline in reversibility in storage systems. Infrared spectroscopy is expected to give complementary information on this process.

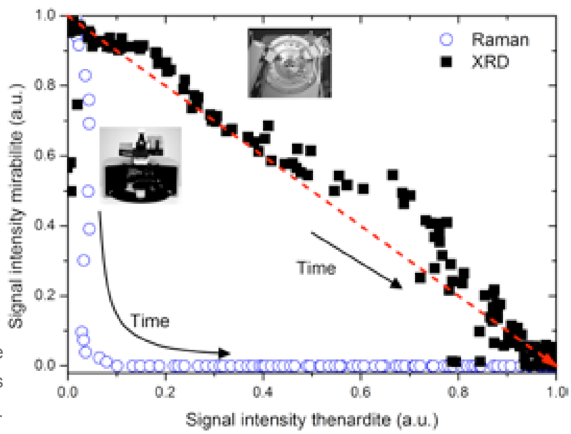
Our goal is to combine such information to understand de-/hydration process in relation to water transport and crystal structure changes. This lays a foundation for choosing optimum salt crystal sizes for a heat battery. In the next steps, our dehydration studies will also address salt complexes with different types of water inside [5]. This will outline our path toward the next generation of compact and stable, long lasting heat batteries.



The dehydration of a single crystal Na2SO4.10H2O as measured by NMR. On the horizontal axis is the position plotted, on the vertical axis the water content relative to its initial content. The time between two profiles is 6 hours and the profiles are given for 48 hours. Air with a relative humidity of 0% at 25°C is blown over the top of sample which is located at 30 mm.

References

1. M. Goldstein, "Some physical chemical aspects of heat storage," in New Sources of Energy, 1958, pp. 411–417.
2. K. E. N'Tsoukpoe, H. Liu, N. Le Pierrès, and L. Luo, "A review on long-term sorption solar energy storage," Renewable and Sustainable Energy Reviews, vol. 13, no. 9, pp. 2385–2396, Dec. 2009.
3. G. Ervin, "Solar heat storage using chemical reactions," Journal of Solid State Chemistry, vol. 22, no. 1, pp. 51–61, Sep. 1977..
4. V. M. van Essen, H. A. Zondag, J. C. Gores, L. P. J. Bleijendaal, M. Bakker, R. Schuitema, W. G. J. van Helden, Z. He, and C. C. M. Rindt, "Characterization of MgSO4 Hydrate for Thermochemical Seasonal Heat Storage," Journal of Solar Energy Engineering, vol. 131, no. 4, p. 041014, 2009.
5. G. G. Malenkov, "Geometry of structures consisting of water molecules in hydrated crystals," Journal of structural chemistry, vol. 3, no. 2, pp. 206–226, 1962.



The signal intensity of Mirabilite plotted against the signal intensity of Thenardite during a dehydration as measured by XRD and Raman spectroscopy.

Single bubble rising through a neutrally buoyant liquid-particle suspension

N Hooshyar[a], JR van Ommen[a], PJ Hamersma[a], S Sundaresan[b], RF Mudde[a]
(a) Dept. Chem. Eng., TU Delft, (b) JMBC Professor, Princeton Univ., USA

Gas-liquid-solid flow can be found in biotechnology, in food processing, in oil and gas flow lines. We even see it in boiling mud pools e.g., in Yellowstone National Park. Whereas bubbles flowing in clear liquid are extensively researched, relatively little attention is paid to the motion of bubbles through a liquid containing small, solid particles. In chemical engineering literature, gas-liquid-solid flows are studied in the context of three-phase slurry reactors, where usually the gas contains one of the reactants, the liquid contains another and the solid is the catalyst. Several correlations for the bubble rise velocity in suspensions can be found in the literature [1]. However, the precise nature of the interaction between the rising bubble and the solids and liquid has received limited attention.

We reduce the complexity of the system by making the solids neutrally buoyant to the liquid. This removes the slip velocity of the solids with respect to the liquid from the problem, and even more importantly, it makes it possible to experiment with a homogeneous solids concentration as gravitational settling will not induce differences in the local solids concentration. We studied four different sizes of polystyrene particles with diameters of 78μm, 587μm, 2.0mm and 4.0mm, respectively. The liquid is a mixture of water and glycerol carefully tuned to have the same density as the particles (1054kg/m3).

The Stokes number, $St = \frac{\tau_p}{\tau_b} = \frac{\rho_p d_p^2 / 18\mu_{liq}}{d_{bub} / v_{bub}}$, for these particles are 0.016, 0.88, 10.1 and 41.2. Thus, the smallest particles will follow the liquid flow like tracers, whereas the bigger ones have enough inertia to actually collide with the passing bubble (see Fig.1). We inject a single bubble of volume equivalent diameter of 3.0mm in the suspension and measure its average rise velocity. For this we used a 4-point optical probe [2] and the fast X-ray scanner of our group [3] (see Fig.2). We varied the solids volume fraction from 0% to 20%.

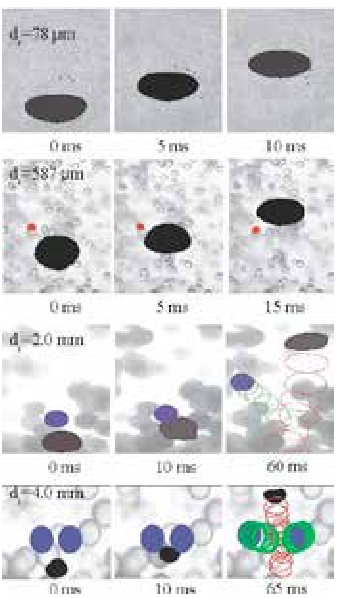


Fig.1. Bubble rising through a neutrally buoyant suspension: small particles with St<<1 (top) behave different from big ones with St>>1 (bottom).

The experiments confirm our hypothesis, that the bubble does not literally collide with the particles when the Stokes number is smaller than 1. In those cases, the bubble perceives the suspension as a pseudo-clear liquid. The suspended solids merely increase the apparent viscosity of the suspension. The bubble rise velocity can be understood by using this viscosity (which is a function of the solids volume fraction) for which several relations can be found.

For suspensions of particles with St>>1 the situation is rather different. The bubble clearly collides with the particles. In this process the bubble gets deformed (see photos in Fig.3) and some of its kinetic energy is converted to surface energy which is partially passed on to the solid particle, which pushed out of the way. In this process the bubble slows down and starts to accelerate again after the collision until the next collision. The resulting average rise velocity can be estimated based on a mean free path approach: the bubble loses a fraction of its energy in a collision and accelerates again over a distance of, on average, the mean free path. Schematically this is shown in the bottom graph of the third figure. Using these ideas, we could predict the average bubble rise velocity as can be seen in the top part of Fig. 3.

References

1. Luo, X. et al. Chem. Eng. Sci, 52, 3693 (1997).
2. Mudde, R.F. and Saito, T., J. Fluid Mech., 693, 201, 2012.
3. Mudde, R.F., Powder Technol., 199, 55, 2010.

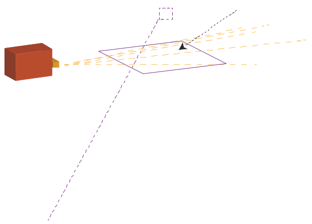
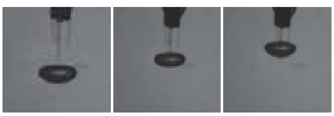


Fig.2. Experimental setup. X-ray attenuation for measuring time of flight of a bubble and a 4-point probe for measurement of bubble velocity and size.



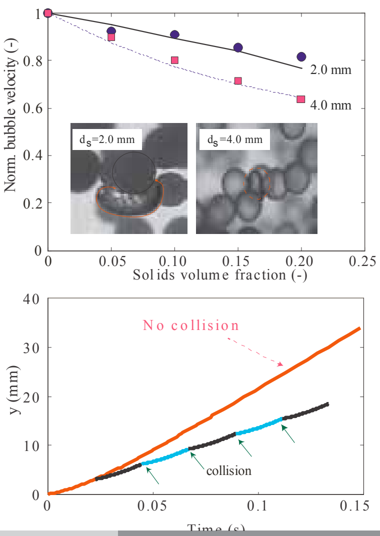


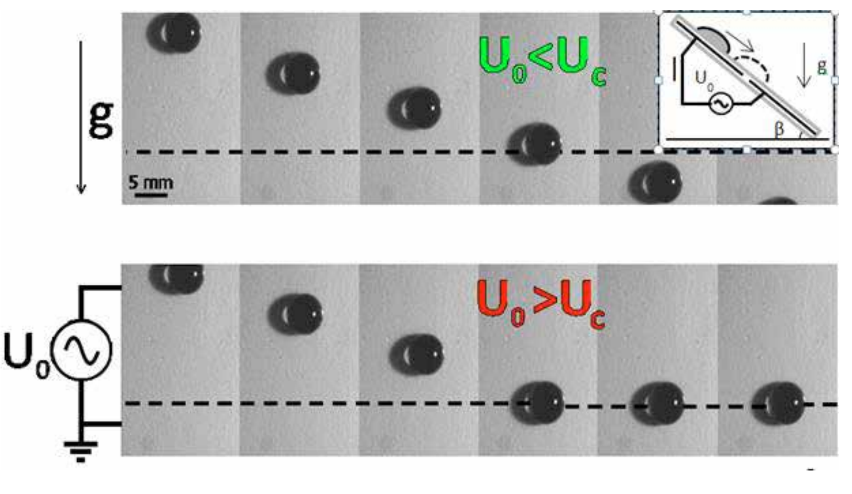
Fig.3. Top: average bubble velocity for the 2.0mm and 4.0mm suspensions. The dashed line represents the mean free path model. In the photos, the red line shows the bubble colliding with the particles.
Bottom: graphical representation of the bubble vertical position. The red line is that of a bubble in a clear liquid, the blue/black one is for a bubble that collides after a mean free path of traveling.

To go or not to go : trapping and release of sessile drops at tunable wetting defects

DJCM ‘t Mannetje, SJ Otten, R Lagraauw, AM Pit, D van den Ende, and F Mugele, UT

Drops moving across solid surfaces are a ubiquitous sight. We encounter them as rain drops on windows, windshields, and aircraft wings, in microfluidic devices, in cleaning, coating, and printing technology, and also in immersion lithography systems in the semiconductor industry. Frequently, it is desirable to remove drops from the surfaces by exposing to some driving force such as gravity, centrifugal forces, and drag forces from an ambient phase. Yet, wetting defects such as topographic heterogeneity and chemical heterogeneity can trap the drops and prevent them from being removed. The goal of this project is to understand the balance of forces that governs the attachment and the release of drops from wetting defects. The work is part of the FOM-IPP Contact Line Dynamics in collaboration with ASML and Océ.

We consider the generic situation of drops sliding down a plane of variable inclination angle. The surface consists of a flat polymer film with two submerged electrodes separated by a small gap. This electrode configuration creates a wetting defect for drop as it slides downhill and passes the gap between the electrodes. The resulting potential well is approximately parabolic as long as the drop overlaps with both electrodes. Its depth scales with the square of the applied voltage U, as usual in electrowetting. As drops slide down the inclined plane they either get trapped or pass the defect, depending or whether not the applied voltage exceeds a certain critical voltage Uc (see Fig. 1). Uc depends on the inclination angle, the drop size, and the viscosity. For highly viscous liquids, the drop motion is overdamped: the momentum equilibrates on a length scale small compared to the size (i.e. the width of the potential well).

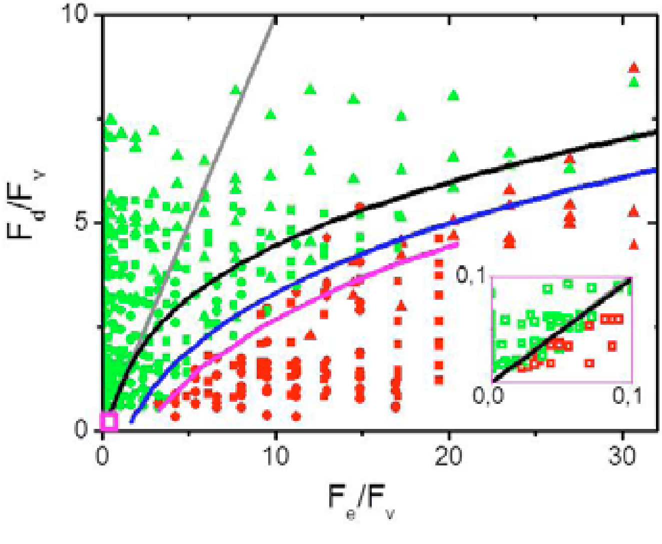


Drop sliding down an inclined plane past a wetting defect of electrically tunable strength.

In this case, drop trapping depends exclusively on whether or not the trapping voltage is strong enough to create a local minimum in the energy landscape experienced by the drop. For low viscosity liquids, however, the momentum does not equilibrate while the drop passes the trap. In this case, inertia can help the drop pass the wetting defect even if there is a local energy minimum. Upon normalizing both the gravitational driving force and the electrical trapping force by a characteristic viscous damping force, all experimental data can be summarized in a single trapping diagram as shown in Fig. 2. The straight line represents boundary between trapping and non-trapping in the purely viscous regime, the curved line represents the full model including inertia, which turns out to be crucial for aqueous drops of millimetric size. (The shifted lines take into account a specific reduction of the intrinsic contact angle due to AC electrowetting within the trap.)

Additional experiments suggest that the electrically controlled traps discussed here can be used as very flexible tools to control the motion of drops in microfluidic two-phase flows.

Trapping diagram. Normalized driving force vs. trapping force. Green symbols: passing drops. Red symbols: trapped drops. Inset: highly viscous glycerol drops.



C Vuik (TUD) and CM Klaij (MARIN)

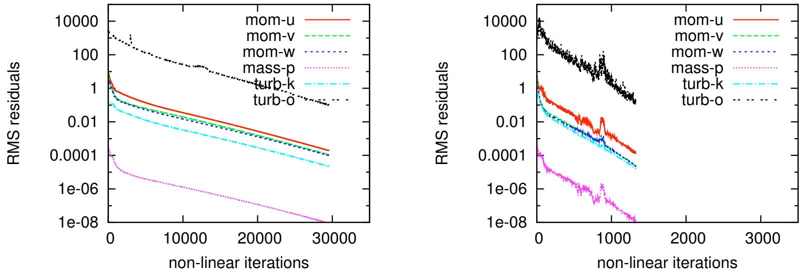
There is a big difference with respect to the design of a ship and that of an airplane. To design a new type of airplane the industry takes 4-6 years to design it, do a number of test flights and adapt the design if necessary. After that 500-5000 planes are built using this design. In contrast to that every ship is designed from the start. Also if there is a series of ships, most of the design is done again due to adaptations in the requirements. This implies that the design of a ship should be fast (a couple of months).

At this moment the maritime industry is booming in The Netherlands especially for special ships as there are: dredging, heavy lift, super yachts, etc. After a ship is designed, it is necessary to check if the properties of the new ship are good. Some of the properties can be checked by model experiments, but nowadays most of the work is done by Computational Flow Dynamics. MARIN (Maritime Research Institute Netherlands) is one of the leading institutes in the world, that is able to do the required computations and simulations for the design of a new ship. At this moment, it can take more than one month to do all the required computations. The aim is to reduce this in the near future to one week. In this paper we describe how one part of the simulations has been accelerated with more than a factor 5 in wall clock time.

In order to do the Computational Flow Dynamics for a ship, the Reynolds averaged Navier Stokes (RaNS) equations are used. They are discretized by a finite volume method with a colocated placement of the unknowns on an unstructured grid. This leads to a huge non-linear system of algebraic equations. The method of choice to solve this systems is the SIMPLE (Semi Implicit Pressure Linked Equations) iterative method. It is important to choose the correct under-relaxation parameters, but then one obtains a robust (but slowly converging) solver.

At the TU Delft, we have a lot of experience with Krylov methods, which can be used to solve linear systems. We also develop robust and efficient preconditioners to solve incompressible Navier Stokes equations. One of these preconditioned methods is the GCR-SIMPLER method used to solve the flow in a glass furnace [1]. In 2010, we have the idea to use the SIMPLE solver of MARIN in combination with a Krylov method to obtain an acceleration of the solver. To do this, a number of adaptations has to be made. One example is the inclusion of the stabilization term in a correct way.

grid	CPU cores	SIMPLE		KRYLOV-SIMPLER	
		# its	Wall clock	# its	Wall clock
2.7m	64	29 578	16h 37mn	1330	3h 05mn



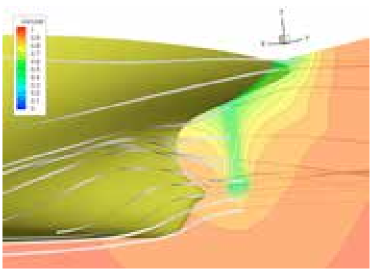
(a) SIMPLE (b) KRYLOV-SIMPLER

Furthermore, in the traditional solver only one iteration is done for the linear velocity pressure system and then the next non-linear iteration is done. To use the Krylov SIMPLER method, we do a number (5-10) iterations for the velocity pressure system, before we go to the next non-linear iteration (this resembles a Newton-Krylov method).

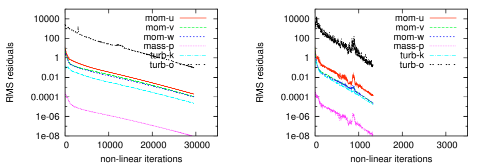
The results are very good for most problems. The figures show the results for a full-scale tanker. Note that this is a real challenging problem, where the Reynolds number is 2 10^9 and the maximum aspect ratio of the nite volumes is 930 000. However, the Krylov SIMPLER method does a really good job. The number of non-linear iterations is down by a factor 20, whereas the wall-clock time is reduced by a factor 5. For more examples we refer to our paper [2].

References

1. C. Vuik and A. Saghir and G.P. Boerstoel The Krylov accelerated SIMPLE(R) method for flow problems in industrial furnaces International Journal for Numerical Methods in fluids, 33 pp. 1027-1040, 2000.
2. C.M. Klaij and C. Vuik SIMPLE-type preconditioners for cell-centered, colocated nite volume discretization of incompressible Reynolds-averaged Navier-Stokes equations International Journal for Numerical Methods in Fluids, 71, pp. 830-849, 2013.



grid	CPU cores	SIMPLE		KRYLOV-SIMPLER	
		# its	Wall clock	# its	Wall clock
2.7m	64	29 578	16h 37mn	1330	3h 05mn



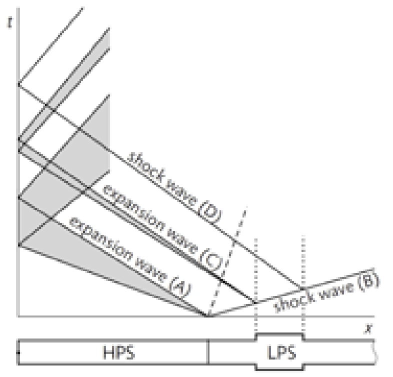
(a) SIMPLE (b) KRYLOV-SIMPLER

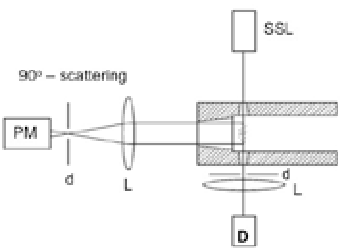
Diffusive micro-droplet growth measured by light scattering and extinction

M Fransen (TU/e), E Sachteleben (TU/e), J Hruby (Thermomechanics Institute, Prague) and D Smeulders (TU/e)

Condensation of water is important for cloud formation in meteorological and climate models. Condensation of carbondioxide is important in natural gas cleaning and CO2 sequestration. This study aims to experimentally investigate micro-droplet growth of water and carbondioxide in an expansion wave tube. A horizontal expansion wave tube was installed which can be used for the optical detection of microscopically small condensate droplets (see Figure 1). A 532 nm laser line-of-sight attenuation (LOSA) measurement is combined with 90 degrees constant angle Mie scattering (CAMS) to measure the concentration and growth of a cloud of condensate droplets over time. The condensation process is triggered by a rapid decrease of pressure and temperature in the setup where typical temperatures of 240 K are reached. This process is controlled by the pressure-time profile which can be selected to obtain a monodisperse cloud of droplets of identical size [1]. The measured CAMS signal displays a characteristic pattern of peaks and troughs that can be matched with the theoretical signal (see Figure 2). Background scattering from the walls must be considered. We find that for larger droplets also nonlinear multiple scattering effects become important. This latter effect can be accounted for by the introduction of a higher-order term that depends on the Lambert-Beer extinction of the laser light [2,3].

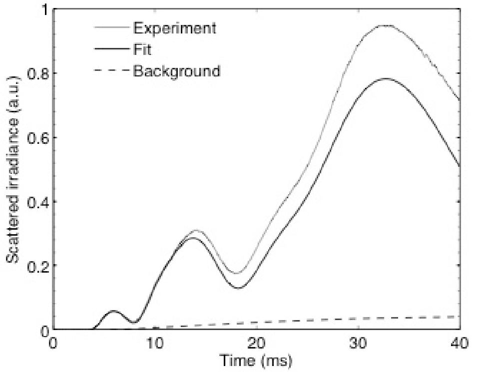
Schematics of the expansion wave tube with high and low-pressure sections (HPS and LPS) and wave pattern (left), and end section of the HPS with laser optics (right). Condensate droplets are formed by pressure decrease in the HPS at x=0. Pressure decrease is initiated by rupture of the diaphragm that separates the HPS from the LPS. This rupture generates expansion wave A. The local widening in the LPS is to deepen and end the pressure decrease (waves C and D, respectively), causing a monodisperse cloud of droplets [1]. Photodiode D and photomultiplier PM detect solid state laser (SSL) light extinction and scattering, respectively.

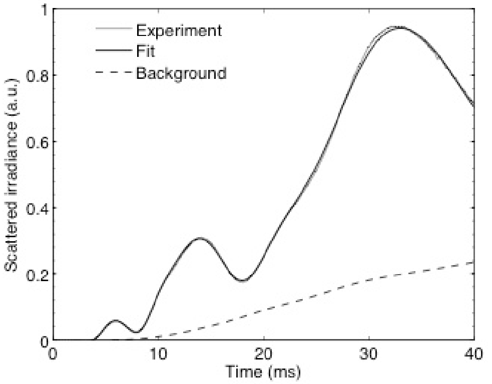




References

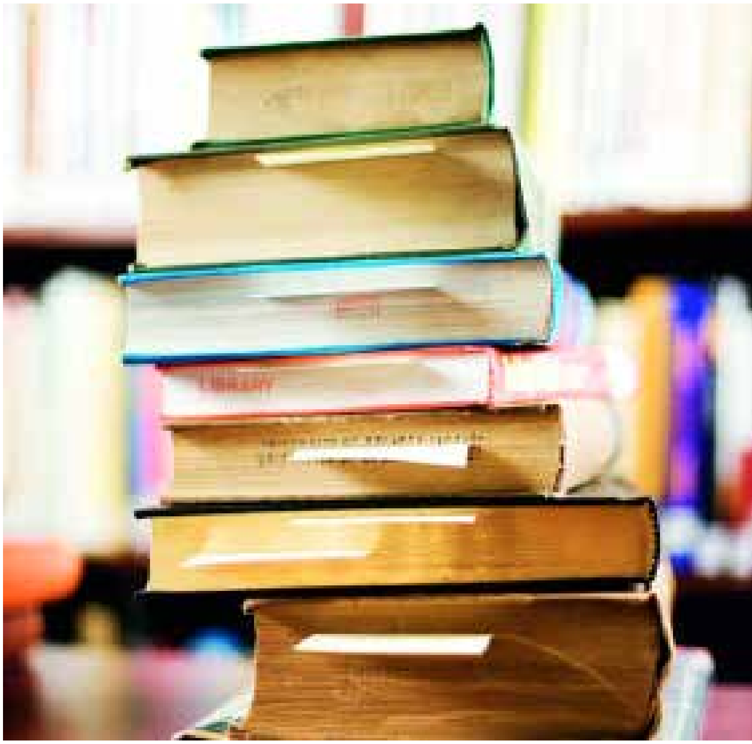
1. Looijmans, K., and van Dongen, M. Exp. Fluids 23, 54-63 (1997).
2. Fransen, M., Sachteleben, E.,Hruby, J., Smeulders, D. Pulse-expansion wave tube for measuring nucleation and droplet growth. Proceedings of the 20th Int. Shock Interaction Symp., Stockholm 20-24 August 2012, pp. 27-30.
3. Fransen, M.A.L.J., Hruby, J., Smeulders, D.M.J. Nucleation and droplet growth measured by a pulse-expansion wave tube. European Aerosol Conference Handbook, Granada, 2-7 September 2012, p116.





CAMS intensity plots. Droplet growth over time causes a characteristic Mie diffraction pattern. The discrepancy between experiment and theory (top) disappears if the full background scattering is taken into account (bottom). Lower droplet size detection limit is on the order of 0.1 µm.

RESEARCH



Research

Introduction

The research programme of the JMBC has been ordered in research themes and focal points. 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

Description of the research themes

1. Complex dynamics of fluids

Fluid flows in the environment or in industrial applications are almost always characterised by some form of complexity. Frequently it is this complexity that makes the flow an interesting topic of research. Below we will sketch several examples of such flows and flow phenomena which form research topics carried out in the various groups of the J.M. Burgerscentrum.

The first form of complex dynamics which comes to mind is turbulence in contrast to a laminar flow. Here complexity appears in the form of strong non-linearity. Due to its chaotic behaviour turbulence can be considered as the archetype of a complex flow, and - being far from solved - turbulence will remain a strong focal point of research in the coming period. Turbulence research traditionally addresses the following questions:

- what are the physical processes and interactions governing turbulence,
- how can they be quantified and described mathematically,
- how to predict turbulence and turbulent flow for particular configurations, and
- how to control and manipulate turbulence?

Future research in this field in particular will focus on laminar-to-turbulent and reverse transition, effects of thermal buoyancy, unsteadiness, compressibility and rotation, and on the interaction with chemical reactions. The rol of turbulence in energy conversion processes and equipment are regarded as an intriguing field of applications.

Complexity may also appear in the form of a combined flow of various phases. When these phases are immiscible, phenomena such as free surface flows occur. These may appear in the form of various wave phenomena, for instance on an unobstructed water surface, but also in a confined geometry of a pipe.

Another type of such flow of immiscible phases is when one of the phases is distributed in the form of small particles, bubbles or droplets in the other continuous phase. Various combinations of phases may be selected and each has its own particular problems. This class of flows, generally denoted as dispersed multi-phase flow, at the moment forms a strong focal point of research within the JMBC. The combination of phases that are miscible leads to other interesting problems such as mixing, and - depending on the fluids that take part in the mixing - chemical reactions or combustion.

Finally, complexity of the flow can also appear through its boundary conditions. For instance the flow geometry can strongly influence the flow characteristics by means of straining, shearing and distortion. An example is the wake behind a body in a shearing or straining flow.

Furthermore, the exact formulation of boundary conditions can have a consequence for the type of flow characteristics that appear.

An example is the free convection above a flat surface with a variable the conductivity. Geometry constraints on the flow are also dominant also when one considers a flow in 2D versus3D. Here one should take as an example the quite different characteristics of 2D turbulence versus 3D-turbulence.

An increasingly important JMBC research activity within Theme 1 is aero-acoustics, aimed at the identification and quantification of acoustic sound sources in internal and external flows. Such sources can be related to unsteady vortex shedding, turbulence, combustion and flow-structure interaction. In general there is a strongly non-linear mutual interaction between sound source and acoustic field. The applications and technical implications show a great diversity. The JMBC is actively involved in vortex sounds in ducts, musical instruments (like the flute and the organ pipe), human speech, acoustics in burner stabilized flames, sound generation by turbulent flames, with much attention to analytical and numerical modelling of these flows.

The flow cases mentioned above, which are by no means an exhaustive list of complex fluid flow phenomena, form research topics in the various groups in the J.M. Burgers Centre.

The tools to carry out this research are primarily numerical and experimental. The numerical techniques used to compute flow phenomena are direct and large eddy numerical simulation, turbulence modelling and computational fluid dynamics. The experimental techniques used nowadays are mostly based on various forms of laser diagnostics (e.g. like PIV and PTV for flow measurements and CARS, LIF and Cavity Ring-Down Spectroscopy for temperatures and concentrations). Experiments, simulations and analytical theories in the field of fluid flow analysis complement each other - perhaps more than in other branches of physics. Future research will inevitably make use and take advantage of combined techniques and their complementing roles. Both the research topics themselves and the research techniques to carry out these investigations, form the basis of a strong collaboration within the J.M. Burgerscentrum.

2. Complex structures of fluids

Research in this Theme deals with complex structures of flow, formed in the presence of particles, drops, or bubbles, i.e., two- or even multi-phase flow. Two-phase flow is of paramount importance in contemporary science and technology.

One can readily cite a multitude of examples: the production and transport of oil (where bubbles are purposely injected to help lift thick heavy oil to the surface, or arise due to the release of dissolved gases), energy generation (where boiling is the key process in producing the steam to drive turbines), the chemical industry (where gas-liquid reactors rely on bubbles to increase the contact area between the phases), the oceans (where breaking-wave generated bubbles are important sinks for atmospheric CO2), sedimentation (where sinking sand particles determine the structure oF our coasts), food-industry, and many others.

The challenge in single-phase flow is to understand the complicated dynamics which is generated by the Navier-Stokes equation. In two-phase flow, even the underlying dynamical equations are often not known. E.g., it is not understood why bubbles repel each other when they are close to each other.

But even when the microscopic interactions are known, it is often not clear how the macroscopic structure evolves from this microscopic interaction and the response to external forces.

In many cases instabilities are involved in the macroscopic structure formation process. Very complex self-organising patterns can evolve out of these instabilities. An important example is cluster formation in sedimentating particles and coherent structures in bubble columns and fluidised beds.

Related topics are flow-controlled nucleation and droplet growth processes in high-pressure natural gas, which have important technical applications in the natural gas industry. Different JMBC groups are involved in the design of new types of condensate separators and in the numerical description of swirling supersonic two-phase flows, while a dedicated facility has been developed in order to investigate these condensation processes in a well-defined way experimentally.

How to theoretically describe such a complex system? Two types of approaches have been described in literature: In the first type of approach, the particles/bubbles/drops are treated essentially as points, while no attempt is made to simulate their detailed response to the liquid dynamics.

The advantage of this approach is that many particles/bubbles/drops can be treated, but the price to be paid is a lot of ad-hoc modelling. Fluid dynamical simulations in which the particles/bubbles/drops are modelled through averaged equations also belong to this first type of approach. In the second type of approach the detailed interactions of the particles/bubbles/drops with the flow is simulated, paying the price that - at present - the surrounding flow can not really be turbulent and that only “a few” objects can be treated, in particular, when the interfaces are allowed to deform, i.e., for free boundary problems (drops and bubbles).

One of the main objectives for the research in two-phase flow must be to bridge the gap between these two types of approaches and to carry out a detailed investigation of the interaction between one or a few particles/bubbles/ drops and a nontrivial flow field. Another objective must be to better understand the macroscopic structure formation process out of the microscopic interactions, and thus the instabilities in two-phase flow. It is evident that these objectives can only be achieved through a joint experimental, theoretical, and numerical approach.

On the experimental side, the challenge has always been to monitor and document as much information on the dynamics of the flow field as possible. Through the huge advances in bothdigital imaging techniques and information technology (see Research Theme 3), the field is now flourishing, and the research on two-phase flow will strongly benefit from this. The same is to be expected from the advances with numerical techniques (see Research Theme 4), as brute force numerics will not be sufficient to address the problem of structure formation in two-phase flow. New algorithms and techniques are required and moving toward parallel computing will be essential.

3. Mathematical and computational methods for fluid flow analysis

Advanced mathematical and computational techniques have become indispensible instruments for the description and understanding of complicated flow phenomena. This approach to fluid mechanics has evolved into a full-fledged counterpart to the experimental approach and provides new insight in complex flow physics, in for instance turbulence, combustion, multi-phase and rheological flows.

The use of computational flow models is supported with analytical techniques, which provide deeper insight in canonical flow problems, and strongly interacts with advanced experimental techniques, which are capable of measuring and visualizing complex three-dimensional unsteady flow fields. These techniques require advanced post-processing of the flow field data to understand the flow dynamics and have developed into a research subject in itself. Here tools from non-linear dynamical systems theory can be useful, as well as the decomposition of flow data through POD and wavelet analysis.

The rapid increase in computational power has significantly stimulated the use of computational techniques in flow analysis, but the development of better algorithms has been the most important source for improved numerical techniques for flow analysis.

Many flows are, however, simply too complex for computational techniques and flow modelling remains an essential issue. Compromises have to be found between the inaccuracies in flow modelling and computational constraints. In areas such as turbulent flow simulation much progress has been made through refined modelling via Large-Eddy Simulation (LES) and Direct Numerical Simulation (DNS). There is also an interest for stochastic methods, such as the use of the Langevin equation for the velocity. In the other areas the same trends have become feasible, e.g. PDF modelling in combustion and Brownian Dynamics in rheology.

It can be foreseen that the improvements in numerical algorithms and the growing computational power will open up new applications of flow analysis in other disciplines, such as chemistry, biomedicine and structural mechanics, and will continue to grow in importance. This will be stimulated by the development of new numerical techniques which can efficiently capture flow structures with large differences in length and time scales, the continuous increase in computing power, and by exploiting computational fluid dynamics in multi-physics applications.

Review of progress in research projects

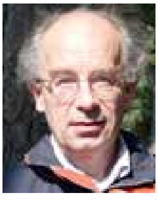
As agreed by the project leaders of the JMBC only doctoral thesis, (contributions to) books, and publications in scientific journals and in proceedings of conferences with a referee system, are given in the output for each project. Only 2009 publications are taken up in the project descriptions.

An important output for various JMBC-groups is in the form of special reports for industries, technological institutes, etc. Those reports are not mentioned in the output of the projects. For more information, please contact the relevant project leaders. A list of all the projects can be found at the end of this book.

Fluid Mechanics

Prof.dr.ir. J Westerweel

Prof.dr.ir. BJ Boersma



Prof.dr.DJEM Roekaerts

Prof.dr.ir. RAWM Henkes

Prof.dr. JCR Hunt

Prof.dr.ir. G Ooms

Within the Department Process & Energy the chair of energy technology of prof. BJ Boersma, the chair of fluid mechanics of prof. J. Westerweel, and the chair of turbulent reacting flows of prof.dr. DJEM Roekaerts, are complemented by: dr.ir. WP Breugem, dr. P Colonna, dr. R Delfos, dr.ir. GE Elsinga, dr.ir. W de Jong, dr. R Pecnic, dr.ir. C Poelma, dr.ir. MJBM Pourquie, dr. D Tam, dr.ir. M Tummers, and part-time chairs: prof.dr. B Eckhardt, prof.dr.ir. RAWM Henkes, prof.dr. JCR Hunt FRS, and prof.dr.ir. G Ooms.

The common themes of the research in the department group are: (i) turbulence and complex flows, such as multiphase flows, microfluidics, biological flows, and fluid mechanics of sports, (ii) turbulence in supercritical fluids, rotating machinery and gas turbines, energy conversion processes, and aeroacoustics, and (iii) turbulent mixing in non-reacting and reacting flows, turbulence-chemistry-radiation interaction in flames, and turbulent heat transfer.

The research is aimed at fundamental aspects of flows, but always with a clear connection to a practical application or process in industry. Experimental and computational studies are made of systems at different scales, from labscale to industrial scale. Detailed investigations are made using laser diagnostic techniques (such as particle image velocimetry, laser-induced fluorescence, and other spectroscopic methods) and using advanced computational models, such as large-eddy simulation and direct numerical simulation. The program responds to a substantial drive from society and industry, for example for more environmentally friendly combustion processes avoiding the formation of NOx and particulates (soot) in industrial combustion systems (furnaces, gas turbines, engines), and for the development of energy efficient processes (e.g., through drag reduction). The activities in microfluidic flows aim at the investigation of small-scale cardiovascular flows, flow geometries with complex boundary conditions (such as microflagella), and micro-scale multiphase flows.

Prof.dr.ir. B Eckhardt

Dispersion by turbulence in the urban environment (DisTUrbE)

Projectleaders
J Westerweel, BJ Boersma,
DJEM Roekaerts, RAWM Henkes,
JCR Hunt, G Ooms, B. Eckhardt

Researchtheme
Complex dynamics of fluids

Participants
JM Tomas, HE Eisma,
M Goudarvishwanatappa,
MJBM Pourquie, GE Elsinga,
HJJ Jonker, J Westerweel

Cooperations
-

Funded

University	-
FOM	-
STW	90 %
NWO Other	-
Industry	7 %
TNO	3 %
GTI	-
EU	-
Scholarships	-

Start of the project
2012

Information
JM Tomas
015 278 5797
j.m.tomas@tudelft.nl

Project Aim

This research aims to elucidate the role of flow structures in urban dispersion using novel numerical and experimental approaches, which are able to provide accurate instantaneous 3D velocity and concentration data in the turbulent flow. The project focusses on the flow and pollution dispersion near (major) roadways in urban areas on the scale of 10-1000m. Large-eddy simulations are done to simulate this type of flow. 3D (time-resolved) Particle Image Velocimetry (PIV) and Laser Induced Fluorescene (LIF) are used to study both flow structures as well as dispersion. Advanced data reduction methods will be applied to extract the relevant flow features for turbulent dispersion.

Progress

The Dutch Atmospheric Large-Eddy Simulation (DALES) model has been modified to include obstacles like buildings and fences using an Immersed Boundary Method (IBM). Moreover, the model is now applicable to wind/water tunnel-like simulations by using inflow and outflow boundary conditions. The IBM has been validated by comparing results from simulations with experimental data. Moreover, first simulations of the flow around a surface-mounted fence are performed. In the experimental part, planar Particle Image Velocimetry (PIV) measurements have been performed around a fence immersed in a Turbulent Boundary Layer (TBL). The results are used for validation of the DALES code. Furthermore, high accurate DNS code for studying ideal cases has been developed to study scaling phenomenon in scalar transport.

Dissertations

-

Scientific Publications

-

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

Project Aim

The project aims at improving the basic understanding of a key aspect of multiphase flow in pipelines as used in the gas and oil industry, which is the liquid accumulation in systems under turndown operational conditions. The experimental lab configuration will consist of a V-shaped piece of pipeline, representing the low spot. The turbulence levels will be measured using Particle-image Velocimetry. The experimental data will be used to improve the one-dimensional models used in the gas and oil industry, as well as in the next generation type of models, based on three-dimensional Reynolds Averaged Navier Stokes (RANS) equations.

Progress

A dynamic model was built to determine the stability of the liquid holdup in a low spot. If the gas velocity is sufficiently low the model has multiple steady state values for the holdup. If the gas velocity is increased above a critical value then only the zero liquid holdup solution is found. This marks the conditions where the liquids are removed from the low spot, or from an upward inclined section. The model predictions were compared with own experimental data and with data from the literature. A twophase PIV setup was built which comprises a 10.3 m long horizontal transparent pipe with an inner diameter of 50 mm. Air and water are circulated in a closed loop, and the flow conditions covered are 0 to 7.5 m/s for air and 0.004 to 0.04 m/s for water. For some conditions, waves with different characteristics are encountered (capillary, regular 2D, irregular 3D, etc.). A combined 2D PIV and profile capturing technique was implemented. A second double frame camera was employed to capture images of the interface. A phase averaging procedure was applied which conditionally averages the velocity data according to the local phase of the wave. In this way, the velocity fluctuations arising due to turbulence and those due to waves can be distinguished.

Dissertations

-

Scientific Publications

1. Ramdin, M., Henkes, R.A.W.M., CFD modeling of Benjamin and Taylor bubbles in two-phase flow in pipes, Trans. ASME J. Fluids Eng. 134 (4), paper 41303 (8 pgs), 2012.
2. Kjeldby, T.K., Henkes, R.A.W.M., Nydal, O.J., A Lagrangian one-dimensional three-phase slug tracking model, Proc. 8th North American Conference on Multiphase Technology, Banff, pp. 335-443, 2012.
3. Birvalski, M., Henkes, R.A.W.M. Experiments and modeling of multiple holdup states for gas/liquid flow in a pipeline, Proc. 8th North American Conference on Multiphase Technology, pp. 289-303, 2012.
4. Singh, A , Henkes, R.A.W.M., CFD modeling of the flow around a by-pass pig, Proc. 8th North American Conference on Multiphase Technology, pp. 229-243, 2012.

Projectleaders

J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

M Birvalski, RAWM Henkes, MT Tummers, R Delfos

Cooperations

Shell

Funded

Shell

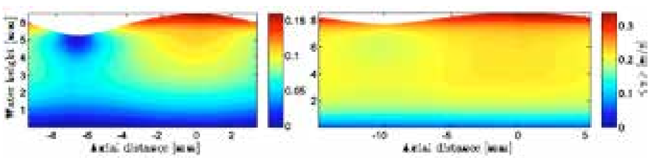
University	25 %
FOM	-
STW	-
NWO Other	-
Industry	75 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2010

Information

RAWM Henkes
015 278 1323
R.A.W.M.Henkes@tudelft.nl



Phase averaged axial velocity (left: low Reynolds number, right: increased Reynolds number).

Performance of foamers for deliquification of gas wells

Projectleaders
J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme
Complex structures of fluids

Participants
D van Nimwegen, RAWM Henkes, L Portela

Cooperations
NAM/Shell

Funded
NAM

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

Start of the project
2010

Information
RAWM Henkes
015 278 1323
R.A.W.M.Henkes@tudelft.nl

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 12 m, 5 cm diameter facility.

Progress

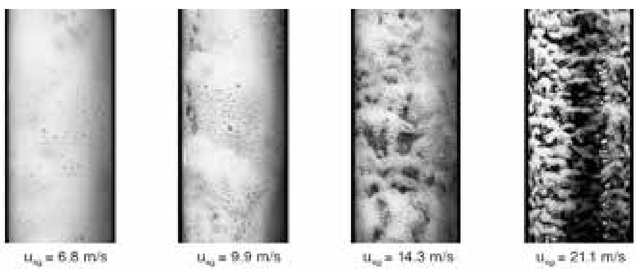
The experiments in the flow facility were continued. It was observed that adding foamers (surfactants) to water will lead to a lower pressure drop at superficial gas velocities below the transition limit from annular flow to churn annular flow (which is around 15 m/s at atmospheric pressure) and at superficial liquid velocities between 0.5 and 2 cm/s. Visualisation of the flow with a high speed camera indicates that the decrease in the pressure drop is due to the more regular nature of the flow when the water is foaming: churning of the flow is suppressed by the foam. This is confirmed by the decrease of the pressure oscillations in the presence of foamers. The water holdup was measured with quick closing valves. The qualitative flow visualization and the quantitative measurements for the pressure drop and liquid holdup were combined to describe the physical mechanisms of the flow features. The angle effect was investigated by increasing the angle up to 70 deg. from the vertical. The surfactants are more effective at steep inclinations and smaller liquid flow rates. Flow visualisation shows that surfactants can form a very regular foam substrate at the wall when the liquid film at the wall is not too thick. When the film thickness becomes larger, due to an asymmetry in the distribution of the liquid film at smaller inclinations or an increase in the liquid flow rate, the foam is less able to suppress all irregularities in the film morphology. This leads to a smaller decrease of the interfacial friction. Experiments were also carried out with an alternative type of surfactant..

Dissertations

-

Scientific Publications

1. Van Nimwegen. A.T., Portela, L.M., Henkes, R.A.W.M., A first look at the hydrodynamics of air-water-foam flow for gas well deliquification, Proc. 8th North American Conference on Multiphase Technology, pp. 367-379, 2012.



Air-water-foam flow at a constant liquid flow-rate (usl= 1 cm/s), while varying the superficial gas velocity. The foamer concentration is 500 ppm.

Modelling the influence of flow on asphaltene agglomeration and deposition

Project Aim

Asphaltenes are heavy organic deposits that can be formed when the oil transport from subsurface reservoirs undergoes a sharp drop in pressure. This can be at the inflow sections from the reservoir into the well bore, or inside the wellbore, pipeline, or downstream facilities. For example injection of chemicals can help to prevent blockage of the production system. Models are used for the design of asphaltene prediction, which in turn are used for 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 literature review on asphaltenes formation and modeling was completed. A numerical model was developed to study the formation and break-up of rigid agglomerates from primary particles in turbulent channel flows. The turbulent continuous phase is simulated through a Direct Numerical Simulation, and the dispersed particles are simulated with Lagrangian tracking. In the model the agglomerates are broken when the tensile force on the inter-particle bonds exceeds the strength of these bonds. The simulation results show that due to the local gradient in the stream-wise fluid velocity, agglomerates preferentially are formed and broken in the proximity of the channel walls. While the structure of agglomerates is found to be invariant to the strength of inter-particle bonds, a linear increase in the mean value and variance of the steady-state agglomerate mass spectra is found when increasing the agglomerate strength. Furthermore, although dilute dispersions are considered in this work, the structure of the agglomerates formed is found to be dependent on the primary particle concentration.

Dissertations

-

Scientific Publications

-

Projectleaders

J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

K Schutte, RAWM Henkes, LM Portela, A Twerda

Cooperations

TNO, ENI (ISAPP2)

Funded

ENI

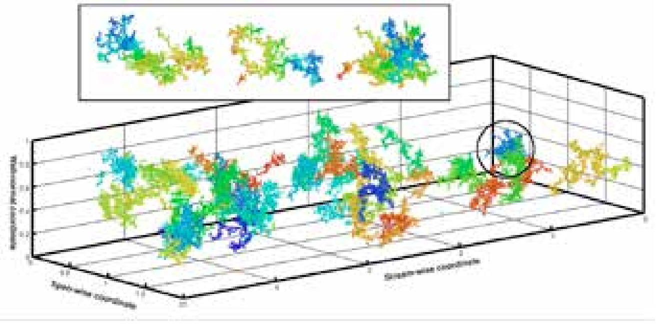
University	25 %
FOM	-
STW	-
NWO Other	-
Industry	75 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2011

Information

RAWM Henkes
015 278 1323
R.A.W.M.Henkes@tudelft.nl



Snapshot of the steady-state agglomerate distribution that was obtained for agglomerates that are broken by binary breakage

Projectleaders
J Westerweel, BJ Boersma,
DJEM Roekaerts, RAWM Henkes,
JCR Hunt, G Ooms, B. Eckhardt

Researchtheme
Complex dynamics of fluids

Participants
G Oldenziel, J Westerweel,
GE Elsinga, R Delfos

Cooperations
-

Funded
FOM

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

Start of the project
2009

Information
G Oldenziel
G.Oldenziel@tudelft.nl

Project Aim

Droplet collisions are studied in a turbulent environment. Flows where events like these occur can be encountered in nature, for example during rain formation in clouds, as well as in industrial applications, like the production of mayonnaise. In this project, droplet collisions are studied with special attention to the outcome of the collision, i.e. bouncing or coalescence. The influence of external turbulence on this is investigated.

Progress

Measurements of droplet collisions without turbulence are finished. In order to study the influence of external turbulence, droplet collisions are performed in the turbulent flow between two counter rotating discs, also known as a Von Kármán flow. The droplets are tracked using shadowgraphy and three high speed camera's. Measurements are currently being performed.

Dissertations

-

Scientific Publications

1. G. Oldenziel, R. Delfos, J. Westerweel, Measurements of liquid film thickness for a droplet at a two-fluid interface. Phys. Fluids 24, (2012).

Dynamics of vortex cavitation

Project Aim

Cavitating vortices trailing from a ship propeller are a source of inboard noise and vibration. When these vortices flow past rudders they could induce severe erosion. Ideally these harmful results should be prevented in the design stage. To be able to quantify sound emission and erosion more understanding is needed of the dynamics of cavitating vortices. Therefore the aim of this project is to first study the dynamics and sound emission of a cavitating vortex in isolation. Second is the study of the interaction of multiple vortices possibly near a surface. The final goal is to recreate the flow of a cavitating tip vortex past a rudder and determine its erosive properties.

Progress

Tip vortices are flow structures with concentrated vorticity which can persist far downstream of a propeller. To be able to experimentally study these vortices in the cavitation tunnel at the department of Maritime Engineering at Delft University of Technology the test section of the cavitation tunnel is replaced with a test section with a visual access 1.9 m in stream wise direction.

Dissertations

-

Scientific Publications

-

Projectleaders
J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme
Complex dynamics of fluids

Participants
PC Pennings, TJC van Terwisga, J Westerweel and R Delfos

Cooperations
Part of the International Institute for Cavitation Research (IICR), cooperation with the Dynamics of Vortex Cavitation on Ship and Pump Impellers (DYNVOR) and the STW Ship Drag Reduction projects

Funded
Entirely funded by the Lloyd's Register Educational Trust

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

Start of the project
2011

Information
PC Pennings
015 278 8351
p.c.pennings@tudelft.nl
pe.tudelft.nl

PROJECTLEADERS
J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
C Poelma, A Kloosterman, J Westerweel

COOPERATIONS
Erasmus MC, LUMC, AMC, Imperial College London

FUNDED
Medical Delta, TUD

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

START OF THE PROJECT
2006

INFORMATION
C Poelma
015 278 2620
C.Poelma@tudelft.nl

PROJECT AIM

We analyze and quantify the role of fluid mechanics in biomedical applications, in particular relating to cardiovascular flow. We do this by developing and applying in vivo flow measurement techniques to document blood flow patterns and the associated hemodynamic forces. Furthermore, we study disease-related blood flow phenomena in vitro (e.g. transition to turbulence in a stenosis, flow patterns in an aneurysm). Experiments are supplemented by computational hemodynamics studies.

PROGRESS

Experimental techniques that have been developed in previous years have successfully been applied to address problems in biomedical research. Examples include the role of fluid mechanics in the development of vascular networks and flow analysis of a lab-on-a-chip design suitable for zebrafish development studies. We have also further refined the accuracy and applicability of ultrasound-based particle image velocimetry methods for non-invasive in vivo blood flow measurements.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Poelma C, Kloosterman A, Hierck BP and Westerweel J “Accurate blood flow measurements: are artificial tracers necessary?” PLoS ONE 7(9): e45247.
2. Poelma C, Van der Mijle RME, Mari JM, Tang M-X, Weinberg PD and Westerweel J “Ultrasound imaging velocimetry: toward reliable wall shear stress measurements” European Journal of Mechanics - B / Fluids 35 70-75 (2012).
3. Trip R, Kuik DJ, Westerweel J and Poelma C “An experimental study of transitional pulsatile pipe flow” Physics of Fluids 24 1 14103 (2012).
4. Van Ooij P, Guédon A, Poelma C, Schneiders J, Rutten MCM, Marquering HA, Majoie CB, van Bavel E and Nederveen AJ “Complex flow patterns in a real-size intracranial aneurysm phantom: phase contrast MRI compared with particle image velocimetry and computational fluid dynamics” NMR in Biomedicine 25 (1) 14-26 (2012).
5. Fraser K, Zhou BH, Poelma C, Tang MX and Weinberg PD “Towards Small Animal Echo-PIV” Bioengineering 2012 (6-7 September; Oxford, UK).
6. Poelma C, Kloosterman A, Hierck BP, Pries A and Westerweel J “Quantitative analysis of hemodynamics in the developing vitelline network Bioengineering 2012 (6-7 Sept.; Oxford, UK).

Fully resolved simulations of dense turbulent sediment transport

Project Aim

The aim of this PhD project is two-fold: 1) the development of a state-of-the-art computational method for fully resolved simulations of dense particle-laden turbulent flows and 2) the improvement of the understanding of the structure and dynamics of such flows by means of fully resolved simulations.

Progress

A novel second-order accurate Immersed Boundary Method for fully resolved simulations of flows laden with finite-size particles was published by Breugem in J. Comp. Phys. in 2012. Currently, we are working on an extension of this model with a soft-sphere collision model for accommodating (oblique) collisions between particles.

Dissertations

-

Scientific Publications

1. W.-P. Breugem. A second-order accurate Immersed Boundary Method for fully resolved simulations of particle-laden flows. Journal of Computational Physics, 231(13), 4469-4498, 2012.

Projectleaders

J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

PS Costa, WP Breugem, BJ Boersma, J Westerweel

Cooperations

-

Funded

FCT, The Portuguese Foundation for Science and Technology

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

Start of the project

2012

Information

PS Costa
015 278 4194
p.simoes.costa@gmail.com
http://www.pe.tudelft.nl/node/663

PROJECTLEADERS
J Westerweel, BJ Boersma,
DJEM Roekaerts, RAWM Henkes,
JCR Hunt, G Ooms, B. Eckhardt

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
S Drost, J Westerweel, SJ Picken,
MT Kreutzer

COOPERATIONS
Teijin Aramid B.V.

FUNDED
Teijin Aramid B.V.

University	40 %
FOM	-
STW	-
NWO Other	-
Industry	60 %
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2011

INFORMATION
S Drost
s.drost@tudelft.nl

PROJECT AIM

Investigate the instabilities occurring in contraction flows of viscoelastic liquids in general and liquid crystalline polymer solutions in specific. Such contraction flows are relevant in many industrial extrusion processes, such as fiber spinning. Ultimately, the instabilities should be controlled, leading to increased process efficiency.

PROGRESS

Visualized flow of 19.8% PPTA in H2SO4 in glass flow cell with 100:1 contraction at realistic flow rate. Developed fitting method to extract power-law index from streamline curvature in Hele-Shaw flow and derived condition for validity of this method. Performed numerical simulations of contraction flow of Giesekus fluid with realistic relaxation spectrum (determined from oscillatory rheometry data). In both experimental and numerical work: investigating 3D effects on stability of quasi-2D flow.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Rheometry in a microfluidic contraction flow device (presentation + conference paper at Microfluidics 2012, 3-5 December, Heidelberg, Germany).
2. Rheometry in Hele-Shaw flow (presentation during Midwinter Meeting of the British Society of Rheology, 17 & 18 December, 2012, Aberystwyth, Wales).

Development of long-range micro-PIV for high Reynolds number turbulence

Project Aim

The long-range microscopic PIV technique has been proposed in the last years to examine microscopic flow phenomena in macroscopic flows such as boundary layers and jets at high Reynolds numbers. The first goal is to implement this technique in our high pressure vessel to measure jet flow. The main aim is then to measure and characterize the small scale in this turbulent flow such as occurring in the interface between turbulent and non-turbulent flow region.

Progress

Characterization of the turbulence in the jet was performed, with a particular focus on the fully-developed region, where hot-wire signals were acquired. Using a spectral filter, the large-scale fluctuations, responsible for turbulence production, were separated from the fine scales. An interaction between the turbulent scales was found. In particular, the large-scale fluctuations modulate the small, dissipative scales both in amplitude and frequency. The different contributions of the large-scale fluctuations on the amplitude and frequency modulation were quantified. This work is going to be presented at the Conference on turbulence and shear flow phenomena (TSFP). Furthermore, the long-range microscopic PIV set-up is operational. The first images have already been acquired.

Dissertations

-

Scientific Publications

-

Projectleaders

J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

D Fiscaletti, J Westerweel, GE Elsinga

Cooperations

Universitaet der Bundeswehr Muenchen

Funded

EU

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

Start of the project

2011

Information

D Fiscaletti
D.Fiscaletti@tudelft.nl
www.pe.tudelft.nl/Chairs/FM

The hemodynamics of vascular remodelling

Projectleaders
J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme
Complex dynamics of fluids

Participants
A Kloosterman, C Poelma, J Westerweel

Cooperations
Leiden University MC and Erasmus MC Rotterdam

Funded

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

Start of the project
2008

Information
A Kloosterman
015 278 4194
a.kloosterman@tudelft.nl
www.ahd.tudelft.nl

Project Aim

Fluid mechanics plays a critical role in the formation and adaption of vascular networks. The wall shear stress has been identified as one of the key parameters in this interaction. This project will focus on the quantification of flow conditions relevant for angiogenesis and vascular adaption. With a recently developed micro-PIV method for in-vivo measurement of blood flow, it is possible to measure instantaneous flow and wall shear stress data. This micro-PIV system will be used for in-vivo measurements of the vitelline network and cardiovascular system in chicken embryos.

Progress

Better understanding of vascular remodelling requires improved insight into the relation between hemodynamics and remodelling, and quantitative information about velocity profiles, flow rate and wall shear stress is essential. For this, consecutive in vivo micro-PIV velocity measurements have been performed in the vitelline (extraembryonic) network of seven chicken embryos at different developmental stages. To characterize the developing network, the velociy fields have been reduced to a model consisting of a set of connected vessel segments, with defined diameters, lengths, and velocities. Now, the changing distribution of morphological and hemodynamic parameters (e.g. blood vessel diameters and flow velocities) in time can be investigated and since the structure of the network can still be traced to the next time step, it allows to also relate specific morphological changes to hemodynamic parameters and their respective changes.

Dissertations

-

Scientific Publications

-

Nanoscale contact line dynamics based on total internal reflection fluorescence microscopy

Project Aim

The aim of the project is to visualize and understand the behavior of a contact line at nanoscale level. A measurement method is to be developed in order to measure the interface of a droplet at nanoscale level .The method should have sufficient spatial as well as temporal resolution to capture the interface at nanoscale level at various contact line velocities. The experiments should give insight in the way contact line instabilities occur and how these can be prevented.

Progress

A measurement method based on Total Internal Reflection Fluorescence Microscopy (TIRFM) is developed in order to study the dynamics of precursor films. This developed measurement technique is validated with non disturbing imaging by Atomic Force Microscopy (AFM), and is used to study the dynamics of precursor films formed ahead of a droplet. The shape of a moving precursor film is measured for the very first time in the case of a partial wetting droplet, and therefore provide valuable information for numerical simulations. Furthermore, the results for the precursor film profile of both advancing and receding precursor films were characterized by a power-law fit, where the fitted exponent was used to characterize the precursor film. The fitted exponent (representing the shape of the precursor film) for the advancing as well as the receding situation is independent of contact line velocity. Moreover, based on the lubrication approximation, the slip length is found to be proportional with the contact line velocity. Our findings indicate that slip does exist, and is in agreement with both experimental as numerical work.

Dissertations

-

Scientific Publications

-

Projectleaders

J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

MJZ Franken, C Poelma, J Westerweel

Cooperations

ASML, UT, TU/e

Funded

EU

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

Start of the project

2008

Information

MJZ Franken
015 278 2861
m.j.z.franken@tudelft.nl
http://www.pe.tudelft.nl/Chairs/FM

Ship drag reduction by air lubrication

Projectleaders
J Westerweel, BJ Boersma,
DJEM Roekaerts, RAWM Henkes,
JCR Hunt, G Ooms, B. Eckhardt

Researchtheme
Complex dynamics of fluids

Participants
O Zverkhovskyi, T van Terwisga,
J Westerweel, R Delfos

Cooperations
Delft University of Technology
Twente University, PPG industries,
MARIN

Funded
STW, PPG, MARIN

University	-
FOM	-
STW	87 %
NWO Other	-
Industry	13 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2009

Information
O Zverkhovskyi
015 278 2861
O.Zverkhovskyi@tudelft.nl

Project Aim

The aim of this project is to enhance the effects of air lubrication on frictional drag significantly, by improving our knowledge on the detailed mechanisms and its scale effects. With this knowledge the effectiveness of air lubrication should be increased in order to make application on ships feasible.

Progress

The efficiency of air cavities has been studied experimentally on laboratory scale in a medium-speed water tunnel containing an optically accessible test section, equipped with a PIV system and cameras to obtain boundary layer- and cavity characteristics, and a force balance to measure the drag. The results of this study confirm that the drag reduction is proportional to the amount of non-wetted area. Based on experimental observations, a design criterion is defined for obtaining stable cavities with a low rate of air consumption. Furthermore, the experiments give insight into the formation and stability of air cavities, including the interaction between a series of cavities along the stream-wise direction.

Dissertations

-

Scientific Publications

1. O. Zverkhovskyi, R. Delfos, J. Westerweel, T. van Terwisga "Experimental study on developed air cavities under a horizontal flat plate" Proceedings of the 8th International Symposium on Cavitation CAV2012, August 14-16, 2012, Singapore.

Coherent structures in turbulent Taylor-Couette flow

Project Aim

The aim of the project is to experimentally investigate the instantaneous flow structures in turbulent Taylor-Couette flow. In combination with torque measurements, tomographic PIV will be used to measure the 3D velocity fields of coherent turbulent structures and their influence on torque change at constant shear rate. The details of the coherent turbulent flow structures that are responsible for the reported change of the torque will be studied.

Progress

Measured flow fields were processed to separate the instantaneous large and smaller-scale flow structures at different rotation rates of the cylinders. The analysis showed that, even at a constant shear Reynolds number, depending on the relative rotational speeds and directions of the cylinders, the characteristics of the instantaneous large scale structures change significantly. At the cases close to only inner cylinder rotation, the large scale structures are found to be elongated in the azimuthal direction, similar to Taylor vortices. However, they are aligned in the axial direction, for the cases close to the only outer cylinder rotation, resembling the Taylor columns. A model, based on the organizational change of the instantaneous structures, was developed to explain the reported change of the torque.

Dissertations

-

Scientific Publications

1. Tokgoz S., Elsinga G.E., Delfos R. and Westerweel J. Spatial resolution and dissipation rate estimation in Taylor-Couette flow for tomographic PIV. Experiments in Fluids. 53(3) pp. 561-583. 2012. doi:10.1007/s00348-012-1311-7.
2. Tokgoz S., Elsinga G.E., Delfos R. and Westerweel J. Influence of Rotation Number to Coherent Structures and Torque Scaling in Turbulent Taylor-Couette Flow. In: Proceedings of 65th American Physical Society Annual Fall DFD Meeting, November 18–20, 2012.
3. Tokgoz S., Elsinga G.E., Delfos R. and Westerweel J. Taylor-Couette in the turbulent regime: coherent structures and their influence on torque scaling. In: Proceedings of 9th European Fluid Mechanics Conference, September 09–13, 2012.
4. Tokgoz S., Elsinga G.E., Delfos R. and Westerweel J. A Spatial resolution study of tomographic PIV using Taylor-Couette flow. In: Proceedings of 16th International Symposium on Applications of Laser Techniques to Fluid Mechanics, July 09–12, 2012.

Projectleaders

J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

S Tokgoz, G E Elsinga, R Delfos, J Westerweel,

Cooperations

TU Delft

Funded

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

Start of the project

2012

Information

S Tokgoz
015 278 2961
s.tokgoz@tudelft.nl
www.ahd.tudelft.nl

Numerical simulation of core-annular flow

Projectleaders
J Westerweel, BJ Boersma,
DJEM Roekaerts, RAWM Henkes,
JCR Hunt, G Ooms, B. Eckhardt

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
G Ooms, MJBM Pourquie, P Poesio

Cooperations
University of Brescia, Italy

Funded
TUDelft

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

Start of the project
2011

Information
G Ooms
015 278 1176
g.ooms@tudelft.nl

Project Aim

To study the levitation problem of core-annular flow in a horizontal pipe.

Progress

A numerical study (taking into account inertial -, viscous - and pressure forces) has been made of eccentric core-annular flow through a horizontal pipe, special attention being paid to the vertical force on the core. The viscosity of the core is assumed to be so large that it behaves as a rigid solid. A wave is present at its surface. The shape of the wave is based on experimental results published earlier in the open literature. Due to the eccentricity the centre line of the core is shifted in the upward vertical direction with respect to the centre line of the tube. The vertical force on the core was found to be dependent on the Reynolds number: at small values of the Reynolds number the force is in the upward vertical direction, at large values the force is downward. This means that at large values of the Reynolds number an upward buoyancy force on the core due to a density difference between core and annulus can be counterbalanced. So a stationary core-annular flow is then possible.

Dissertations

-

Scientific Publications

1. G. Ooms, M.J.B.M. Pourquie and P. Poesio, Int.J.Multiphase Flow 42 (2012) 74-79.

Heavy Fuel-oil combustion in a HiTAC boiler

Project Aim

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

Progress

Ethanol spray flames were studied both in hot-vitiated coflow (HiTAC) conditions and in a co-flow or cold air. Five ethanol spray flames in different hot-vitiated co-flow conditions (O2=6.6%, 8.6% and 9.8%) were studied in detail using Phase Doppler Anemometry (PDA). Radial profiles of droplet diameter and velocity statistics were measured at nine heights above the burner. Co-flow oxygen and velocity profiles for each case were measured by means of a flue gas analyzer and Laser Doppler anemometry (LDA). The radial O2 concentration and mean and rms velocity profiles of the coflow are found to be nearly flat. Moreover, sufficient turbulence levels are achieved in the co-flow demonstrating successful burner design. At the lowest station no major difference in the Sauter mean diameter profile between the different cases was observed. The atomizer yields a spray flame with small droplets in the central, near axis, region and larger droplets in the outer off-axis region. Depending on the co-flow temperature the center region gets depleted of droplets due to the effects of the entrainment of the hot coflow. Although the visual appearance of the flames presents no corrugation and resembles laminar conditions, high turbulence levels are present in the spray flame. At the lowest station strong anisotropy between axial and radial rms velocity is present and no significant differences are observed between the different cases. Next also an acetone spray flame in hot-vitiated conditions was characterized by PDA. The co-flow conditions were similar to one of the ethanol cases. Acetone spray flames were found to be more irregular clearly exhibiting a different breakup and atomization regime. The experimental databases are available for model validation studies.

Dissertations

-

Scientific Publications

1. H. Rodrigues, M.J. Tummers, D.J.E.M. Roekaerts. Experiments on turbulent ethanol reacting sprays in HiTAC conditions. In proceedings of 12th International Conference on Liquid Atomization and Spray Systems, Heidelberg, September, 2-6, 2012.
2. Shanglong Zhu, Artur Pozarlik, Theo van der Meer, Hugo Rodrigues, Mark Tummers, and Dirk Roekaerts Ethanol spray combustion under HiTAC conditions, Proceedings of the Thirthy-Fourth International Symposium on Combustion, Warsaw, 2012 , W4P101.

Projectleaders

J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

HRC Rodrigues

Cooperations

T.H. van der Meer (U Twente)
S. Zhu (U Twente), MJ Tummers, DJEM Roekaerts

Funded

Technology Foundation STW (CCC program), Stork Thermeq, Shell

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

Start of the project

2010

Information

HRC Rodrigues
015 278 6745
h.r.correiarodrigues@tudelft.nl
www.cleancombustionconcepts.nl

PROJECTLEADERS
J Westerweel, BJ Boersma,
DJEM Roekaerts, RAWM Henkes,
JCR Hunt, G Ooms, B. Eckhardt

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
L Ma, DJEM Roekaerts

COOPERATIONS
-

FUNDED

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

START OF THE PROJECT
2012

INFORMATION
L Ma
015 278 6745
l.ma@tudelft.nl

PROJECT AIM

Spray flames widely used in industrial furnaces, power generation system, etc. and there is a need for computational model to predict their properties. The objective is to develop and validated 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

This project is in the start-up phase. A literature study is ongoing, and also some first modeling attempts of an ethanol spray flame in hot vitiated coflow are being made using Eulerian-Lagrangian RANS models available in Ansys-Fluent. Next the use of Lagrangian-Lagrangian methods (PDF methods) will be explored.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Flameless combustion conditions and efficiency improvement of single- and multi-burner-FLOXTM furnaces in relation to changes in fuel and oxidizer composition (flexFLOX). Part 1a: Experimental studies in single-burner systems

Project Aim

The objective of the flexFLOX project is to investigate both experimentally and computationally the impact of changes in fuel and oxidizer composition on flameless combustion. To reach the flameless combustion regime the air (and/or fuel) streams are diluted with hot combustion products with a temperature sufficiently high for the combustion process to be stable and occurring in a distributed reaction zone. The objective of part 1a of the project is gaining fundamental understanding of the flameless regime via laser diagnostic experiments in single burner systems, in particular the Delft jet-in-hot-coflow (DJHC) burner operated with different fuels.

Progress

Experimental studies on the characteristics of jet in coflow flames were made. Both hot coflow (lean combustion products) and cold coflow (air) were studied. The effects of hydrogen and carbon dioxide on the flow field in Dutch Natural Gas (DNG) flames were studied using Particle ImageVelocimetry (PIV) complementing earlier studies of the high speed recordings of the flame luminescence. It was found that hydrogen addition has a strong effect on the liftoff height for all studied flames. For flames oxidized in air, the liftoff height decreases together with its rms fluctuations. The mean velocity and its rms fluctuations at the mean stabilization point have similar magnitudes for all the studied flames. For flames oxidized in hot coflow, the trend in the liftoff height is comparable to the cold coflow cases but the velocity flow field is not considerably affected by the combustion. Carbon dioxide dramatically reduces the stability when air is used as oxidizer but with a hot coflow only a small downstream shift of the flame stabilization region is noticed. The work suggests that preferential diffusion of hydrogen is responsible for the considerable reduction in liftoff height for the hydrogen containing studied flames while carbon dioxide does not alter significantly the stabilization region in flames stabilized in hot coflow despite the reduction of caloric value. Temperature measurements were made using CARS. The database of the PDF of temperature along radial traverses at several heights for the different cases, completes the experimental database suitable for model validation.

Dissertations

-

Scientific Publications

1. L.D. Arteaga Mendez, M.J. Tummers and D.J.E.M. Roekaerts. Effect of fuel and oxidizer composition on jet-in-coflow flames, In: A. Dreizler, A. Kemp land R. Barlow (Eds.), Book of abstracts of TNF11 “Eleventh International Workshop on Measurement and Computation of Turbulent Flames”, July 26–28, 2012, Darmstadt, Germany, pp 54-55.
2. L.D. Arteaga Mendez, M.J. Tummers and D.J.E.M. Roekaerts. Effect of fuel and oxidizer composition on jet-in-coflow flames, In Book of Abstracts, Combura’12, October 3-4, 2012, Maastricht, The Netherlands, Published by Technology Foundation STW, Utrecht, The Netherlands Pages 4-5.

Projectleaders

DJEM Roekaerts, MJ Tummers, W de Jong

Researchtheme

Complex dynamics of fluids

Participants

LD Arteaga Mendez, EH van Veen

Cooperations

WS-Prozesstechnik, Stuttgart
TNO glass group (Celsian BV)
Tata Steel, Numeca Int., Brussels

Funded

Technology Foundation STW, Tata Steel, Shell, NVV, Numeca Int., TNO

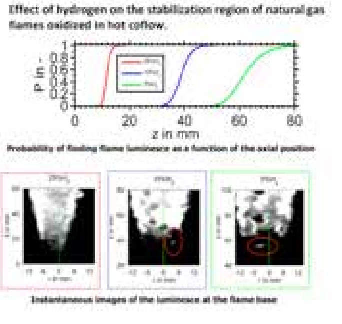
University	-
FOM	-
STW	80 %
NWO Other	-
Industry	15 %
TNO	5 %
GTI	-
EU	-
Scholarships	-

Start of the project

2009

Information

LD Arteaga Mendez
015 278 2418
l.d.arteagamendez@tudelft.nl
www.cleancombustionconcepts.nl



FlexFLOX
Part 1b: Computational studies of the jet-in-hot-coflow burner

Projectleaders
DJEM Roekaerts, MJ Tummers, W de Jong

Researchtheme
Complex dynamics of fluids

Participants
G Sarras

Cooperations
MK Stollinger

Funded
Technology Foundation STW, Corus, Shell, NVV, Numeca Int., TNO

University	-
FOM	-
STW	80 %
NWO Other	-
Industry	15 %
TNO	5 %
GTI	-
EU	-
Scholarships	-

Start of the project
2010

Information
G Sarras
015 278 2186
g.sarras@tudelft.nl
www.et.3mE.tudelft.nl

Project Aim

The objective of the flexFLOX project is to investigate both experimentally and computationally the impact of changes in fuel and oxidizer composition on flameless combustion. To reach the flameless combustion regime the air (and/or fuel) streams are diluted with hot combustion products with a temperature sufficiently high for the combustion process to be stable and occurring in a distributed reaction zone. The objective of part 1b of the project is to develop and validate computational models using the Delft Jet-in-Hot-Coflow burner as a model system.

Progress

A transported probability density function (PDF) method is used for modeling the flameless combustion in the Delft-Jet-in-Hot-Coflow (DJHC) burner. The main advantage of the PDF method is that complex finite-rate chemistry is treated exactly and the method accounts for the turbulence-chemistry interaction. To reduce the computational time, a tabulated chemistry model based on the Flamelet Generated Manifold (FGM) is adopted in the PDF method. The FGM table that describes the inhomogeneity of the coflow and the entrainment of the ambient air is based on unsteady counterflow diffusion flames, using two mixture fractions and one progress variable. The different levels of temperature at different radial locations in the coflow, and the corresponding enthalpy loss or gain is taken into account by assuming a strict correlation between second mixture fraction and enthalpy loss. A comparison in performance between two transported PDF methods, joint velocity-composition PDF (JVCPDF) and joint composition PDF (JCPDF), with different mixing models (IEM, EMST, Modified CD) has been made (see figure). In order to overcome the limitations of the assumption of correlation between oxygen concentration and temperature in the coflow radial inlet profile, a further model development is made. Enthalpy now is considered an additional independent scalar variable, in addition to the two mixture fractions and the progress variable. Again using a set of FGM's a tabulated chemistry is constructed, now with four independent variables. Simulations with the four dimensional table are in progress.

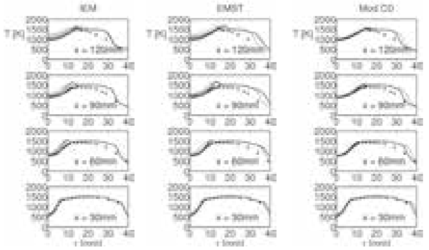
Dissertations

-

Scientific Publications

1. G. Sarras, M.K. Stoellinger and D.J.E.M. Roekaerts, Transported PDF simulations of the Delft-jet-in-hot-coflow burner based on 3D FGM tabulated chemistry. In: Turbulence, Heat and Mass Transfer 7, Editors: K. Hanjalic, Y. Nagano, D. Borello and S. Jakirlic. Begell House, Inc., 2012, pp 729-732.

JVCPDF(--), JCPDF(-), Experiment(o)



Project Aim

The objective of the flexFLOX project is to investigate both experimentally and computationally the impact of changes in fuel and oxidizer composition on flameless combustion. To reach the flameless combustion regime the air (and/or fuel) streams are diluted with hot combustion products with a temperature sufficiently high for the combustion process to be stable and occurring in a distributed reaction zone. The objective of part 2 of the flexFLOX project is to do experimental and computational studies of a multi-burner FLOX furnace (MEEC furnace).

Progress

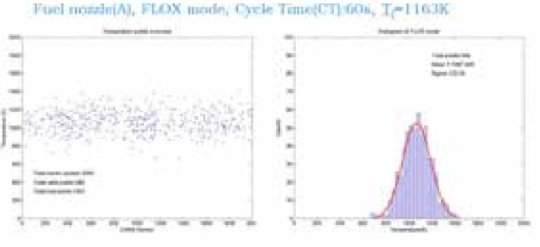
Experimental studies in the MEEC furnace have been continued. The multiburner furnace was operated in two burning modes: parallel firing and staggered firing. A setup was built to measure the instantaneous local temperature using the non-intrusive laser diagnostic technique Coherent anti-Stokes Raman Spectroscopy (CARS). The setup was successfully tested and used. CARS measurements were made in both the flame regime and the flameless regime and revealed the characteristics of the temperature fluctuations in both regimes. From the set of measured temperatures the mean and standard deviation were extracted. In addition the local mean temperature was measured in the near burner region along the axial distance away from the burner using a 2m long S-type thermocouple. The experimental results were compared with numerical simulation using the Eddy Dissipation Concept model in ANSYS-Fluent. Numerical results showed slower mixing and ignition phenomena in comparison with actual experimental results. In order to be able to operate the furnace with biofuel (DNG+CO2 mixture) or surrogate fuel (DNG+N2 mixture) a change in the fuel injectin system was made. First results were obtained with DNG+N2 mixture. This was compared with the DNG case regarding efficiency and emissions. The N2 diluted fuel showed amuch lower CO emission which appeared to relate to the enhancement of the mixing of air and fuel by the higher fuel velocity. Computational fluid dynamics studies of the MEEC furnace for operation with DNG, with DNG+N2 and with DNG+CO2 as fuel have been performed.

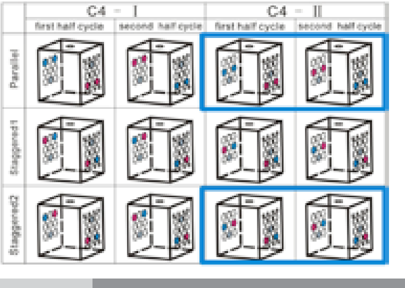
Dissertations

-

Scientific Publications

1. Jie Lu, Eun-Seong Cho, Eric van Veen, Wiebren de Jong and Dirk Roekaerts Coherent Anti-Stokes Raman spectroscopy measurement in a regenerative multi-burner furnace, Abstract of Work-in-Progress poster, Proceedings of the Thirthy-Fourth International Symposium on Combustion, Warsaw, 2012, W5P035.





Projectleaders

W de Jong , DJEM Roekaerts, MJ Tummers

Researchtheme

Complex dynamics of fluids

Participants

ES Cho, L Jie (CSC), EH van Veen, D Shin (Kookmin University)

Cooperations

WS-Prozesstechnik, Stuttgart
TNO glass group (Celsian BV)
Tata Steel, Numeca Int., Brussels

Funded

Technology Foundation STW, Tata Steel, Shell, NVV, Numeca Int., TNO

University	-
FOM	-
STW	80 %
NWO Other	-
Industry	15 %
TNO	5 %
GTI	-
EU	-
Scholarships	-

Start of the project

2009

Information

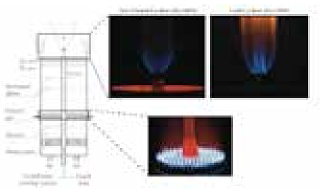
W de Jong
015 278 9476
wiebren.dejong@tudelft.nl
www.cleancombustionconcepts.nl

Heavy Fuel-oil combustion in a HiTAC boiler

Projectleaders
MJ Tummers, DJEM Roekaerts
Researchtheme
Complex dynamics of fluids
Participants
HRC Rodrigues
Cooperations
TH van der Meer (U Twente), S Zhu (U Twente)
Funded
Technology Foundation STW (CCC program), Stork Thermeq, Shell

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

Start of the project
2010
Information
HRC Rodrigues
015 278 6745
h.r.correiarodrigues@tudelft.nl
www.cleancombustionconcepts.nl



Project Aim

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

Progress

Ethanol spray flames were studied both in hot-vitiated coflow (HiTAC) conditions and in a co-flow or cold air. Five ethanol spray flames in different hot-vitiated co-flow conditions ($O2$=6.6%, 8.6% and 9.8%) were studied in detail using Phase Doppler Anemometry (PDA). Radial profiles of droplet diameter and velocity statistics were measured at nine heights above the burner. Co-flow oxygen and velocity profiles for each case were measured by means of a flue gas analyzer and Laser Doppler anemometry (LDA). The radial $O2$ concentration and mean and rms velocity profiles of the coflow are found to be nearly flat. Moreover, sufficient turbulence levels are achieved in the co-flow demonstrating successful burner design. At the lowest station no major difference in the Sauter mean diameter profile between the different cases was observed. The atomizer yields a spray flame with small droplets in the central, near axis, region and larger droplets in the outer off-axis region. Depending on the co-flow temperature the center region gets depleted of droplets due to the effects of the entrainment of the hot coflow. Although the visual appearance of the flames presents no corrugation and resembles laminar conditions, high turbulence levels are present in the spray flame. At the lowest station strong anisotropy between axial and radial rms velocity is present and no significant differences are observed between the different cases. Next also an acetone spray flame in hot-vitiated conditions was characterized by PDA. The co-flow conditions were similar to one of the ethanol cases. Acetone spray flames were found to be more irregular clearly exhibiting a different breakup and atomization regime. The experimental databases are available for model validation studies.

Dissertations

-

Scientific Publications

1. H. Rodrigues, M.J. Tummers, D.J.E.M. Roekaerts. Experiments on turbulent ethanol reacting sprays in HiTAC conditions. In proceedings of 12th International Conference on Liquid Atomization and Spray Systems, Heidelberg, September, 2-6, 2012.
2. Shanglong Zhu, Artur Pozarlik, Theo van der Meer, Hugo Rodrigues, Mark Tummers, and Dirk Roekaerts Ethanol spray combustion under HiTAC conditions, Proceedings of the Thirthy-Fourth International Symposium on Combustion, Warsaw, 2012 , W4P101.

PROJECT AIM

Spray flames widely used in industrial furnaces, power generation system, etc. and there is a need for computational model to predict their properties. The objective is to develop and validated 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

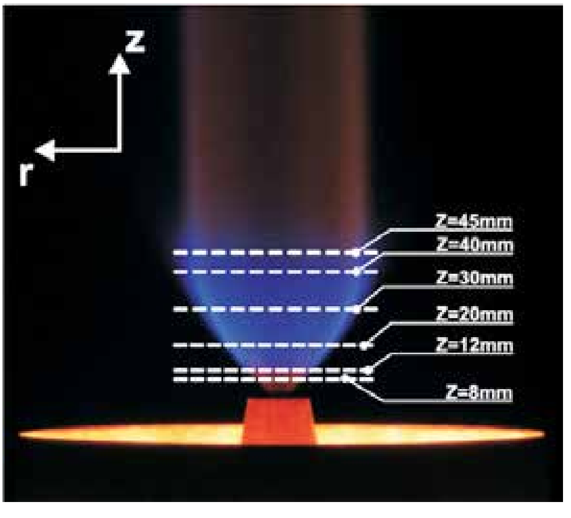
This project is in the start-up phase. A literature study is ongoing, and also some first modeling attempts of an ethanol spray flame in hot vitiated coflow are being made using Eulerian-Lagrangian RANS models available in Ansys-Fluent. Next the use of Lagrangian-Lagrangian methods (PDF methods) will be explored.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



PROJECTLEADERS

DJEM Roekaerts

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

L Ma

COOPERATIONS

-

FUNDED

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

START OF THE PROJECT

2012

INFORMATION

L Ma
015-2786745
l.ma@tudelft.nl

Dynamic behaviour of a Multi-burner Excess Enthalpy Combustion (MEEC) system for industrial process furnaces

Projectleaders
DJEM Roekaerts, MJ Tummers

Researchtheme
Complex dynamics of fluids

Participants
E Oldenhof, MK Stöllinger

Cooperations
W de Jong, ES Cho, G Sarras

Funded
Technology Foundation STW, NVV, Fluent, TNO, WS Prozesstechnik

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

Start of the project
2007

Information
MJ Tummers
015 278 2477
m.j.tummers@tudelft.nl
www.pe.tudelft.nl/node/343

Project Aim

Excess Enthalpy Combustion (EEC, also known as flameless combustion) is a new combustion technology that promises higher efficiencies, higher product qualities and lower emissions. Although EEC has already been used in industry, many problems remain to be solved before this technology can be used in furnaces where a large number of burners are needed to deliver the required thermal input. Especially fundamental knowledge is needed regarding the dynamic behavior of this type of novel regenerative burners. For this purpose flames from a "jet-in-hot-coflow burner (JHC)" are studied.

Progress

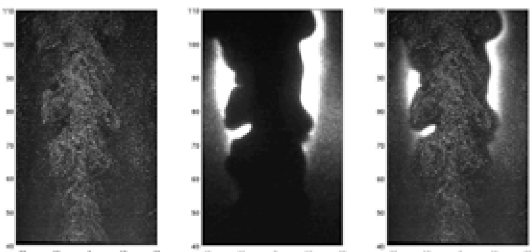
The research activities of this project have been completed in 2011. In 2012 Ernst Oldenhof defended his PhD Thesis and an article on transient response of the Delft JHC flames was published. The work done by Michael Stöllinger contributed to a modeling study of the JHC flames using transported PDF methods. The modeling modeling study is continued in the frame of the flexFLOX project by Gerasimos Sarras (see other page).

Dissertations

1. E. Oldenhof, Auto-ignition and flame stabilisation processes in turbulent non-premixed hot coflow flames, Delft University of Technology, 2012.

Scientific Publications

1. Oldenhof, Ernst, Tummers, M.J., van Veen, E.H. and Roekaerts, D.J.E.M. Transient response of the Delft jet-in-hot coflow flames. Combustion and flame, 159 (2) : 697-706, 2012 http://dx.doi.org/10.1016/j.combustflame.2011.08.001.
2. G. Sarras, M.K. Stöllinger and D.J.E.M. Roekaerts. Transported PDF simulations of the Delft-jet-in-hot-coflow burner based on 3D FGM tabulated chemistry In: Turbulence, Heat and Mass Transfer 7, Editors: K. Hanjalic, Y. Nagano, D. Borello and S. Jakirlic.Begell House, Inc., 2012, pp 729-732.



Ultra Rich Combustion of Hydrocarbons and Soot Formation (ULRICO)

Project Aim

Combustion of natural gas in the range of atmospheric pressure to high pressure (up to ~6-8 bar) at globally rich conditions will be studied computationally and experimentally with the objective to identify trends in production of soot and fixed nitrogen species (HCN, NH3) with burner design and operating conditions and to find the optimal operating conditions resulting in the lowest production of these unwanted by-products. The project is executed jointly by University Twente and TU Delft with TU Delft contributing to the modeling part.

Progress

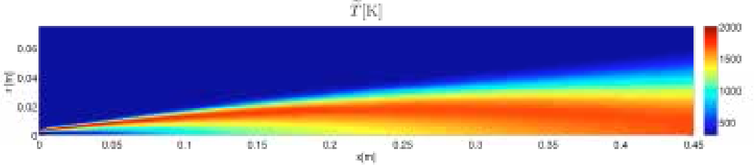
A main difficulty when modeling the formation of soot in turbulent flames are the non-linear interactions between turbulence, chemistry and soot formation. Moreover, the presence of soot greatly enhances radiative heat losses and hence there will be a strong interaction between soot formation and radiative heat transfer. Transported probability density function (PDF) methods have been developed in the past to account for turbulence-chemistry interaction. The PDF method was extended by including a two-equation soot model (developed by Brookes and Moss). To account for the radiative heat transfer, the radiative transfer equation was solved by means of an efficient Ray tracing technique, the so called discrete transfer method (DTM). The implementation of the DTM was combined with the PDF method. To test this newly developed method, two laboratory scale, non-premixed, methane-air flames at one and three bar pressure have been studied numerically. Analysis of the PDF results for the Brookes and Moss flames and laminar flame calculations revealed a strong influence of the radiative heat loss on the concentration of C2H2 (main soot precursor) and OH (main soot oxidation species). Therefore, in order to have an accurate representation of local composition, we developed a new method to create a Flamelet Generated Manifold (FGM). It uses an FGM constructed from transient solutions of laminar counterflow diffusion flames, including heat gain or heat loss from radiation. We applied it in CFD simulations of the one and three bar Brookes and Moss flames and found better agreement with experiments than when using the simpler approach in which heat loss only influences the temperature and not the composition.

Dissertations

-

Scientific Publications

1. Michael Stöllinger and Dirk Roekaerts, PDF modeling of soot formation and radiation in turbulent non-premixed flames, Abstract of Work-in-Progress poster, Proceedings of the Thirthy-Fourth International Symposium on Combustion, 2012.



Projectleaders

DJEM Roekaerts

Researchtheme

Complex dynamics of fluids

Participants

MK Stöllinger

Cooperations

JBW Kok (U Twente),
MF Woolderink (U Twente)

Funded

STW (CCC program)

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

Start of the project

2010

Information

DJEM Roekaerts
015 278 2418
d.j.e.m.roekaerts@tudelft.nl
www.pe.tudelft.nl/node/427
www.cleancombustionconcepts.nl

DNS MODELING OF COALESCENCE AND BREAKUP OF DROPLETS IN TURBULENT FLOW

PROJECTLEADERS
BJ Boersma
RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
BJ Boersma, WP Breugem, N Talebanfard
COOPERATIONS
-
FUNDED
FOM

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

START OF THE PROJECT
2010
INFORMATION
N Talebanfard
015 278 9111
n.talebanfard@tudelft.nl

PROJECT AIM

The objective of this project is to develop a numerical model for a large number of droplets colliding, deforming and evaporating. A coupled level set and volume of fluid method is applied to capture the interfaces in the computational domain while conserving mass and volume.

PROGRESS

Heat and mass transfer have been implemented in a multiple marker coupled level-set and volume-of-fluid method. The problem of heat transfer in falling, colliding and deforming droplets is considered.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. N. Talebanfard, B.J. Boersma, Numerical simulation of heat transfer of a spherical particle in an air stream, Proceedings of CHT12 symposium, England, 2012.

Turbulent flow and heat transfer near the critical point of CO2 using Direct Numerical Simulation (DNS)

Project Aim

The proposed test problem is the classical pipe flow. Fully developed isothermal turbulent pipe will enter a section where a constant heat flux is applied to the pipe wall. This configuration can be considered representative of a wide range of technical devices. The turbulent in flow will be taken from a fully developed pipe flow simulation with a bulk Reynolds number in the range of 5000-20000 while the temperature will be fixed slightly below the pseudo critical temperature. The heat flux at the wall will be fixed at a value which will bring the temperature locally just above the pseudo critical temperature. The local effect of heat addition on turbulence, friction, buoyancy, and the heat transfer coefficient will be studied in detail.

Progress

I started to get to know the Linux, DNS, MPI (Massage passing Interface) etc. by reviewing literatures. I got the DNS code (pipe) written by Bendiks Jan Boersma. I could produce the results of J.G.M. Eggels for a periodic pipe. After that I implemented energy equation is the code and I could change the pipe from periodic boundary condition to a open boundary condition (Re=5300). The code works for constant thermo-physical properties. For the inlet velocity boundary condition we take the data of a plan of periodic pipe. The code also works for ideal gas. Next step is to produce the results for real super-critical CO2 that is almost done.

Dissertations

-

Scientific Publications

-

Projectleaders

BJ Boersma, R Pecnik

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Hassan Nemati, Dr. Rene Pecnik
Prof. Bendiks Jan Boersma

Cooperations

TUD

Funded

Iran and TU Delft

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

Start of the project

2012

Information

H Nemati
015 278 1862
h.nemati@tudelft.nl
www.pe.tudelft.nl/Chairs/ET/People

Investigation of heat transfer to turbulent supercritical fluids by means of direct numerical simulation

Projectleaders
M Rohde

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
JWR Peeters, BJ Boersma, R Pecnik, THJJ van der Hagen, M Rohde

Cooperations
-

Funded
STW

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

Start of the project
2012

Information
JWR Peeters
015 278 6628
j.w.r.peeters@tudelft.nl
http://pe.tudelft.nl/node/603

Project Aim

Heat transfer to supercritical fluids shows exotic behaviour, due to sharp fluid property changes. As a result, it is difficult, if not impossible, to accurately predict heat transfer to such fluids. The goal of this project is to investigate the complex physics involved and to develop an accurate design correlation for the prediction of heat transfer to supercritical fluids. With Direct Numerical Simulations, it is possible to investigate the physics involved in great detail. These investigations will then be used for the design of a heat transfer relation.

Progress

A 6th order precision finite difference/spectral code has been developed to solve the low-Mach number Navier-Stokes equations in an annular geometry. The code has been validated against various analytical cases (heat transfer to laminar fluids with variable fluid properties), as well as turbulent Direct Numerical Simulation cases (heat transfer to fluids with constant fluid properties) with good results. The code is currently being validated against experimental results (heat transfer to strongly heated gas).

Dissertations

-

Scientific Publications

-

Fluid dynamics of flows evolving close to the liquid-vapor critical point

Project Aim

The aim of the project is the study, modeling, and simulation of compressible flows evolving close to the liquid-vapor critical point. This thermodynamic region is very attractive for the new generation energy conversion systems (e.g., organic Rankine cycles or supercritical CO2 Brayton cycles turbines). Particular attention will be focused on the analysis of the numerical aspects of real gas RANS simulations (e.g., properties and fluxes evaluation). The theoretical and numerical study of the two phase flow regime in the proximity of the critical point will also be one of the main research topics. The ability to correctly estimate the parameters of general interest for the energy systems (e.g., efficiency) will be of primary interest.

Progress

The Reynolds-averaged Navier—Stokes solver was enriched with multiple options for the real gas convective fluxes. The look-up table approach for themophysical properties evaluation was improved, and more accurate interpolation functions were implemented. An extended analysis of the tables interpolation performance was carried out. An in-house meshing tool was completed and applied for the analysis of a complete scCO2 radial compressor (including the tip clearance gap and the vaned diffuser). Results were submitted to the ASME Turbo Expo 2013 conference. The comparison with experimental data shown an improved prediction capability. The detailed analysis of the numerical aspects of real gas RANS simulations (e.g., importance of properties evaluation, fluxes and Jacobians definition, convergence of steady state problems, etc.) was performed and is still under investigation.

Dissertations

-

Scientific Publications

1. Rinaldi, E., Pecnik, R., and Colonna, P., Steady state CFD investigation of a radial compressor operating with supercritical CO2, Submitted to the ASME Turbo Expo Conference 2013.
2. Rinaldi, E., Pecnik, R., and Colonna, P.; Eberhardsteiner, J., Böhm, H. J., and Rammerstorfer, F. G. (Eds.), Accurate and Efficient Look-up Table Approach for Dense Gas Flow Simulations, 6th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), Vienna University of Technology, Austria, 2012, 1-15.
3. Pecnik, R., Rinaldi, E., and Colonna, P., Computational Fluid Dynamics of a Radial Compressor Operating With Supercritical CO2, Journal of Engineering for Gas Turbines and Power, ASME, 2012, 134, 122301.

Projectleaders

P Colonna

Researchtheme

Complex dynamics of fluids

Participants

Piero Colonna, Rene Pecnik, Enrico Rinaldi

Cooperations

-

Funded

TU Delft

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

Start of the project

2011

Information

P Colonna
015 278 2172
p.colonna@tudelft.nl
www.pe.tudelft.nl/ET/PieroColonna

Direct numerical simulation of droplet formation in annular two-phase flow

Projectleaders
BJ Boersma
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
Sawat Poomsawat
Cooperations
-
Funded
Faculty of Engineering at Kamnhaeng Saen, Kamphaeng Saen Campus Kasetsart University Thailand. & TU Delft

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

Start of the project
2010
Information
S Poomsawat
015 278 2186
S.Poomsawat@tudelft.nl
www.pe.tudelft.nl/ET/Sawat

Project Aim

This project is aim to enhance the understanding of the mechanisms of droplet formation from liquid film in annular flow by Direct Numerical Simulation. A DNS code is developed and used to study the wave generation and the droplet breakup mechanism in three dimensional. A combined Volume of Fluid and Level Set method is used to define the interface between two phases. The accuracy of the model will be validated against analytical solutions and experiment results.

Progress

The interfacial instability of the turbulence flow overs a thin film was performed by 3D Direct Numerical Simulation. Firstly, the flat interface between two fluids was used in the simulation to determine the base flow of both fluids. Then we started a new simulation with interfacial disturbance by replacing the flat interface by a small amplitude sinusoidal wave and using the simulated base flow from DNS as the initial flow field. The amplitude of the input mode was calculated by using Fourier Transform to extract the wave input mode from the others generated mode. The wave speed and growth rate from DNS show good agreement with the numerical solution of Orr-Sommerfeld linear stability theory.

Dissertations

-

Scientific Publications

-

Unraveling the inner-workings of flagellar synchronization

Project Aim

Motile cilia and flagella are micron sized hair-like cell projections and are central to variety of micro-scaled physical processes such as locomotion, fluid transport, mixing and mechanical signal transduction. The ability of cilia to generate micron-scale flow patterns is of tremendous interest in micro-system engineering and a source of inspiration for biomimetic microfluidic devices. The capacity of cilia to manipulate, mix and transport fluid relies on its unique ability to interact with the surrounding fluid by spontaneously beating and synchronizing. This PhD work is concerned with investigating fundamental mechanisms of fluid-structure interactions in microscale biolocomotion. More specifically, this project aims at identifying the minimal mechanical and dynamical ingredients necessary to achieve spontaneous beating and synchronization of flagella.

Progress

Building of the instrumentation in under way. Optical trap is built, though not yet calibrated. Piezo-stage is installed and micropipette aspiration assay is in place. Cell culture is also established.

Dissertations

-

Scientific Publications

-

Projectleaders

J Westerweel, BJ Boersma, DJEM Roekaerts, RAWM Henkes, JCR Hunt, G Ooms, B. Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

G Quaranta, DSW Tam

Cooperations

Dr. M.E. Aubin

Funded

TU Delft

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

Start of the project

2013

Information

D TAM
015 278 2991
D.S.W.Tam@tudelft.nl

Prof.dr.ir. RHM Huijsmans

Prof.dr.ir. TJC van Terwisga

Seakeeping and Manoeuvring - prof. RHM Huijsmans

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.

ComFLOW-3 : Extreme wave impact on offshore platforms and coastal structures

Project Aim

To further improve, develop and validate the ComFLOW program for complex free-surface flows in the offshore industry and make it useable for advanced engineering applications by improved functionality and speed-up of the algorithms.

Progress

Implementation of local grid refinement is further improved. Testing of the turbulence models continues along with further modification especially regarding the filtering. New Volume-of-fluid (VOF) method is implemented and the testing still continues. Moving body feature is added to the program specifications. Parallelization and several other speed-up modifications are incorporated into the program. Dispersive directional absorbing boundary condition is currently investigated.

Dissertations

-

Scientific Publications

1. Duz, B., Huijsmans, R.H.M., Wellens, P. R., Borsboom, M.J.A. and Veldman, A. E. P., "Application of an absorbing boundary condition in a wave-structure interaction problem", Proceedings of the 31st International Conference on Ocean, Offshore and Arctic Engineering, OMAE 2012-83744, Rio de Janeiro, Brazil.

Projectleaders

AEP Veldman, RHM Huijsmans

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Bulent Duz (TUDelft), Henri J.L. van der Heiden (RUG), Peter van der Plas (RUG), Roel Luppes (RUG).

Cooperations

RUG, TUDelft, Marin, Deltares, Force Technology (Oslo)

Funded

STW, Force Technology (Oslo), Deltares, Marin, Hyundai, ABS, Gusto MSC, Aker Solutions, Chevron, Petrobras, Statoil, Conocophillips, DNV.

University	-
FOM	-
STW	63 %
NWO Other	-
Industry	37 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2010

Information

T Bunnik
0317 49 34 29
t.bunnik@marin.nl

Active motion control of fast ships

Projectleaders
RHM Huijsmans, JA Keuning
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
Ir. A.A.K. Rijkens
Cooperations
-
Funded
IOP Maritiem, TU Delft, Damen Shipyard Group, Ministry of Defense MARIN, Bureau Veritas, Lloyd's Register, Imtech Marine & Offshore, Quantum Controls

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

Start of the project
2011
Information
AAK Rijkens
015 278 6872
a.a.k.rijkens@tudelft.nl
www.3me.tudelft.nl/mtt

Project Aim

The aim of the PhD project is to develop an advanced ride control system for fast ships in order to improve its seakeeping behavior. The motions of these ships can be controlled by use of active flaps or interceptors located at the stern of the vessel. This project focuses on the control of these mechanisms by a proactive system that uses wave information at some distance in front of the bow. A very fast onboard simulation routine will be used to find the optimal settings of the control devices to increase the operability of the vessel in a seaway.

Progress

A systematic series of model tests has been carried out in the towing tank of the Delft University of Technology to determine the hydrodynamic characteristics of (fast) oscillating transom flaps and interceptors. The experimental results are implemented in a conceptual computer model that simulates the dynamics of a fast ship in waves. This conceptual model is used to develop a proactive control strategy that controls both the forward speed of the ship as well as the settings of the control mechanisms. The model demonstrates that an increase in operability can be realized by reducing the vertical peak accelerations while maintaining a high average forward speed.

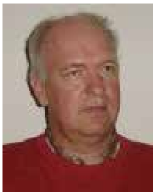
Dissertations

-

Scientific Publications

-

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.

Modeling of rock-water-mixtures in cutter suction heads

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

The project started in November 2012. In the two months the literature was assessed and the processes in the cutter head were studied. This resulted in a preliminary report on the state-of-the-art knowledge on mixing in dredge cutter heads.

Dissertations

-

Scientific Publications

-

.

Projectleaders

C van Rhee, RFJ Neelissen

Researchtheme

Complex dynamics of fluids

Participants

GH Keetels, AM Talmon,
IK van Giffen, PJ Steinbusch,
A van Es

Cooperations

Royal Boskalis Westminster,
van Oord

Funded

Stichting Speurwerk Baggertechniek (SSB)

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

Start of the project

2012

Information

B Nieuwboer
015 278 9296
B.J. Nieuwboer@tudelft.nl

Reduction of hydroabrasive wear in the dredging industry

Projectleaders
C van Rhee
Researchtheme
Complex dynamics of fluids
Participants
EA Chemmalasseri, G Keetels,
AM Talmon
Cooperations
Boskalis, Van Oord, IHC Merwede
MTI
Funded
Materials Innovation Institute

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

Start of the project
2012
Information
EA Chemmalasseri
015 278 7430
E.A.Chemmalasseri@tudelft.nl

Project Aim

Pipelines used for slurry transport in dredging applications have been observed to wear in some projects up to about 1 mm per month. On-board tubing may even wear faster. This project originates from a long-standing wish to accurately predict service life of components on dredging vessels and to prolong service life in an economic way. The scientific aim of the project is to quantify the wear rate from the actual physical wear processes, providing a scientific basis for the suggestion of methods to improve the service life of equipment for hydro transport systems in dredging.

Progress

The project is currently at the literature review stage. Literature regarding microscopic mechanisms governing wear in slurry pipelines, models describing wear, and previous attempts to couple hydrodynamics of slurry flow and wear models is being studied. At the end of this stage, the literature will be documented in the form of a report.

Dissertations

-

Scientific Publications

-

CFD2 Phase

Project Aim

The project aim is to numerical model the hydrodynamical behavior of water/sediment mixtures. This is done using constitutive relations, modeling sediment, and the Navier-Stokes equations. The resulting differential equations are solved using numerical techniques. The sediment fractions are described as a contiunuum, reducing calculation costs.

Progress

The followingh actions have been done in 2010 : set up a numerical framework solving the Navier-Stokes equations, using the Fractional Step Method of Chorin (3D); modeling different advection schemes such as first order upwind and various fluxlimiters; modeling Turbulence using LES; literature review of modeling wallfunctions (e.g. Thin Boundary Layer Equatuions)

The following actions have been done in 2011 : Implemented the WALE turbulence model (LES); Added a drift flux model for modeling sand fractions of different sizes; implemented wallfunctions; implemented various other numerical schemes e.g. quick algorithm; convergence study

The following actions have been done in 2012 : Added a rheological model Bingham; Added sand viscosity Thomas; Added sedimentation; extended the drift flux model with accelerations; Compared model with experimental results sedimentation; Added penalty method for sand bed modeling.

Dissertations

-

Scientific Publications

-

Projectleaders

C van Rhee

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

J Goeree, C van Rhee, A Talmon, C van Rhee.
TUDelft: C van Rhee/A Talmon
IHC: E van der Blom / H Bugdayci / H Van Muijen / EA Munts / H Bugdayci
Utwente: H Hoeijmakers / N Kruijt

Cooperations

TUDelft, Utwente, AgentschapNL, IHCMerwede BV

Funded

IHCMerwedeBV/AgentschapNL

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

Start of the project

2010

Information

C van Rhee, J Goeree
015 278 3297
j.c.goeree@tudelft.nl

An experimental and numerical study of vertical hydraulic transport for deep sea mining applications

Projectleaders
C van Rhee

Researchtheme
Complex dynamics of fluids

Participants
JM van Wijk, AM Talmon

Cooperations
-

Funded
IHC Merwede

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

Start of the project
2008

Information
JM van Wijk
06 48 92 96 78
JM.vanWijk@mtiholland.com
jortvanwijk@tudelft.nl

Project Aim

To assess flow assurance of the vertical hydraulic transport process, especially the risk of riser blockage is studied.

Progress

Conducted two experiments:

- fluidization test to verify hindered settling theory of particles in a riser with d/D > 0.1
- closed flowloop experiments to investigate the effect of suspended solids on the axial dispersion process in a riser
- constructed a test setup with a 8m riser to investigate the mechanism leading to the formation of plugs of solids in the riser
- built a dynamic 1D model of a vertical hydraulic transport system in which experimentally verified models for particle transport velocities, axial dispersion and wall friction can be included.

Dissertations

-

Scientific Publications

1. Wijk, J.M. van; Talmon, A.M. and Rhee, C. van (2012) Flow Assurance of Vertical Solid-Liquid Two Phase Riser Flow During Deep Sea Mining. Offshore Technology Conference, May 2012, Houston, TX USA.

PROJECT AIM

The aim is to understand the complex mixing of a water-silt-sand-air plume from a dredge vessel with the ambient water. Numerical simulations are carried out for this purpose. Also scale (1:50) and field (1:1) measurements are planned. Due to the non stationary behaviour of a dredge plume the numerical approach is to use LES and not RANS. A big challenge is the large scale of the simulations with very high Reynolds numbers (up to 10 million) on relatively coarse meshes. The end goal is to find the amount of silts (fine sediments) originating from the dredge plume which stay suspended in the water column after the transition to a passive plume has taken place.

PROGRESS

- Model validation with laboratory experiments
- Model validation with field measurements near dredging vessels
- Writing of 2 journal papers, 1 paper submitted December 2012 to J. of Flow Turbulence and Combustion, 1 submitted February 2013 in J. of Hydraulic Engineering.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Wit, L. d. and C. van Rhee (2012). Testing different advection schemes for coarse high re les simulations of jet in crossflow and coflow. Proceedings of ETMM9.

PROJECTLEADERS

C van Rhee

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

L de Wit

COOPERATIONS

-

FUNDED

Building with Nature

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

START OF THE PROJECT

2008

INFORMATION

L de Wit
015 278 3583
l.dewit@tudelft.nl

NUMERICAL ANALYSIS

Prof.dr.ir. C Vuik

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 speciality 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.

Mathematical investigation into smoothness-increasing accuracy-conserving methods for streamline visualization

Project Aim

The purpose of the proposed research is the mathematical and algorithmic development of smoothness-increasing accuracy-conserving filters with application to post-processing and visualizing discontinuous Galerkin simulation results.

Progress

This past year focused on the theoretical and computational viability of the SIAC filter for applications. Specifically, we were able to demonstrate the efficiency of the filter computationally as well as applicability with GPU computing. Computational investigations into the correct kernel scaling were performed. Additionally, computationally efficient boundary filters where developed.

Dissertations

-

Scientific Publications

1. J. King, H. Mirzaee, J.K. Ryan, and R.M. Kirby, "Smoothness-Increasing Accuracy-Conserving (SIAC) Filtering for discontinuous Galerkin Solutions: Improved Errors Versus Higher-Order Accuracy," Journal of Scientific Computing, vol. 53 (2012), pp. 129-149.
2. H. Mirzaee, J.K. Ryan, and R.M. Kirby, "Efficient Implementation of Smoothness-Increasing Accuracy-Conserving (SIAC) Filters for Discontinuous Galerkin Solutions." Journal of Scientific Computing, vol. 52 (2012), pp. 85-112.

Projectleaders

JK Ryan

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

X Li

Cooperations

University of Utah, Salt Lake City, UT

Funded

European Office of Aerospace Research and Development/U.S. Air Force Office of Research and Development

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

Start of the project

2009

Information

JK Ryan
015 278 8755
J.K.Ryan@tudelft.nl
http://ta.twi.tudelft.nl/NW/users/ryan/

Projectleaders
C Vuik, A Segal

Researchtheme
Complex dynamics of fluids

Participants
C Vuik, A Segal, JM Tang, R Nabben

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

Funded
TUD, TNO-TPD, BRICKS

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

Start of the project
1996

Information
C Vuik
015 278 5530
c.vuik@tudelft.nl
http://ta.twi.tudelft.nl/users/vuik

Project Aim

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

Progress

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

Dissertations

-

Scientific Publications

1. T.B. Jonsthovel and M.B. van Gijzen and S. MacLachlan and C.Vuik and A. Scarpas. Comparison of the deflated preconditioned conjugate gradient method and algebraic multigrid for composite materials. Computational Mechanics, 50, pp. 321-333, 2012.
2. S.P. Pereira and C. Vuik and F.T. Pinho and J. M. Nobrega. Porting a 2D Unstructured CFD code from the CPU to the GPU. Proceedings of the 6th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), September 10-14, 2012, Vienna, Austria Editors: H.A. Mang and J. Eberhardsteiner and H.J. Bohm and F.G. Rammerstorner ECCOMAS, 2012, CDROM, ISBN: 978-3-9502481-9-7.
3. F.J. Lingen and P.G. Bonnier and R.B.J. Brinkgreve and M.B. van Gijzen and C. Vuik. A parallel linear solver exploiting the physical properties of the underlying mechanical problem. Delft University of Technology. Delft Institute of Applied Mathematics Report 12-12.

Solution methods for Navier-Stokes problems

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. P. van Slingerland and C. Vuik. Fast linear solver for pressure computation in layered domains. Delft University of Technology. Delft Institute of Applied Mathematics. Report 12-10.
2. P. van Slingerland and C. Vuik. Scalable two-level preconditioning and deflation based on a piecewise constant subspace for (SIP)DG systems. Delft University of Technology. Delft Institute of Applied Mathematics. Report 12-11.

Projectleaders

C Vuik

Researchtheme

Complex dynamics of fluids

Participants

C Vuik, S Maclaclan, Geenen, A Segal, P van Slingerland

Cooperations

TNO-Science and Industry
Utrecht University, Sepra Tufts University USA, MARIN

Funded

STW, TUD, TNO-Science and Industry, Nuffic-HEC, MARIN

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

Start of the project

1992

Information

C Vuik
015 278 5530
c.vuik@tudelft.nl
http://ta.twi.tudelft.nl/users/vuik

PROJECTLEADERS
C Vuik, FJ Vermolen
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
D Ibrahim, FJ Vermolen, C Vuik, WK van Wijngaarden-van Rossum
COOPERATIONS
-
FUNDED
Deltares

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

START OF THE PROJECT
2007
INFORMATION
FJ Vermolen
015 278 7298
F.J.Vermolen@tudelft.nl

PROJECT AIM

Develop numerical methods for industrial flow problems.

PROGRESS

PhD-candidate Ibrahim defended his PhD-thesis on the density-enthalpy method for two-phase flow in porous media. Furthermore, analytical solutions for a model for biogrout, consisting of a system of hyperbolic partial differential equations has been developed. Next to the analytic solution, a numerical formalism capable of treating boundary conditions on complicated manifolds has been constructed successfully. The method is based on the solution of the Darcy equation on the manifold using an streamline upwinding-like technique. The novel method proves to be very robust with good accuracy properties due to the need of only a very small upwinding contribution.

DISSERTATIONS

1. Ibrahim. The density-enthalpy method applied to model two-phase Darcy flow. Delft University of Technology, May 31, 2012.

SCIENTIFIC PUBLICATIONS

1. Ibrahim, F.J. Vermolen, C. Vuik. On the density-enthalpy method for the 2D-Darcy flow. Enumath 2012 proceedings, Springer Series (2012).
2. W.K. van Wijngaarden, F.J. Vermolen, G.A.M. van Meurs, C. Vuik. A mathematical model for Biogrout: bacterial placement and soil reinforcement, Computational Geosciences, DOI 10.1007/s10596-012-9316-6, (2012).
3. W.K. van Wijngaarden, F.J. Vermolen, G.A.M. van Meurs, C. Vuik. Various flow equations to model the new soil improvement method Biogrout, Enumath 2012 proceedings, Springer Series (2012).
4. W.K. van Wijngaarden, F.J. Vermolen, G.A.M. van Meurs, C. Vuik. A mathematical model and analytical solution for the fixation of bacteria in Biogrout, Transport in Porous Media (2012) 92: 847--866, DOI 10.1007/s11242-011-9937-0.
5. S. Mazumder, F.J. Vermolen, J. Bruining. Analysis of a model for anomalous diffusion behavior of CO$_2$ in the macromolecular network structure of coal and its significance for CO$_2$ sequestration, SPE J. (2012) 16 (4): 856--863. SPE-109506-PA. http://dx.doi.org/10.2118/109506-PA.

Two-phase respiratory flow

Project Aim

The purpose of the project is to extend the Mass Conserving Level Set method to complex domains, by a reformulation for unstructured discretisation of the flow equations, specifically to be able to model two-phase flow in the human respiratory system.

Progress

The model for the evolution of the interface of the Mass Conserving Level-Set method has been extended to a discretisation on triangular control volumes, leading to a formulation with complexity that is comparable to the formulation for the Cartesian case. The method accurately conserves mass on general triangular grids. The baseline algorithm has now to be complemented by a reinitialization strategy for the level set function to handle more intricate interface shapes. A number of these strategies are under investigation.

Dissertations

-

Scientific Publications

-

Projectleaders

C Vuik, DR van der Heul

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

F Raees

Cooperations

-

Funded

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

Start of the project

2011

Information

DR van der Heul
015 278 2632
D.R.vanderHeul@tudelft.nl

Rigorous modeling of 3D wave propagation

Projectleaders
C Vuik, CW Oosterlee
Researchtheme
Complex dynamics of fluids
Participants
C Oosterlee, C Vuik, D Lahaye, A Sheikh
Cooperations
TUD Chem.Tech, Philips, Shell, NLR, TU Berlin
Funded
SenterNovem, NLR, Nuffic

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

Start of the project
2001
Information
C Vuik
015 278 5530
C.Vuik@tudelft.nl
http://ta.twi.tudelft.nl/users/vuik

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

-

Numerical methods for phase transformations in metals and alloys

Project Aim

Develop numerical methods for moving boundary problems and evolution of the statistical size distribution of particles.

Progress

A fully finite-element-based level-set method for the dissolution and growth of secondary phases in metals has been developed. We implemented an efficient reinitialization technique based on elementary principles for the computation of distances in a neighborhood of an interface. Further, a Slyozov-Lifschitz model for the evolution of the statistical distribution of the particle size has been extended succesfully to multi-phase and multi-component alloys.

Dissertations

-

Scientific Publications

1. D. den Ouden, F.J. Vermolen, L. Zhao, C. Vuik, J. Sietsma. Application of the level--set method to a mixed--mode and curvature driven Stefan problem, Enumath 2012 proceedings, Springer Series (2012).

Projectleaders

FJ Vermolen

Researchtheme

Complex dynamics of fluids

Participants

D den Ouden, FJ Vermolen, C Vuik, L Zhao, J Sietsma

Cooperations

-

Funded

M2i (Materials, Metals Innovation)

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

Start of the project

-

Information

FJ Vermolen
015 278 7298
F.J.Vermolen@tudelft.nl
http://ta.twi.tudelft.nl/users/vermolen

PROJECTLEADERS
FJ Vermolen
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
S Zemskov, FJ Vermolen
COOPERATIONS
-
FUNDED
DCMat (Delft Centre of Materials)

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

START OF THE PROJECT
-
INFORMATION
FJ Vermolen
015 278 7298
F.J.Vermolen@tudelft.nl
http://ta.twi.tudelft.nl/users/vermolen

PROJECT AIM

Develop models and methods for the simulation of self-healing of materials.

PROGRESS

A model for bacterial self healing of concrete has been developed. The model is based on two coupled moving boundary problems.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. S.V. Zemskov, H.M. Jonkers, F.J. Vermolen. A mathematical model for bacterial self--healing of cracks in concrete, Journal of Intelligent Material Systems and Structures, (2012), DOI: 10.1177/1045389X12437887.
2. S.V. Zemskov, H.M. Jonkers, F.J. Vermolen. Mathematical models to predict the critical conditions for bacterial self--healing of concrete. Lecture Notes in Computational Science: Mathematical Modeling and Computational Science, Springer-Verlag, Berlin--Heidelberg (2012) 108--127.
3. J E. Javierre, J.M.C. Mol, S. Garcia, F.J. Vermolen, C. Vuik, S. van der Zwaag. Tailoring the release of encapsulated corrosion inhibitors from damaged coatings: controlled release kinetics by overlapping diffusion fronts, to appear in Progress in Organic Coatings (2012).

Project Aim

Develop numerical methods for several problems related to health issues.

Progress

PhD-candidate Prokharau defended his PhD-thesis on the bone regeneration around endosseous implants. A formalism for the modeling of cell differentiation using maturation principles, giving a semi-deterministic approach has been implemented succesfully. The apposition of bone is modeled through a moving boundary problem in two physical dimensions and a dimension for the maturation space. A model for wound healing on a cell-colony based approach has been implemented and successfully applied to modeling infectious wound healing. The formalism will be applied to model tumor growth and initiation. Furthermore, a model for cell deformation and migration has been developed. This model is applied to simulate the immune system.

Dissertations

1. P.A. Prokharau. Modeling bone regeneration around endosseous implants, Delft, 2012, November 1.

Scientific Publications

1. P.A. Prokharau, F.J. Vermolen, J.M. Garcia--Aznar. Model for direct bone apposition on pre--existing surfaces, during peri--implant osseointegration, Journal of Theoretical Biology, 304 (2012) 131--142.
2. F.J. Vermolen, O.W.M van Rijn. A mathematical model for wound contraction and angiogenesis. Book Chapter In: Tissue Regeneration: From Basic Biology to Clinical Application, Intech Open Science, DOI: 10.5772/26507, (2012).
3. F.J. Vermolen, A. Gefen. A phenomenological model for chemico--mechanically induced cell shape changes during migration and cell--cell contacts, to appear in Biomech Model Mechanobiol (2012).
4. P.A. Prokharau, F.J. Vermolen. Stability analysis for a peri--implant osseointegration model, Journal of Mathematical Biology (2012) DOI 10.1007/s00285-012-0513-1.
5. F.J. Vermolen, A. Gefen, J.W.C. Dunlop. In--vitro 'wound' healing: Experimentally-based phenomenological modeling, Advanced Engineering Materials (2012) 14(3): B76--B88, 10.1002/adem.201180080.
6. F.J. Vermolen, E. Javierre. A finite--element model for healing of cutaneous wounds combining contraction, angiogenesis and closure, Journal of Mathematical Biology (2012) DOI 10.1007/s00285-011-0487-4.
7. F.J. Vermolen, A. Gefen, J.W.C. Dunlop. In--vitro 'wound' healing: Experimentally-based phenomenological modeling, Advanced Engineering Materials (2012) 14(3): B76--B88, 10.1002/adem.201180080.
8. F.J. Vermolen, A. Gefen. A semi--stochastic cell-based formalism to model the dynamics of migration cells in colonies. Biomech Model Mechanobiol, 11 (2012) 183--195, DOI 10.1007/s10237-011-0302-6.

Projectleaders

FJ Vermolen

Researchtheme

Complex dynamics of fluids

Participants

PA Prokharau, D Koppenol, A Gefen, FJ Vermolen

Cooperations

\-

Funded

Dutch Burns Foundation

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

Start of the project

\-

Information

FJ Vermolen
015 278 7298
F.J.Vermolen@tudelft.nl
http://ta.twi.tudelft.nl/users/vermolen

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

Projectleaders
C Vuik, DR van der Heul

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
J van Zwieten

Cooperations
Shell

Funded
Shell

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

Start of the project
2011

Information
DR van der Heul
015 278 2632
D.R.vanderHeul@tudelft.nl

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 numerical model for one-dimensional multiphase pipe flow based on a discontinuous Galerkin discretisation has been realized. The model has been applied for a number of test cases and the results show improved accuracy of the solution in comparison with a finite volume discretisation for a given number of degrees of freedom. The model is currently extended to include h-p refinement and several strategies to handle the case of single-phase flow are investigated.

Dissertations

-

Scientific Publications

-

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

The function relating the volume of fluid to the level-set field that forms the heart of the Mass Conserving Level-Set method has been formulated for a cylindrical coordinate system and incorporated in an algorithm to solve the Navier-Stokes equations on cylindrical domains.

Dissertations

-

Scientific Publications

-

Projectleaders

DR van der Heul

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

G Oud

Cooperations

-

Funded

SHELL, DELTARES, TNO

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

Start of the project

2011

Information

DR van der Heul
015 278 2632
D.R.vanderHeul@tudelft.nl

Mathematical Physics

Prof.dr.ir. AW Heemink

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

The research aims at the design and implementation of high performance and parallel algorithms for sparse matrix computations. The applicability and limitations of the grid computing technology will also be investigated.

PROGRESS

In the project financed by the EU on the application of Grid Computing, the research focuses on power flow simulation of large electrical power systems. Work on multi-level preconditioning methods and Jacobian-free preconditioned Krylov type methods are currently under study for power flow analysis. In recent years, GPU (General-purpose graphical units) has been increasing applied as accelerators for number crunching computational problems, we have studied the problem of optimization of the sparse-matrix operations (SpMV) on GPUs.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Shiming Xu and Wei Xue and Ke Wang and Hai Xiang Lin, “Fast time domain simulation of power systems using multilevel preconditioners with adaptive reconstruction strategies”, Simulation Modelling Practice and Theory, Vol.25, 2012, pp. 90-105.
2. H.X. Lin, “Communication scheduling in parallel task executions on large parallel systems”, Indonesian Journal of Electronic Engineering (Special Issue of int’l conf. ICECCS’2012), Vol.10, 2012, pp.1151-1155.

PROJECTLEADERS
AW Heemink, HX Lin

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
HX Lin, SM Xu

COOPERATIONS
Tsinghua University, China,
GUCAS, China

FUNDED

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

START OF THE PROJECT
2005

INFORMATION
HX Lin
015 278 7229
H.X.Lin@tudelft.nl
http://mathematicalphysics.ewi.tudelft.nl

Data assimilation in CFD

Projectleaders
AW Heemink

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
M Rojas, R Hanea, UM Altaf, N van Velzen, M Verlaan, AW Heemink, I Garcia, JC Pelc, C Maris, S Szklarz

Cooperations
Deltares, RIVM, Shell, MIT, TNO, Vortech

Funded
Deltares, Shell, TNO, NWO

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

Start of the project
2001

Information
AW Heemink
015 278 5813
a.w.heemink@tudelft.nl

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 "Smart Wells" in corporation with the faculty CiTG, MIT and Shell have started. In these PhD projects we will develop and apply model reduction and filtering techniques for assimilating data into multi-phase flow models in order to solve reservoir engineering problems. New application areas are also ecological coastal sea models and morphodynamic models.

Dissertations

1. W. Lawniczak, Feature-based estimation for applications in reservoir engineering, PhD thesis Delft University of Technology, 2012, promotoren: A.W. Heemink and J.D. Jansen.

Scientific Publications

1. Efficient identification of uncertain parameters in a large-scale tidal model of the European continental shelf by proper orthogonal decomposition, Altaf, M. U., Verlaan, M., Heemink, A. W. INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN FLUIDS, Volume: 68, Issue: 4, Pages: 422-450, 2012.
2. Application of model reduced 4D-Var to a 1D ecosystem model, Pelc, Joanna S.; Simon, Ehouarn; Bertino, Laurent; et al., OCEAN MODELLING, Volume: 57-58, Pages: 43-58, 2012.

.

Flexible computational methods for transport applications

Project Aim

Our aim is to apply and develop flexible numerical methods for transport applications in real-life large-scale environmental studies.

Progress

The study of oil spill modeling for the Persian Gulf has been continued. A paper describing a simplified flow model has been submitted. Oil spill simulations have been done and a report presenting the results is in progress.

Dissertations

-

Scientific Publications

1. Badri A.M. and Wilders, P, Flow estimation for the Persian Gulf using a Kelvin wave expansion, Indian Journal of Marine Sciences, vol. 41(3), pp. 249-158, 2012.

Projectleaders

AW Heemink

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

P Wilders, MA Badri

Cooperations

Deltares, Isfahan University

Funded

EEMCS, Isfahan University

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

Start of the project

2009

Information

P Wilders
015 278 7291
p.wilders@tudelft.nl
http://mathematicalphysics.ewi.tudelft.nl

Perturbation methods for partial differential equations

Projectleaders
AW Heemink

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
WT van Horssen, HM Schuttelaars, JLA Dubbeldam, M Rafei, A Chernetsky, OV Pischans'kyy, SH Sandilo, T Akkaya, N Gaiko, R Ali, M Kumar, X Wei, MAK Bulelzai

Cooperations
-

Funded

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

Start of the project
2003

Information
WT van Horssen
015 278 3524
W.T.vanHorssen@tudelft.nl
http://math.ewi.tudelft.nl

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); and the dynamics of polymers in shear flow.

Progress

In 2012 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. M. Rafei, On asymptotics for difference equations, TU-Delft, 02 February 2012, promotor: A.W. Heemink; co-promotor: W.T. van Horssen.
2. O.V. Pischans'kyy, On a single degree of freedom oscillator with a time-varying mass, TU-Delft, 31 January 2012, promotor: A.W. Heemink; co-promotor: W.T. van Horssen.
3. A.S. Chernetsky, Trapping of sediment in tidal estuaries, TU-Delft, 10 April 2012, promotor: A.W. Heemink; co-promotor: H.M. Schuttelaars.

Scientific Publications

1. Entrance/exit losses and cross-sectional stability of double inlet systems, R.L. Brouwer, J. van de Kreeke, H.M. Schuttelaars. Estuarine Coastal and Shelf Science 107, pp. 69-80.
2. Quasi-static analysis of two-dimensional rolling contact with slip-velocity dependent friction, E.A.H. Vollebregt, H.M. Schuttelaars. Journal of Sound and Vibration 331 (9), pp. 2141-2155.
3. Importance of cross-channel bathymetry and eddy viscosity parameterization in modeling estuarine flow, T.J. Zitman, H.M. Schuttelaars. Ocean Dynamics 62 (4), pp. 603-631.
4. Analysis of Tidal Straining as Driver for Estuarine Circulation in Well-Mixed Estuaries, H. Burchard, H.M. Schuttelaars. Journal of Physical Oceanography 42 (2), pp. 261-271.
5. Solving systems of nonlinear difference equations by the multiple scales perturbation method, M. Rafei, W.T. van Horssen. Nonlinear Dynamics 69 (4), pp. 1509-1516.
6. On the nonlinear dynamics of a single degree of freedom oscillator with a time-varying mass, O.V. Pischanskyy, W.T. van Horssen. Journal of Sound and Vibration 331 (8), pp 1887-1897.
7. On Boundary Damping for an Axially Moving Tensioned Beam, S.H. Sandilo, W.T. van Horssen. Journal of Vibration and Acoustics-Transactions of the ASME 134 (1), nr. 011005
8. Forced translocation of a polymer: Dynamical scaling versus molecular dynamics simulation, J.L.A. Dubbeldam, V.G. Rostiashvili, A. Michev, T.A. Vilgis. Physical Review E 85 (4), nr. 041801.
9. Long time evolution of atherosclerotic plaques, M.A.K. Bulelzai, J.L.A. Dubbeldam. Journal of Theoretical Biology 297, pp. 1-10.

Transport Phenomena

Prof.dr.ir. CR Kleijn

Prof.dr. RF Mudde

Prof.dr.ir. HEA van den Akker

Prof.dr.S Sundaresan

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

Modelling of interface evolution in advanced welding (MintWeld)

Project Aim

The MINTWELD project aims to improve welding processes by using simulation models working on a range of length scales and knowledge gained from industrial experiments. Our contribution is to develop computational models for the prediction of the influence of hydrodynamics on the interface evolution in advanced welding processes.

Progress

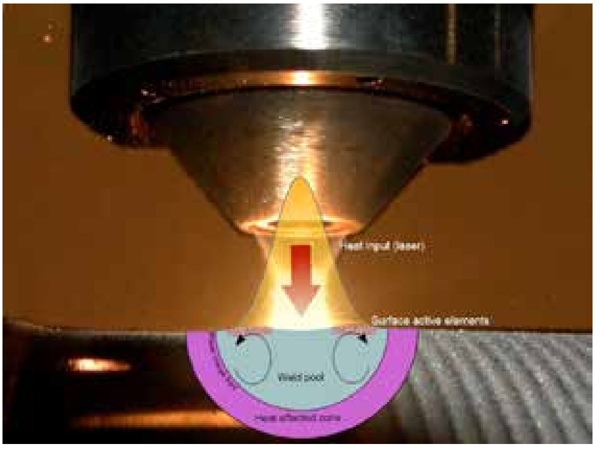
We have completed a software tool to predict laser welding processes, which requires the simulation of the transient flow of molten steel driven by thermocapillary forces, the dynamics of the liquid free surface as well as the heat distribution in the base metal and the final weld pool shape, both of which are highly dependent on the flow within the pool. Furthermore, we have developed code to enable the simulation of arc welding processes, which require the computation of the current distribution in the weld, the resulting Lorentz forces, and the inclusion of the shear exerted by the arc on the liquid pool. The code has been extensively validated against test cases from literature as well as experimental welding trials conducted at TUD-3ME. Results obtained so far demonstrate the strong influence of surfactants on the welding process and confirm the importance of surface tension differences as a main driving force.

Dissertations

1. Z.S. Saldi, Marangoni driven free surface flows in liquid weld pools.

Scientific Publications

-



Projectleaders

CR Kleijn, S Kenjeres

Researchtheme

Complex dynamics of fluids

Participants

A Kidess, CR Kleijn, S Kenjeres

Cooperations

Prof. Ian Richardson, Dr. Chuangxin Zhao (both TU Delft Materials Science and Engineering)
University of Leicester; University College Dublin; University of Oxford; Norwegian Institute of Science and Technology; Royal Institute of Technology Stockholm; Ecole Polytechnique Federale de Lausanne; Tata Steel UK; TWI; Frenzak; Polish Welding Centre of Excellence

Funded

EU FP7

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

Start of the project

2009

Information

CR Kleijn
015 278 2835
C.R.Kleijn@TUDelft.NL
www.msp.tudelft.nl

Numerical flow simulations on improved continuous casting through electromagnetic flow control

Projectleaders
CR Kleijn, S Kenjereš, M Tummers

Researchtheme
Complex dynamics of fluids

Participants
B Righolt

Cooperations
Tata Steel, ABB

Funded
STW, Tata Steel, ABB

University	-
FOM	-
STW	88 %
NWO Other	-
Industry	12 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2010

Information
BW Righolt
015 278 7084
b.w.righolt@tudelft.nl

Project Aim

The aim of the project is to provide a fundamental understanding of, and experimentally validated models for, the influence of electromagnetic fields on flow, turbulence and heat transfer in liquid steel during continuous casting. These insights and models will make it possible to design and to optimize new strategies for controlling steel casting processes, leading to significant energy savings, increased productivity and improved product quality.

Progress

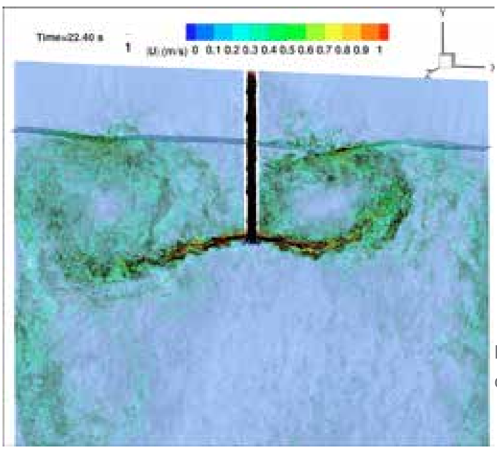
An analytical model has been developed for the combined free surface and magnetohydrodynamic flow. The flow features and free surface deformation for a special case have been derived. The analytical model has been used for the validation of two numerical solvers including free surface flow and magnetohydrodynamic forces in OpenFOAM. The first numerical solver is a Volume Of Fluid solver and the second a Moving Mesh Interface Tracking method. Furthermore, the accurate modeling (see figure below) of the experimental facility shows the agreement with the sub-surface flow features experimentally observed, with respect to size and location of recirculation zones. Also, preliminary numerical models have shown the applicability of the present models to numerically predict the heat transfer and electromagnetic forcing of a continuous steel caster.

Dissertations

-

Scientific Publications

-



Large Eddy Simulation of the turbulent flow in a continuous caster model at Re_{jet}=12,500

Flow and chemical breakthrough in protective textiles

Project Aim

The goal of this project is to develop predictive models for the protective behavior and thermal comfort of Nuclear-Biological-Chemical protective textiles, with a special focus on chemical breakthrough. We study air flow, heat and mass transfer through the textile at multiple scales, ranging from that of the textile fibers and carbon particles to that of an entire person, in combination with the penetration of both gaseous and liquid toxic components.

Progress

The protection factor and pressure drop coefficient of single layers of active carbon particles in protective garments have been computed from computational fluid dynamics simulations of airflow and mass transport. A closed-form analytical model has been proposed for the protection factor and the pressure drop coefficient as a function of layer porosity, particle diameter, and cross airflow velocity. This model has been validated against experimental data in literature. It can be used to find an optimal compromise between high protection factor and low pressure drop coefficient. We developed a computational model for flow, heat and mass transfer to a solid cylinder, mimicking a limb, sheathed by CBRN protective garment material, and exposed to a turbulent cross flow of air with a tracer amount of hazardous gas. The computational model has been successfully validated against published experimental data. The model shows that, for realistic conditions, the introduction of a single layer of carbon material with an open area fraction as large as 0.6 reduces the mass deposition of tracer gas onto the cylinder by one to three orders of magnitude, whereas heat transfer is decreased by tens of percents, thus optimizing the balance between protection and thermal comfort.

Projectleaders
CR Kleijn

Researchtheme
Complex dynamics of fluids

Participants
D Ambesis, CR Kleijn

Cooperations
TNO Defense and Security

Funded
TNO

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

Start of the project
2009

Information
CR Kleijn
015 278 2835
C.R.Kleijn@TUDelft.NL
www.msp.tudelft.nl

Dissertations

-

Scientific Publications

1. D. Ambesi and C.R. Kleijn (2012) ”Laminar forced convection heat transfer to ordered and disordered single rows of cylinders”, INTERNATIONAL JOURNAL OF HEAT AND MASS TRANSFER, 55 (21-22), 2012, pp. 6170-6180 DOI: 10.1016/j.ijheatmasstransfer.2012.06.038.
2. D. Ambesi and C.R. Kleijn (2012) “Laminar-forced convection mass transfer to ordered and disordered single layer arrays of spheres”, AIChE journal, (published online) doi: 10.1002/aic.13904.
3. Davide Ambesi , Richard Bouma, Emiel den Hartog and Chris R. Kleijn (2012), Predicting the chemical protection factor of CBRN protective garments, Journal of Occupational and Environmental health, VOL 10, ISS 5, #769842.
4. D. Ambesi and C.R. Kleijn (2012), “LAMINAR FORCED CONVECTION MASS TRANSFER TO ORDERED AND DISORDERED SINGLE LAYER ARRAYS OF MICRO-SPHERES”, In: Sushanta Mitra (ed.) Proceedings of the ASME 2012 10th International Conference on Nanochannels, Microchannels, and Minichannels, July 8-12, 2012, Rio Grande, Puerto Rico, paper #ICNMM2012-73022, ASME, New York, 9 pages.
5. D. Ambesi and C.R. Kleijn (2012) “Laminar forced convection heat transfer to a single layer of ordered and disordered spheres”, 6th European Thermal Sciences Conference, September 04 - 07, 2012, Poitiers, FRANCE, J. Phys.: Conf. Ser. 395 #012001.

Dynamic behavior of Taylor flow in distributed microreactor channel networks for large-scale processing

Projectleaders
CR Kleijn, MT Kreutzer
Researchtheme
Complex dynamics of fluids
Participants
Duong Anh Hoang
Cooperations
TU Eindhoven (J.C. Schouten)
Wageningen University (R. Boom)
OSPT-IROP (DSM, Shell, DOW, Akzo-Nobel, Unilever, TNO)
Funded
STW, OSPT-IROP IROP (DSM, Shell, DOW, Akzo-Nobel, Unilever, TNO)

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

Start of the project
2009
Information
CR Kleijn
015 278 2835
C.R.Kleijn@TUDelft.NL
www.msp.tudelft.nl

H Anh Duong
015 278 3210
h.a.duong@tudelft.nl
www.cheme.tudelft.nl

Project Aim

Segmented flow is widely used in microreactor (Process-on-a-Chip and Lab-on-a-Chip) technology because of its high mass transfer, low axial dispersion and rapid micromixing. The generation and control of segmented flow in a single microchannel is well-established. Numbering up towards large-scale processing, however, required techniques for the stable and controlled distribution of segmented flows over networks of channels. As yet, techniques and fundamental understanding of such distributions are limited. In this project, we study the generation and transport of droplets and bubbles in microfluidic networks that comprise a large number of parallel microchannels. The aim is to understand how to form and distribute streams of bubbles or droplets in such networks.

Progress

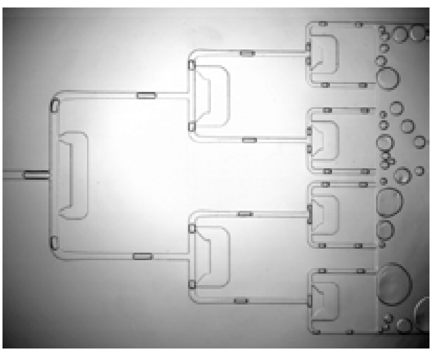
- Investigated and understood the mechanism of the rapid pinch-off during the breakup of droplets in T-junctions using 3-D numerical simulations.
- Designed and experimentally characterized a bubble-breakup-based distributor for multiple microreactor channel networks.

Dissertations

-

Scientific Publications

1. D. A. Hoang, V. Van Steijn, L. M. Portela, M. T. Kreutzer, and C. R. Kleijn (2012), "Modeling of low-capillary number segmented flows in microchannels using openfoam", 10th International Conference of Numerical Analysis and Applied Mathematics, Greece, in: Theodore E. Simos, George Psihoyios, Ch. Tsitouras and Zacharias Anastassi (eds.), AIP Conference Proceedings 1479, American Institute of Physics, ISBN 978-0-7354-1091-6, pp. 86-89.
2. Duong A. Hoang, Volkert van Steijn, Luis M. Portela, Michiel T. Kreutzer, Chris R. Kleijn (2012), "ON THE DYNAMICS OF MICRODROPLET BREAKUP IN T-JUNCTIONS", In: Stéphane Colin, Gian Luca Morini and , Jürgen J. Brandner (eds.), proceedings of the 3rd European Conference on Microfluidics, 3-5 Dec 2012, Heidelberg, SOCIETE HYDROTECHNIQUE DE FRANCE, Paris, ISBN 978-2-906831-93-3, ISSN 2108-4718, Article number 172, 8 pages.



An example of our bubble distributor

Multiphase flow in internally structured microchannels under partial wetting conditions

Project Aim

In this project we aim to develop a CFD model to predict multiphase flow in micro- and millifluidic channels under partial wetting conditions. The partial wetting condition introduces additional fluids-solid interactions, which have a significant influence on the flow behaviour due to the dominance of capillary forces. A quantitative understanding of the fluids-solid interactions is of importance to accurately model the surface tension dominated multiphase flow. Therefore, the focus is on understanding and controlling the dynamics of the fluids-solid interface.

Progress

In order to understand the complex interaction between a partially wetting liquid and a solid we have translated the two-phase micro/milli-fluidic system into a model system of a liquid droplet on a solid substrate. We perform experiments in which we tilt the substrate until the droplet sets in motion and at this moment we determine the pinning force of the substrate from the balance with gravity. We also monitor the shape of the droplet and the contact line as a function of tilt angle. The pinning force arises from a difference in interaction energy between the front and the back of the droplet which can be seen from the difference in contact angles (see figure below). In addition to our experimental studies, we use the finite element package Surface Evolver to minimize the energy of a droplet on an incline. Our numerical results show that even droplets with a low Bond are flattened by gravity and this needs to be accounted for in the calculations of the pinning force. Additionally we find that the way in which the droplet deforms when tilted, depends to a large extend on the difference between the initial contact angle of the droplet and the equilibrium contact angle.

Projectleaders

CR Kleijn, MT Kreutzer

Researchtheme

Complex dynamics of fluids

Participants

M Musterd

Cooperations

JM van Beek (UT), L Lefferts (UT), Shell, DOW, ECN, Sulzer

Funded

ISPT

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

Start of the project

2010

Information

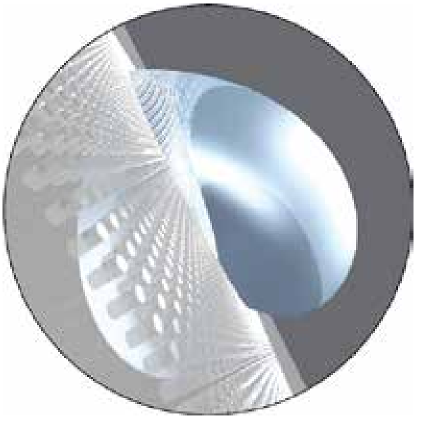
M Musterd
015 278 7084
m.musterd@tudelft.nl
www.msp.tudelft.nl

Dissertations

-

Scientific Publications

1. Improved Reproducibility of Droplet Pinning Measurements on Microscopically Heterogeneous Surfaces, M. Musterd, V. van Steijn, C. R. Kleijn, and M.T. Kreutzer. In Proceedings of the 3rd European Conference on Microfluidics, 3-5 Dec 2012, Heidelberg, 2012.



Model experiments on improved continuous steel casting through electromagnetic flow control

Projectleaders
CR Kleijn, S Kenjereš, M Tummers
Researchtheme
Complex dynamics of fluids
Participants
R Kalter
Cooperations
Tata steel, ABB
Funded
Tata steel, ABB, STW

University	-
FOM	-
STW	88 %
NWO Other	-
Industry	12 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2010
Information
R Kalter
r.kalter@tudelft.nl
015 212 82418
http://cheme.nl/tp/people/kalter.shtml

Project Aim

The aim of the project is to provide a fundamental understanding of, and experimentally validated models for, the influence of electromagnetic fields on flow, turbulence and heat transfer in liquid steel during continuous casting. These insights and models will make it possible to design and to optimize new strategies for controlling steel casting processes, leading to significant energy savings, increased productivity and improved product quality.

Progress

1. The free surface dynamics and sub-surface dynamics in a thin cavity filled with water and with flow from a submerged bifurcated nozzle have been monitored. The flow regimes in this setup have been summarized in a flow regime map with inlet velocity and nozzle depth as independent parameters. The mechanism for the self-sustained oscillation flow regime was analyzed and modeled using results from time-resolved PIV measurements.

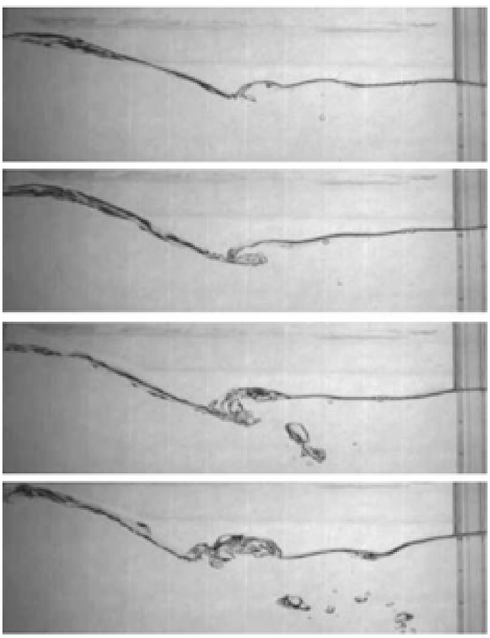
2. Measurements have been performed in the thin cavity with an applied Lorentz body force to analyze the influence of electromagnetic forcing on the flow behavior and consequently on the free surface dynamics. It was found that with the correct application of the Lorentz forcing, the free surface disturbances are reduced significantly due to damping of the self-sustained jet oscillations.

Dissertations

-

Scientific Publications

-



Free surface oscillation and bubble entrainment in a thin water filled cavity

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

Project Aim

This project is part of the long-term investigations started at former Department of Multi Scale Physics aimed at the mathematical modeling and numerical simulations of environmental flows and turbulent dispersion of passive and reactive scalars. In this particular project we focus our investigation at the turbulent flows over complex terrains and urban areas (street canyons) partially covered with vegetation and with different sources of the passive or reactive scalars (the point-, the line- and the area-concentration sources).

Progress

We simulated the flow and spreading of traffic pollution in urban street canyons at lab- and full-scale, and found good agreement with available measurements. Few variants of the models that incorporate effects of trees on velocity and turbulence are implemented too. It is shown that an accurate representation of vegetation requires four-additional terms in the turbulent kinetic energy and its dissipation rate equations. Further investigations including a novel hybrid RANS/LES approach are currently under development. Work in progress also includes implementation of the reactive scalars (modeling of the ozone depletion in the urban street canyons under influence of the sunlight and traffic emission).

Dissertations

-

Scientific Publications

1. Kenjeres S., van der Houwen M. and de Wildt S. (2012), “Capturing transients in turbulent flows over complex urban areas with passive or reactive scalars”, Proceedings of the 7th International Symposium on Turbulence, Heat and Mass Transfer, Palermo, Italy, 24-27 September 2012, Eds. K. Hanjalic, Y. Nagano, D. Borello, S. Jakirlic; Begell House Inc. ISBN 978-1-56700-301-7, pp.975-978.
2. Schrijvers P. J. C., Jonker H. J. J., Kenjeres S., de Roode S. R. (2012), “Simulations of the urban climate at micro-scale”, Proceedings of the 8th International Conference on Urban Climates, August 6-10, 2012, Dublin, Ireland, pp.1-4.

Projectleaders

S Kenjeres, CR Kleijn

Researchtheme

Complex dynamics of fluids

Participants

S Kenjeres, P Schrijvers

Cooperations

Prof. H. J. J. Jonker, CiTG TU Delft
Dr. S.R. De Roode, CiTG, TU Delft

Funded

TU Delft, Kennis voor Klimaat (since 2010)

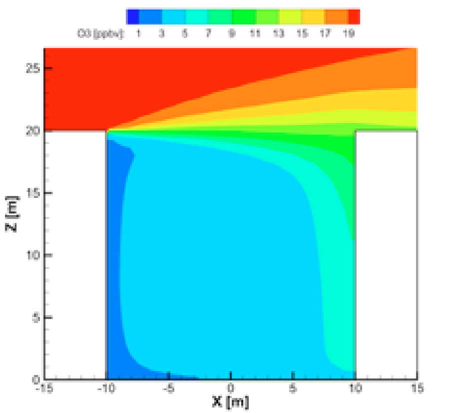
University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2006

Information

S Kenjeres
015 278 3649
S.Kenjeres@tudelft.nl
www.msp.tudelft.nl



Contours of the spatial distribution of the ozone in a street canyon (long-term release) The area sources of NO and NO2 are imposed in the lower part of the street canyon mimicking a traffic emission, Kenjeres et al. (2012).

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

Projectleaders
S Kenjeres

Researchtheme
Complex dynamics of fluids

Participants
S Kenjeres, JS Szmyd, E Fornalik-Wajs

Cooperations
AGH University of Science and Technology, Krakow, Poland

Funded
AGH University of Science and Technology, Krakow, Poland, EC Marie Curie

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

Start of the project
2007

Information
S Kenjeres
015 278 3649
S.Kenjeres@tudelft.nl
www.msp.tudelft.nl

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

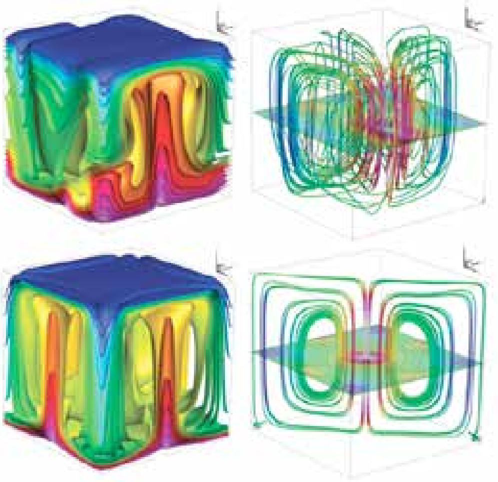
Experimental measurements of the integral heat transfer performed over a range of working parameters for a differentially heated cubical enclosure of a paramagnetic fluid subjected to magnetic gradients of different orientation and strength. DNS studies of the flow and heat transfer performed and detailed comparison with experiments performed.

Dissertations

-

Scientific Publications

1. Kenjeres S., Pyrda L., Wrobel W., Fornalik-Wajs E. and Szmyd J. S. (2012), “Oscillatory states in thermal convection of a paramagnetic fluid in a cubical enclosure subjected to a magnetic field gradient”, Phys. Rev. E 85, 046312 (pp.1-8) (doi: 10.1103/PhysRevE.85.046312).
2. Kenjeres S., Pyrda L., Fornalik-Wajs E., Szmyd J. S. (2012), “Localised turbulence states in differentially heated cubical enclosure of paramagnetic fluid in strong magnetic gradients”, Proceedings of the 7th International Symposium on Turbulence, Heat and Mass Transfer, Palermo, Italy, 24-27 September 2012, Eds. K. Hanjalic, Y. Nagano, D. Borello, S. Jakirlic; Begell House Inc. ISBN 978-1-56700-301-7, pp.1039-1042.
3. Pyrda L, Kenjeres S., Fornalik-Wajs E., Szmyd J. S. (2012),”An analysis of unsteady thermal convection of paramagnetic fluid in cubical enclosure under strong magnetic field gradient”, Proceedings of the 6th Euroepan Thermal Sciences Conference, EUROTHERM 2012, September 4-7 2012, Poitiers-Futuroscope, France, Paper No. 03549, pp.1-8.



Thermal plumes (15 isosurfaces of temperature, θmax = 25 C, θmin = 20 C) (left) and stream traces (colored by vertical velocity, whose contours are also plotted in the central horizontal plane) (right) in a cubical enclosure heated from below and cooled from above with a constant temperature difference θ = 5 ◦C, Pr = 70, and for different intensities of the imposed magnetic field, |b0|max = 0 T (left) and 2 T (middle), Kenjeres et al. (2012),

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

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 flow regimes. We delivered a keynote lecture at ASME 2012 Heat Transfer, Fluids Engineering, Nanochannels, Microchannels and Minichannels Conference.

Dissertations

-

Scientific Publications

1. Kenjeres S. (2012), "Energy spectra and turbulence generation in the wake of magnetic obstacles", Physics of Fluids, Vol. 24 (11), Art. No. 115111, pp.1-19. (doi:10.1063/1.4767726).
2. Kenjeres S. (2012), "Recent Achievements and Challenges in Modelling and Simulation of Complex Multi-Scale MHD Phenomena", Keynote Paper, FEDSM2012-72119, pp.1-25, Proceedings of ASME 2012 Heat Transfer, Fluids Engineering, Nanochannels, Microchannels and Minichannels Conference, July 8-12, 2012, Rio Grande, Puerto Rico.

Projectleaders

S Kenjeres, CR Kleijn

Researchtheme

Complex dynamics of fluids

Participants

S Kenjeres

Cooperations

-

Funded

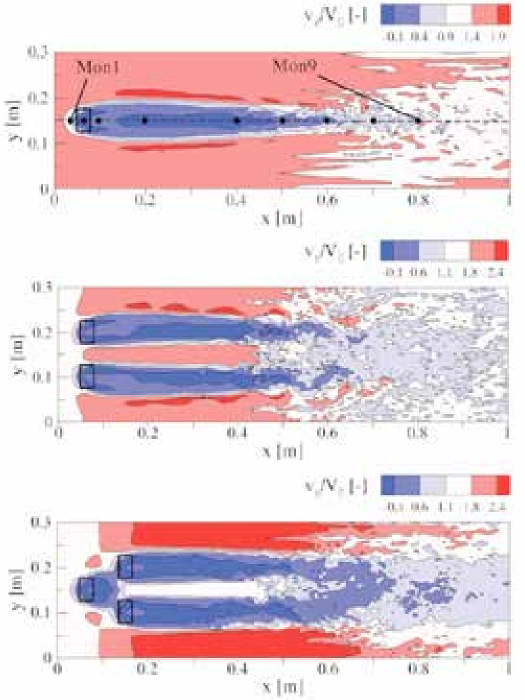
TU Delft	
University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2006

Information

S Kenjeres
015 278 3649
S.Kenjeres@tudelft.nl
www.msp.tudelft.nl



Contours of the instantaneous non-dimensional horizontal velocity (vx /V0) in the central horizontal plane for Re= 1000 and N = 10, one magnetic dipole (top), two magnetic dipoles (middle), and three magnetic dipoles (bottom) configurations, Kenjeres (2012).

Numerical modeling and simulations of blood flow and magnetic particles in simplified and realistic arterial geometries : towards optimized magnetic drug delivery

Projectleaders
S Kenjeres

Researchtheme
Complex dynamics of fluids

Participants
S Kenjeres

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

Funded

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

Start of the project
2006

Information
S Kenjeres
015 278 3649
S.Kenjeres@tudelft.nl
www.msp.tudelft.nl

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

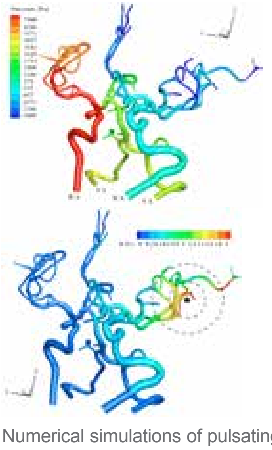
We have developed a comprehensive mathematical model for simulations of blood-flow under the presence of strong non-uniform magnetic fields. The model consists of a set of Navier-Stokes equations accounting for the Lorentz and magnetization forces, and a simplified set of Maxwell's equations (Biot-Savart/Ampere's law) for treating the imposed magnetic fields. The model is then validated for different patient-specific geometries (including a carotid artery and brain vascular system).

Dissertations

-

Scientific Publications

1. Kenjeres S. and Righolt B. W. (2012), "Simulations of magnetic capturing of drug carriers in the brain vascular system", Int. J. Heat and Fluid Flow, Vol.35, pp.68-75. (doi: 10.1016/j.ijheatfluidflow.2012.03.008).
2. Kenjeres S., Righolt B. W., de Mulder A. and Janseen J. (2012), "Simulations of Magnetic Drug Capturing in the Patient Specific Brain Vascular System Under Pulsating Flow Conditions", M. Long (Ed.) World Congress on Medical Physics and Biomedical Engineering, May 26-31, 2012, Beijing, China, IFMBE Proceedings 39, pp.2154-2157.
3. De Loor A., Kenjeres S. (2012),"Towards Numerical Simulations of Atherosclerosis: Modelling of Low-Density-Lipoprotein (LDL) Transport Through Multi-Layered Arterial Wall", M. Long (Ed.) World Congress on Medical Physics and Biomedical Engineering, May 26-31, 2012, Beijing, China, IFMBE Proceedings 39, pp.2158-2161.



Numerical simulations of pulsating blood flow and magnetic drug targeting in the brain vascular system: The pressure (-left) and magnetic field (-right) distributions in a real patient brain vascular geometry, Kenjeres and Righolt (2012).

Experimental and numerical investigations of transitional and turbulent flows over complex surface with heat transfer and emission of passive scalars

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

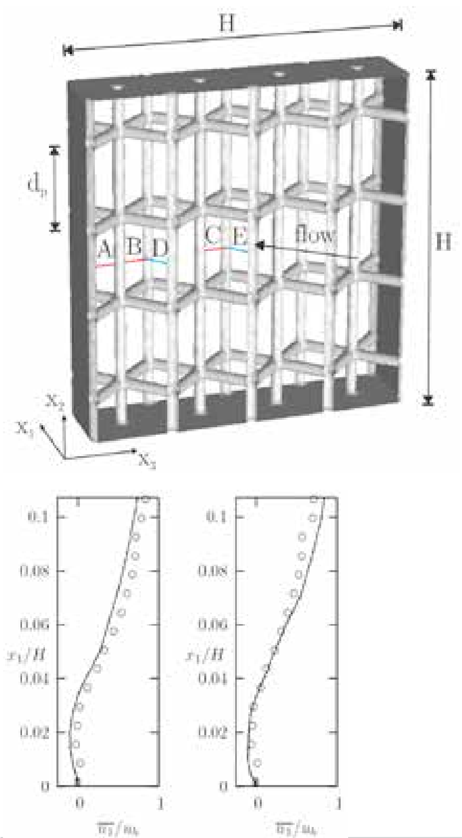
Experimental (PIV, LIF) and numerical studies (DNS, LES with dynamic Lagrangian SGS closure) performed for different configurations of narrow channels with a porous medium.

Dissertations

-

Scientific Publications

-



Projectleaders

S Kenjeres, CR Kleijn

Researchtheme

Complex dynamics of fluids

Participants

S Kenjeres, P Rudolf von Rohr, A Zenklusen

Cooperations

-

Funded

TU Delft, ETH Zurich, HPC-Europa 2

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

Start of the project

2006

Information

S Kenjeres
015 278 3649
S.Kenjeres@tudelft.nl

Sketch of the investigated geometry (-top) and comparative assesment between measured (PIV) And simulated flow field (LES with dynamic Lagrangian SGS closure) (-bottom/left-location D, -bottom/right-location E). The characteristic Reynolds number is 2000

Performance of foamers for deliquification of gas wells

Projectleaders
RAWM Henkes, L Portela

Researchtheme
Complex structures of fluids

Participants
D van Nimwegen

Cooperations
NAM/Shell

Funded
NAM

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

Start of the project
2010

Information
RAWM Henkes
015 278 1323
R.A.W.M.Henkes@tudelft.nl
www.msp.tudelft.nl

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 12 m, 5 cm diameter facility.

Progress

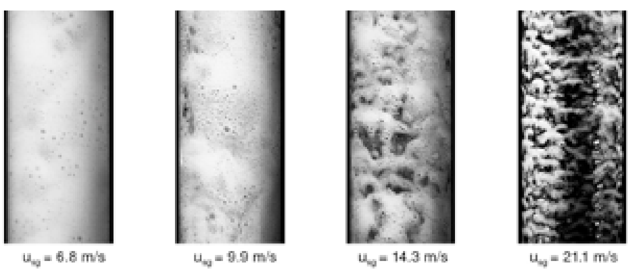
The experiments in the flow facility were continued. It was observed that adding foamers (surfactants) to water will lead to a lower pressure drop at superficial gas velocities below the transition limit from annular flow to churn annular flow (which is around 15 m/s at atmospheric pressure) and at superficial liquid velocities between 0.5 and 2 cm/s. Visualisation of the flow with a high speed camera indicates that the decrease in the pressure drop is due to the more regular nature of the flow when the water is foaming: churning of the flow is suppressed by the foam. This is confirmed by the decrease of the pressure oscillations in the presence of foamers. The water holdup was measured with quick closing valves. The qualitative flow visualization and the quantitative measurements for the pressure drop and liquid holdup were combined to describe the physical mechanisms of the flow features. The angle effect was investigated by increasing the angle up to 70 deg. from the vertical. The surfactants are more effective at steep inclinations and smaller liquid flow rates. Flow visualisation shows that surfactants can form a very regular foam substrate at the wall when the liquid film at the wall is not too thick. When the film thickness becomes larger, due to an asymmetry in the distribution of the liquid film at smaller inclinations or an increase in the liquid flow rate, the foam is less able to suppress all irregularities in the film morphology. This leads to a smaller decrease of the interfacial friction. Experiments were also carried out with an alternative type of surfactant..

Dissertations

-

Scientific Publications

1. Van Nimwegen. A.T., Portela, L.M., Henkes, R.A.W.M., A first look at the hydrodynamics of air-water-foam flow for gas well deliquification, Proc. 8th North American Conference on Multiphase Technology, pp. 367-379, 2012.



Air-water-foam flow at a constant liquid flow-rate (usl= 1 cm/s), while varying the superficial gas velocity. The foamer concentration is 500 ppm.

Simulation of coating of nanoparticles in a fluidized bed

Project Aim

The aim is to investigate the complex agglomerate dynamics and mass transfer phenomena in the fluidized bed reactor by numerical simulation. The challenge is to understand how nanoparticles agglomerate to loose dynamic clusters and understand the agglomeration process in gas flows during coating, such that uniform coatings can be made. Since the relevant length scales range from nm to cm, a multi-scale modeling approach will be required.

Progress

Preliminary simulation results from the DSMC method and a conventional continuum CFD method have been analyzed and compared for a single nanoparticle case.

Dissertations

-

Scientific Publications

-

Projectleaders

JR van Ommen, CR Kleijn

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Wenjie Jin

Cooperations

Venkatesan Dhanasekaran, Andrea Fabre

Funded

European Research Council (ERC)

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

Start of the project

2012

Information

JR van Ommen
015 278 2133
J.R.vanOmmen@tudelft.nl
http://cheme.nl/ppe/people/vanommen.shtml

Modelling the influence of flow on asphaltene agglomeration and deposition

Projectleaders
RAWM Henkes, LM Portela,
A Twerda

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
K Schutte

Cooperations
TNO, ENI (ISAPP2)

Funded
ENI

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

Start of the project
2011

Information
RAWM Henkes
015 278 1323
R.A.W.M.Henkes@tudelft.nl
www.msp.tudelft.nl

Project Aim

Asphaltenes are heavy organic deposits that can be formed when the oil transport from subsurface reservoirs undergoes a sharp drop in pressure. This can be at the inflow sections from the reservoir into the well bore, or inside the wellbore, pipeline, or downstream facilities. For example injection of chemicals can help to prevent blockage of the production system. Models are used for the design of asphaltene prediction, which in turn are used for 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

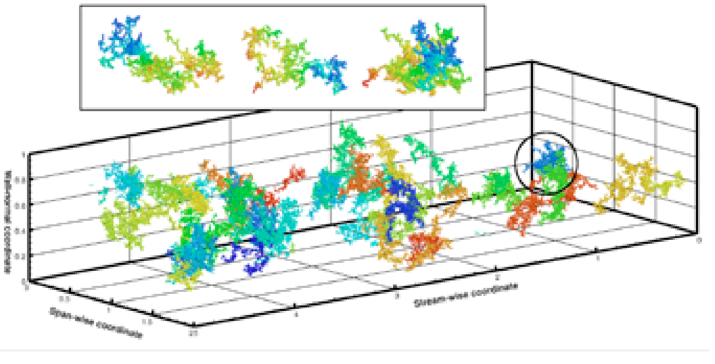
The literature review on asphaltenes formation and modeling was completed. A numerical model was developed to study the formation and break-up of rigid agglomerates from primary particles in turbulent channel flows. The turbulent continuous phase is simulated through a Direct Numerical Simulation, and the dispersed particles are simulated with Lagrangian tracking. In the model the agglomerates are broken when the tensile force on the inter-particle bonds exceeds the strength of these bonds. The simulation results show that due to the local gradient in the stream-wise fluid velocity, agglomerates preferentially are formed and broken in the proximity of the channel walls. While the structure of agglomerates is found to be invariant to the strength of inter-particle bonds, a linear increase in the mean value and variance of the steady-state agglomerate mass spectra is found when increasing the agglomerate strength. Furthermore, although dilute dispersions are considered in this work, the structure of the agglomerates formed is found to be dependent on the primary particle concentration.

Dissertations

-

Scientific Publications

-



snapshot of the steady-state agglomerate distribution that was obtained for agglomerates that are broken by binary breakage

Development of an Omega^2 R separator focussing on oil/water separation

Project Aim

This ISPT project aims at the development of an oil/water separator based on centrifugal forces generated with a static element. The research program is divided into three different parts: theoretical/numerical (Twente University), experimental at bulk scale (Delft University) and on a microscale (Wageningen University). First, understanding of physical properties is generated, which will be used to design a prototype.

Progress

The nature of the Delft part of this project are experimental bulk tests. The first two months of 2012 were spent to clean the rig from polluted oil and to refill it with clean liquids. The following tests aimed at two strategies: geometry variations as top-down approach and detailed LDA and droplet size measurements as bottom up. For the conditions in our experiment, separation is promoted by reducing the swirl strength. This is understood from the reduction in droplet breakup which compensates for the reduction in centrifugal acceleration. From the obtained data, we are building a model that predicts the droplet size inside a cyclone and the subsequent critical droplet size which is being separated. The effect of turbulence on both droplet breakup and the critical droplet size are estimated from single phase LDA data.

Dissertations

-

Scientific Publications

1. L.J.A.M. van Campen, J.J. Slot, R.F. Mudde and H.W.M. Hoeijmakers, A numerical and experimental survey of a liquid-liquid axial cyclone, International Journal of Chemical Reaction Engineering, Volume 10, Issue 1, June 2012.

Projectleaders

RF Mudde

Researchtheme

Complex dynamics of fluids

Participants

LJAM van Campen (phd student TU Delft), JJ Slot (phd student UTwente) HWM Hoeijmakers (professor UTwente), T Krebs (post-doc Wageningen UR), CGPH Schroen (associate professor Wageningen UR)

Cooperations

-

Funded

Institute for Sustainable Process Technology

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

Start of the project

2009

Information

LJAM van Campen
015 278 7084
L.J.A.M.vanCampen@tudelft.nl
www.msp.tudelft.nl

Hot spot formation in trickle bed reactors

Projectleaders
RF Mudde

Researchtheme
Complex dynamics of fluids

Participants
F Mousazadeh, HEA van den Akker

Cooperations
-

Funded
Shell

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

Start of the project
2009

Information
RF Mudde
r.f.mudde@tudelft.nl

Project Aim

Develop a CFD model that can describe and predict the formation of hot spots in a trickle bed reactor.

Progress

We have developed a 2D numerical multiphase model that is capable of simulating reactions with evaporation and condensation in a trickle bed reactor. The reactor consists of millimeter sized catalytic particle forming a packed bed. A gas-liquid mixture flows through this bed in trickle mode. A exothermic chemical is carried out in the liquid phase when in contact with the catalyst. One of the species require for the reaction is in the gas phase. Hence we have modeled the hydrodynamics and the mass transfer. Since the reaction is exothermic, we also compute the energy balance in the reactor. As a consequence of mall distribution a hot spot may develop. We succeeded to simulate such a spot. We investigated the effect of liquid evaporation on the hot spot formation. It helps keeping the temperature down, but doesn't prevent hot spot formation with potential run away of the reactor.

Dissertations

-

Scientific Publications

1. Farzad Mousazadeh, H. E. A. Van den Akker, and R. F. Mudde., 2012, Eulerian Simulation of Heat Transfer in a Trickle Bed Reactor With Constant Wall Temperature, Chem. Eng. Journal, 207 (SI), 675–682.
2. Farzad Mousazadeh, H. E. A. Van den Akker, and R. F. Mudde., 2012, Direct numerical simulation of an exothermic gas-phase reaction in a packed bed with random particle distribution, accepted by Chem. Eng. Sci..

Project Aim

We aim at structuring the slurry bubble column in such a way that a desired flow pattern is imposed to the system. We investigate uniform gas injection using a needle sparger as a structuring methodology to reduce backmixing in slurry bubble columns. On the other hand, to better understand the effect of fine particles on the bubble motion and size; we study the effect of particles in different size on the bubble dynamics.

Progress

We studied the effect of the particles in different sizes on the bubble motion and size. We used four-point optical probes and X-rays to get direct information about bubble motion in an opaque system. Our experimental results show that in systems with low St particles the solid-liquid suspension behaves as a pseudo-pure liquid. Collisions between particles and bubble, which occur at St>>1, lead to bubble deformation and a decrease in bubble velocity (see also the Highlight in this Annual Report).

Dissertations

-

Scientific Publications

1. Hooshyar, N., D. Vervloet, F. Kapteijn, P. J. Hamersma, R. F. Mudde and J. R. van Ommen (2012). "Intensifying the Fischer-Tropsch Synthesis by reactor structuring - A model study." Chemical Engineering Journal 207-208: 865-870.

Projectleaders

RF Mudde, PJ Hamersma, JR van Ommen

Researchtheme

Complex dynamics of fluids

Participants

Nasim Hooshyar

Cooperations

S Sundaresan

Funded

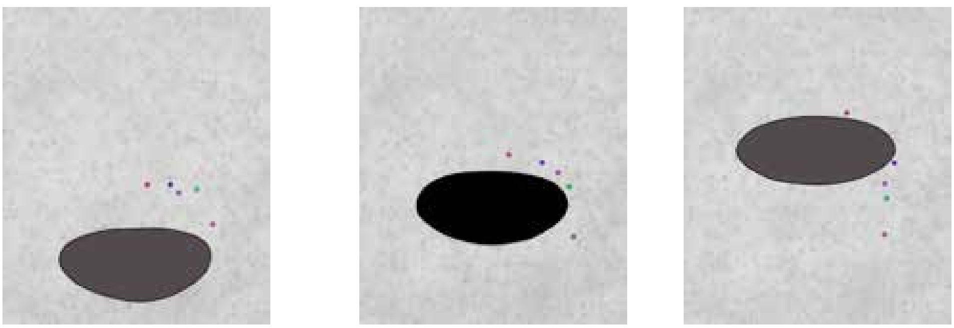
TU Delft	
University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2008

Information

JR van Ommen
015 278 2133
J.R.vanOmmen@tudelft.nl
http://cheme.nl/ppe/people/vanommen.shtml



Motion of a single rising bubble in a St<<1 system

Water purification system for one family in the developing world

Projectleaders
RF Mudde

Researchtheme
Complex dynamics of fluids

Participants
Rajat Bhardwaj

Cooperations
DrTen B.V.

Funded
DrTen B.V.

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

Start of the project
2011

Information
R Bhardwaj
06 34423607
R.bhardwaj@tudelft.nl

Project Aim

To develop an affordable solar distillation system for water purification. The still should be used by the poor in third world countries and hence should rely on solar energy only, have no high tech parts and should be cheap.

Progress

We have investigated the effect of choice of material on which the evaporated water will condense on the production of water from a solar still. We found that using hydrophilic or hydrophobic material has little effect on the production of the still. We have performed experiments to measure the effect of cooling, dripping, salt concentration, inclination angle of the condensing plate and temperature on the water production on a solar still. From these experiments, we found that the water production limiting step is the heat transfer to the environment. By creating extra cooling at the outside, the water production is increased substantially. A complete model describing the energy flow in the still as well as the mass transfer has been made. This allows for further optimization of the still.

Dissertations

-

Scientific Publications

-

Project Aim

Experimentally study severe slugging in a riser-pipeline system and develop a one-dimensional model and numerical approach.

Progress

We have successfully studied the occurance of severe slugging in a gas-liquid flow in a large scale (near) horizontal pipeline connected to vertical riser via a bend. We found experimentally and could predict numerically from a one-dimensional two-fluid model the existence of a slugging regime with a dual frequency: one fast one (tens of seconds) related to the formation of slug and a very slow one with e period of thousand seconds. Furthermore, we have made flow maps and classified the different flow regimes including the severe slugging. We have shown, that severe slugging is a function of the inclination angle of the near horizontal pipe. Moreover, both the experiments and the simulations show that severe slugging can also be present when the pipeline is completely horizontal, in contrast to what has been reported in literature.

Dissertations

1. Malekzadeh, R. Severe Slugging in gas-liquid two-phase pipe flow. Oct. 2012.

Scientific Publications

1. Malekzadeh, R., Mudde, R.F., Henkes, R.A.W.M., 2012, Dual-Frequency Severe Slugging in Horizontal Pipeline-Riser Systems, J. Fluids Eng., 134 (12), 121301.
2. Malekzadeh, R., Henkes, R.A.W.M., Mudde, R.F., 2012, Severe slugging in a long pipeline-riser system: Experiments and predictions, Int. J. Multiphase Flow, 46, 9-21.
3. Malekzadeh, R., Belfroid, S.P.C., Mudde, R.F., 2012, Transient drift flux modelling of severe slugging in pipeline-riser systems, Int. J. Multiphase Flow, 46, 32-37.

Projectleaders

RF Mudde

Researchtheme

Complex dynamics of fluids

Participants

Reza Malekzadeh, Ruud Henkes

Cooperations

Shell, TNO

Funded

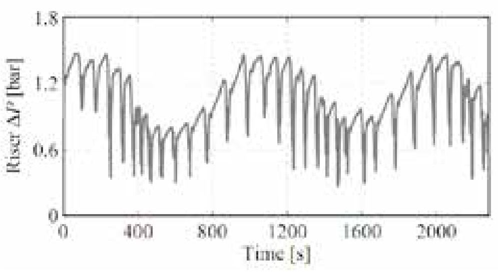
ISAPP	
University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

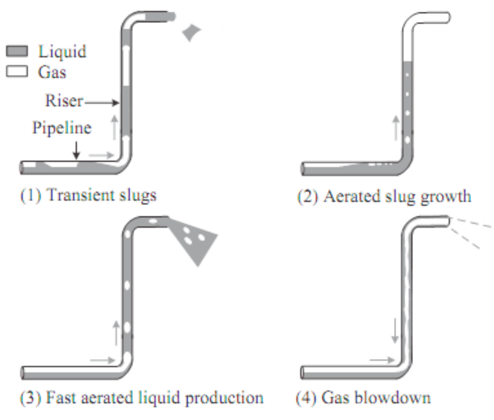
2008

Information

RF Mudde
r.f.mudde@tudelft.nl



Severe slugging with dual frequency



Time-resolved measurement of void structure in gas/solid flow with high speed X-ray tomography

Projectleaders
RF Mudde

Researchtheme
Complex dynamics of fluids

Participants
X Yang, JR van Ommen

Cooperations
-

Funded
TU Delft

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

Start of the project
2011

Information
RF Mudde
r.f.mudde@tudelft.nl

Project Aim

Further develop and use our multi-source high speed X-ray tomography system for the dynamic measurements of flow structures in fluidized bed and similar gas/solid flow system.

Progress

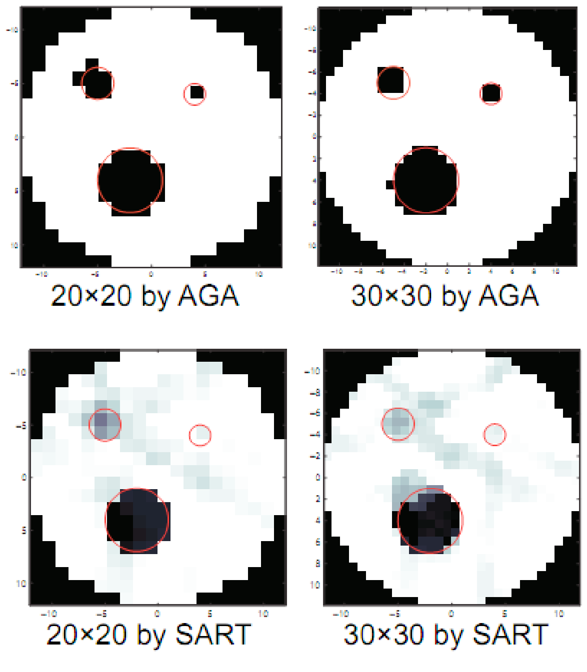
A novel tomographic reconstruction technique based on Genetic Algorithms was developed. It is compared and evaluated with traditional algebraic reconstruction technique. We found that the generic algorithm is less sensitive to noise than standard techniques and is capable of finding smaller object. A hybrid reconstruction technique was developed by combine the genetic algorithm and algebraic reconstruction technique. The new algorithm was tested both with synthetic input data and experimental data. The technique was applied to measure bubbles in a group-A particle fluidized bed with reversed nozzle was done. Secondly, we used the facility to measure the time-resolved position and shape of a spout inside the spouted bed.

Dissertations

-

Scientific Publications

-



Reconstruction of phantoms: genetic algorithm (top) shows much less noise than the traditional algebraic techniques (bottom).

Turbulent drag reduction

Project Aim

To understand the mechanism for drag reduction in turbulent flows due to the addition of spherical additives, such as solid particles or gas bubbles.

Progress

Using direct numerical simulations of turbulent Couette flow, we have predicted drag reduction in suspensions of neutrally buoyant fluid spheres, of diameter larger than the Kolmogorov length scale. The velocity fluctuations are enhanced in the streamwise direction, and reduced in the cross-stream directions, which is similar to the more studied case of drag reduction using polymers. Despite these similarities, the drag reduction mechanism is found to originate in the logarithmic region, while the buffer region contributes to a slight drag increase, which is opposite to polymer-induced drag reduction. Another striking difference is the reduction of the turbulent energy at the large scales and an enhancement at the small scales.

Dissertations

-

Scientific Publications

-

Projectleaders

JJJ Gillissen

Researchtheme

Complex structures of fluids

Participants

JJJ Gillissen

Cooperations

S Sundaresan, T Odijk

Funded

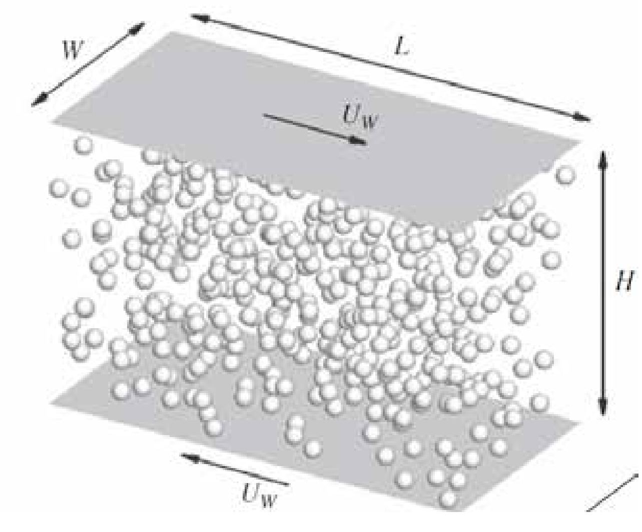
TU Delft	
University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2010

Information

JJJ Gillissen
J.J.J.Gillissen@tudelft.nl



Interphasial energy transfer and particle dissipation in particle-laden wall turbulence

Projectleaders
JJJ Gillissen
Researchtheme
Complex structures of fluids
Participants
JJJ Gillissen
Cooperations
S Sundaresan
Funded
TU Delft

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

Start of the project
2010
Information
JJJ Gillissen
J.J.J.Gillissen@tudelft.nl

Project Aim

To study the mechanism for the transfer of mechanical energy between solid spherical particles and a turbulent Newtonian wall flow.

Progress

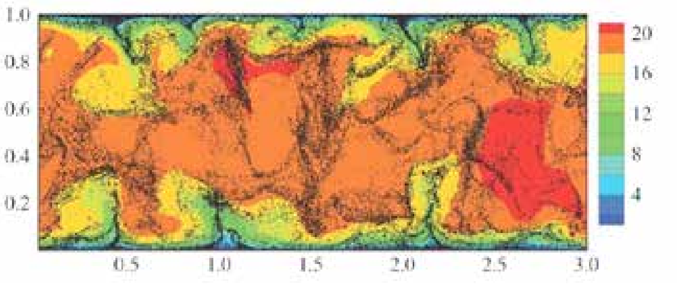
Transfer of mechanical energy between solid spherical particles and a Newtonian carrier fluid has been explored in two-way coupled direct numerical simulations of turbulent channel flow. The inertial particles have been treated as individual point particles in a Lagrangian framework and their feedback on the fluid phase has been incorporated in the Navier-Stokes equations. At sufficiently large particle response times the Reynolds shear stress and the turbulence intensities in the spanwise and wall-normal directions were attenuated whereas the velocity fluctuations were augmented in the streamwise direction. The physical mechanisms involved in the particle-fluid interactions were analysed in detail, and it was observed that the fluid transferred energy to the particles in the core region of the channel whereas the fluid received kinetic energy from the particles in the wall region. A local imbalance in the work performed by the particles on the fluid and the work exerted by the fluid on the particles was observed. This imbalance gave rise to a particle-induced energy dissipation which represents a loss of mechanical energy from the fluid-particle suspension. An independent examination of the work associated with the different directional components of the Stokes force revealed that the dominating energy transfer was associated with the streamwise component. Both the mean and fluctuating parts of the Stokes force promoted streamwise fluctuations in the near-wall region. The kinetic energy associated with the cross-sectional velocity components was damped due to work done by the particles, and the energy was dissipated rather than recovered as particle kinetic energy. Componentwise scatter plots of the instantaneous velocity versus the instantaneous slip-velocity provided further insight into the energy transfer mechanisms, and the observed modulations of the flow field could thereby be explained.

Dissertations

-

Scientific Publications

1. Lihao Zhao, Helge I. Andersson and Jurriaan J. J. Gillissen. Interphasial energy transfer and particle dissipation in particle-laden wall turbulence. J. Fluid Mech. (2013), vol. 715, pp. 32-59. doi:10.1017/jfm.2012.492.



Instantaneous flow contours in a cross-sectional plane: streamwise fluid velocity (colour contours) and point particle distribution (black dots)

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

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 share 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 analyze an existing chemical reactor on relevant issues such as the occurrence of hot-spot formation.

Progress

Currently several projects are ongoing. Firstly, the effects of spurious velocities in the Shan-Chen multi-phase model on mass transfer is being investigated. For diffusion of a tracer material from a stationary gas bubble, no deviations from theory are observed. The effect is currently being analyzed for a non-stationary gas bubble. Secondly, an implementation has been developed to account for differing component molecular masses. This is relevant when reaction stoichiometry yields a net change in the number of moles and thus must be accompanied with a change in pressure. The implementation is validated against a testcase used in literature for other such implementations. These results will be submitted for publication in the near future. Thirdly, an ongoing project for much of the research is a transition to a numerical code based on a GPU architecture.

Dissertations

-

Scientific Publications

-

Projectleaders

HEA van den Akker

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

N Looije, JJJ Gillissen

Cooperations

S Sundaresan (Princeton Uni.)

Funded

Shell Global Solutions

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

Start of the project

2011

Information

HEA van den Akker
015 278 5000
H.E.A.vandenAkker@tudelft.nl

Product and Process Engineering

Prof.dr.ir. MT Kreutzer

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.

Continuous-flow synthesis of core-shell nanoparticles

Project Aim

The aim of the project is to synthesize monodisperse core-shell nanoparticles with pre-defined properties, understand factors influencing the morphology (size, shape and dispersity), as well as applied these nanoparticles in catalysis.

Progress

Progress in fabrication of microfluidic devices with well-established mixing, injection, cooling rate, multiple temperature zones for reactions carried out in compartments (droplets) dispersed in unreactive oils. We developed 2-layered PDMS devices for precise injection of fluid into moving droplets in order to synthesize Au-Ag core-shell nanoparticles with controlled shell thickness. Initial results of the synthesis of Au-Ag nanoparticles in microreactors shows that the coating of Au nanoparticles is improved in comparison with a batch mode synthesis. Progress was made also in modeling of the nucleation and growth of gold-citrate nanoparticles involving implementation of population balance into the model.

Dissertations

-

Scientific Publications

-

Projectleaders

JR van Ommen, F Kapteijn, MT Kreutzer

Researchtheme

Complex dynamics of fluids

Participants

B Kampa

Cooperations

Catalysis Engineering group of ChemE, TU Delft

Funded

NRSC-C

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

Start of the project

2009

Information

BM Kampa,
015 278 8188
b.m.kampa@tudelft.nl
www.cheme.tudelft.nl/ppe

Dynamic behavior of Taylor flow in distributed microreactor channel networks for large-scale processing

Projectleaders
CR Kleijn, MT Kreutzer

Researchtheme
Complex dynamics of fluids

Participants
Duong Anh Hoang

Cooperations
TU Eindhoven (J.C. Schouten),
Wageningen University (K. Schroen)
OSPT-IROP (DSM, Shell, DOW, Akzo-Nobel, Unilever, TNO)

Funded
STW, OSPT-IROP IROP (DSM, Shell, DOW, Akzo-Nobel, Unilever, TNO)

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

Start of the project
2009

Information
CR Kleijn
015 278 2835
C.R.Kleijn@TUDelft.NL
www.msp.tudelft.nl

DA Hoang
015 278 7084
h.a.duong@tudelft.nl
http://www.cheme.tudelft.nl

Project Aim

Segmented flow is widely used in microreactor (Process-on-a-Chip and Lab-on-a-Chip) technology because of its high mass transfer, low axial dispersion and rapid micromixing. The generation and control of segmented flow in a single microchannel is well-established. Numbering up towards large-scale processing, however, required techniques for the stable and controlled distribution of segmented flows over networks of channels. As yet, techniques and fundamental understanding of such distributions are limited. In this project, we study the generation and transport of droplets and bubbles in microfluidic networks that comprise a large number of parallel microchannels. The aim is to understand how to form and distribute streams of bubbles or droplets in such networks.

Progress

- Investigated and understood the mechanism of the rapid pinch-off during the breakup of droplets in T-junctions using 3-D numerical simulations.
- Designed and experimentally characterized a bubble-breakup-based distributor for multiple microreactor channel networks.

Dissertations

-

Scientific Publications

1. D. A. Hoang, V. Van Steijn, L. M. Portela, M. T. Kreutzer, and C. R. Kleijn (2012), “Modeling of low-capillary number segmented flows in microchannels using openfoam”, 10th International Conference of Numerical Analysis and Applied Mathematics, Greece, in: Theodore E. Simos, George Psihoyios, Ch. Tsitouras and Zacharias Anastassi (eds.), AIP Conference Proceedings 1479, American Institute of Physics, ISBN 978-0-7354-1091-6, pp. 86-89.
2. Duong A. Hoang, Volkert van Steijn, Luis M. Portela, Michiel T. Kreutzer, Chris R. Kleijn (2012), “ON THE DYNAMICS OF MICRODROPLET BREAKUP IN T-JUNCTIONS”, In: Stéphane Colin, Gian Luca Morini and , Jürgen J. Brandner (eds.), proceedings of the 3rd European Conference on Microfluidics, 3-5 Dec 2012, Heidelberg, SOCIETE HYDROTECHNIQUE DE FRANCE, Paris, ISBN 978-2-906831-93-3, ISSN 2108-4718, Article number 172, 8 pages.

Process intensification of Fischer-Tropsch synthesis in tubular fixed bed reactors

Project Aim

We aim to significantly intensify the Fischer-Tropsch (FT) process in tubular fixed bed reactors. We do this by replacing the conventional randomly dumped catalyst packing with structured catalytic packing elements. The structures guide the multiphase flow through a channel network that can be described with several geometric parameters, which are chosen to optimally facilitate the FT reaction.

Progress

We conducted the following experimental studies of multiphase flow through structured packing elements:

- The liquid residence time distribution
- The liquid flow distribution
- Liquid flow paths in a pseudo-2D transparent set-up

Compared to the conventional, randomly dumped beds, structured packings yield: (1) a shorter (decoupled) catalyst diffusion length, (2) much lower pressure drop, (3) much larger heat transport rates, and (4) an expanded window for reactor design and operating conditions.

Dissertations

-

Scientific Publications

1. Hooshyar, N., D. Vervloet, F. Kapteijn, P. J. Hamersma, R. F. Mudde and J. R. van Ommen (2012). "Intensifying the Fischer-Tropsch Synthesis by reactor structuring - A model study." Chemical Engineering Journal 207-208: 865-870.
2. Vervloet, D., F. Kapteijn, J. Nijenhuis and J. R. Van Ommen (2012). "Fischer-Tropsch reaction-diffusion in a cobalt catalyst particle: Aspects of activity and selectivity for a variable chain growth probability." Catalysis Science and Technology 2(6): 1221-1233.

Projectleaders

JR van Ommen, F Kapteijn

Researchtheme

Complex dynamics of fluids

Participants

D Vervloet, J Nijenhuis

Cooperations

-

Funded

STW

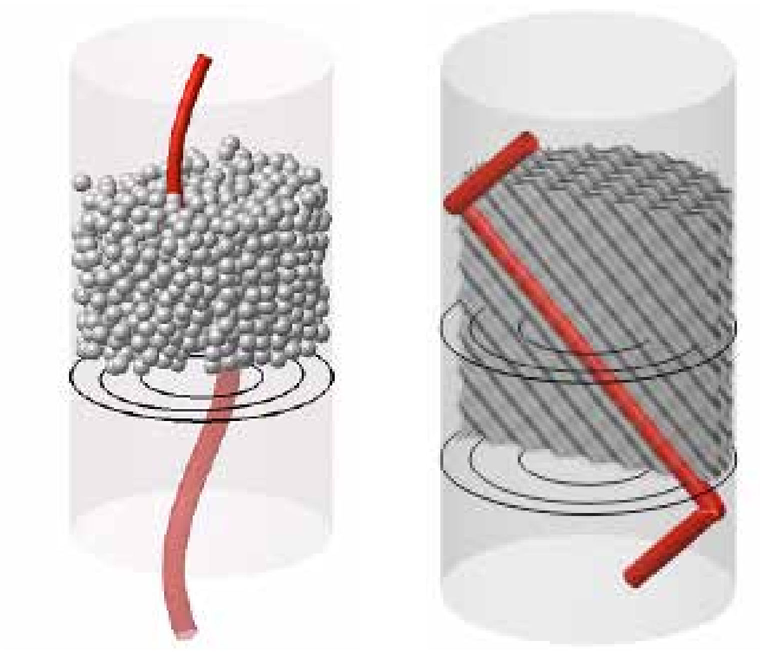
University	-
FOM	-
STW	75 %
NWO Other	-
Industry	25 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2007

Information

JR van Ommen
015 278 2133
J.R.vanOmmen@tudelft.nl
http://cheme.nl/ppe/people/vanommen.shtml



In a randomly packed bed (left), there is no convective transport of gas and liquid in radial direction, leading to a poor cooling of gas and liquid. The structured packings we use (right) have diagonal channels, forcing an efficient heat exchange of the gas and liquid with the wall.

PROJECTLEADERS
RF Mudde, PJ Hamersma, JR van Ommen

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
Nasim Hooshyar

COOPERATIONS
S Sundaresan

FUNDED
TUD

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

START OF THE PROJECT
2008

INFORMATION
JR van Ommen
015 278 2133
J.R.vanOmmen@tudelft.nl
http://cheme.nl/ppe/people/vanommen.shtml

PROJECT AIM

We aim at structuring the slurry bubble column in such a way that a desired flow pattern is imposed to the system. We investigate uniform gas injection using a needle sparger as a structuring methodology to reduce backmixing in slurry bubble columns. On the other hand, to better understand the effect of fine particles on the bubble motion and size; we study the effect of particles in different size on the bubble dynamics.

PROGRESS

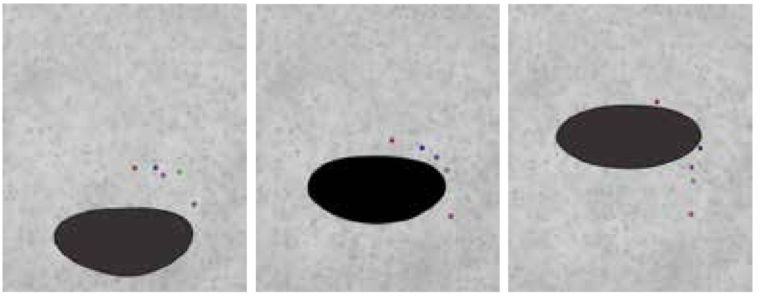
We studied the effect of the particles in different sizes on the bubble motion and size. We used four-point optical probes and X-rays to get direct information about bubble motion in an opaque system. Our experimental results show that in systems with low St particles the solid-liquid suspension behaves as a pseudo-pure liquid. Collisions between particles and bubble, which occur at St>>1, lead to bubble deformation and a decrease in bubble velocity (see also the Highlight in this Annual Report).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Hooshyar, N., D. Vervloet, F. Kapteijn, P. J. Hamersma, R. F. Mudde and J. R. van Ommen (2012). “Intensifying the Fischer-Tropsch Synthesis by reactor structuring - A model study.” Chemical Engineering Journal 207-208: 865-870.



Motion of a single rising bubble in a St<<1 system

PROJECT AIM

The goal of this project is to develop design rules for multiphase slurry photocatalytic reactors, by integrating optics and hydrodynamics. Our objective is to develop simple analytical expressions to predict the quantum efficiency and teach the optimum operating conditions for measuring kinetic data and photonic efficiencies in such reactors. Based on simplified mathematical modeling, we aimed to study photon losses at different chain of photocatalytic events, investigate the effect of scattering by bubbles on the photoreaction rate in bubbly slurry photoreactors, and analyze diffusion limitations in such reactors.

PROGRESS

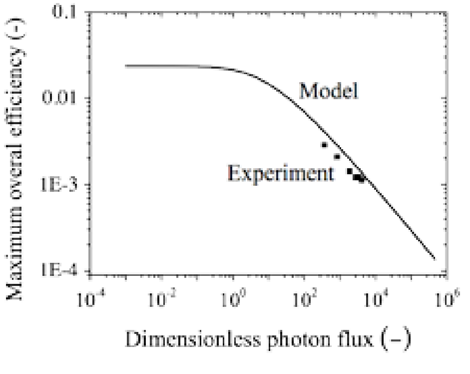
We quantified the local rate of photon absorption and photon losses in different steps of a photocatalytic reaction. To achieve this, we used a 1D description of optics in multiphase photocatalytic reactors, considering both low and high light intensities, leading to a linear and square root dependence of reaction rate on the local volumetric rate of photon absorption, respectively. We further studied the effect of introducing bubbles in slurry photocatalytic reactors on the scattering of photons and the eventual rate of photon absorption by photocatalytic particles. We quantified the threshold for the gas fraction that results in a noticeable (>5%) loss of photons due to scattering. Additionally, we studied diffusion limitations caused by the gradient in the rate of photon absorption in slurry photocatalytic reactors and reported the circumstances at which diffusion limitations can hinder accurate kinetic measurements.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. M. Motegh, J.R. Van Ommen, P.W. Appel, M.T. Kreutzer, R. F. Mudde, “Bubbles scatter light, yet that doesn’t hurt bubbly photocatalytic reactor performance”. J. Chem. Eng. Sci., published on-line, 2013. doi: 10.1016/j.ces.2013.02.022.
2. M. Motegh, J. Cen, J.R. Van Ommen, P.W. Appel, M.T. Kreutzer, “Guidelines for the design of two- phase slurry photocatalytic reactors”. Chem. Eng. J. 2012, 207-208, 607 – 615.



Overal photonic efficiency in slurry photocatalytic reactors vs. dimensionless photons flux

PROJECTLEADERS
JR van Ommen, PW Appel, MT Kreutzer

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
M Motegh

COOPERATIONS
-

FUNDED
Delft University of Technology

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

START OF THE PROJECT
2009

INFORMATION
JR van Ommen
015 278 2133
J.R.vanOmmen@tudelft.nl
http://cheme.nl/ppe/people/vanommen.shtml

The interplay between agglomeration and coating of nanoparticles in the gas phase

Projectleaders
JR van Ommen
Researchtheme
Complex dynamics of fluids
Participants
L de Martín
Cooperations
WG Bouwman, Andrea Fabre
Funded
ERC Starting Grant

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

Start of the project
2012
Information
JR van Ommen
015 278 2133
J.R.vanOmmen@tudelft.nl
cheme.nl/ppe/people/vanommen.shtml

Project Aim

Understanding and controlling the agglomerating nature of nanoparticles in gas flows during coating, such that uniform coatings can be made. Characterizing the agglomerates formed by the nanoparticles by means of fractal analysis. Unraveling the mechanism of formation and breaking of the agglomerates in the fluidized bed.

Progress

In 2012 we have:

- Characterized the structure of the fluidized agglomerate by means of spin-echo small angle neutron scattering.
- Got preliminary insights of the dependency of the agglomerate structure with the environment conditions.
- Proposed a model to model the van der Waals interaction between two agglomerates taking into account the properties of the nanoparticles and the fractal dimension of the agglomerates
- Developed a methodology for faster simulations of Diffusion Limited Aggregation, a model for nanoparticle agglomeration.

Dissertations

-

Scientific Publications

1. L. de Martin and J. R. van Ommen . Estimation of the overall mass flux in inclined standpipes by means of pressure fluctuation measurements. Chemical Engineering Journal 2012, 204 , 125–130.

Example of a simulation result of 2D Diffusion Limited Aggregation with 10^6 particles

Elucidating the physics of nanoparticle interaction and cluster dynamics

Project Aim

The aim is to investigate the interaction between individual nanoparticles, simple agglomerates and complex agglomerates. There will be a focus on the effect of surface modification on the previously studied interactions, and the development of techniques for efficient use of nanopoders from the acquired knowledge.

Progress

Models describing the attractive interactions among particles have been analyzed and compared. Many methods to measure these forces have been considered, reaching to a final conclusion of choosing the best ones.

Dissertations

-

Scientific Publications

-

Projectleaders

JR van Ommen, MT Kreutzer

Researchtheme

Complex dynamics of fluids

Participants

A Fabre, W Jin

Cooperations

-

Funded

European Research Council (ERC)

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

Start of the project

2012

Information

JR van Ommen
015 278 2133
J.R.vanOmmen@tudelft.nl
cheme.nl/ppe/people/vanommen.shtml

Coating fine particles with ultrathin films using atomic layer deposition in fluidized bed reactors

Projectleaders
JR van Ommen, GMH Meesters, MT Kreutzer

Researchtheme
Complex dynamics of fluids

Participants
David Valdesueiro

Cooperations
-

Funded
Marie Curie ITN program and DSM

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

Start of the project
2011

Information
D Valdesueiro
015 278 9111
d.valdesueiro@tudelft.nl

Project Aim

The goal of the project is the production of core-shell micron-sized particles, by using the coating technique called Atomic Layer Deposition (ALD). ALD can provide particles with thin layers. This process is carried out in a fluidized bed reactor. The particles are coated with two different aims. The first is to protect the core particle from degradation via e.g. oxidation or dissolution. The second one is to activate the surface of the particles by depositing valuable materials, such as a catalyst.

Progress

During the last year we worked on the optimization of the fluidization process, which is hindered by the tendency of the fine particles to form agglomerates. By using an external input of energy in form of mechanical vibration, microjet or mechanical agitation, the interparticle attractive forces, i.e. van der Waals interaction, can be overcome. We produced the first batches of core-shell structured material by depositing a layer of aluminum oxide by ALD, using trimethyl aluminum and water as gas-phase precursors. Further work will be aimed at studying the properties of such a core-shell material.

Dissertations

-

Scientific Publications

-

Simulation of coating of nanoparticles in a fluidized bed

Project Aim

The aim is to investigate the complex agglomerate dynamics and mass transfer phenomena in the fluidized bed reactor by numerical simulation. The challenge is to understand how nanoparticles agglomerate to loose dynamic clusters and understand the agglomeration process in gas flows during coating, such that uniform coatings can be made. Since the relevant length scales range from nm to cm, a multi-scale modeling approach will be required.

Progress

Preliminary simulation results from the DSMC method and a conventional continuum CFD method have been analyzed and compared for a single nanoparticle case.

Dissertations

-

Scientific Publications

-

Projectleaders

JR van Ommen, CR Kleijn

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

W Jin

Cooperations

Venkatesan Dhanasekaran, Andrea Fabre

Funded

European Research Council (ERC)

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

Start of the project

2012

Information

JR van Ommen
015 278 2133
J.R.vanOmmen@tudelft.nl
cheme.nl/ppe/people/vanommen.shtml

Multiphase flow in internally structured microchannels under partial wetting conditions

Projectleaders
CR Kleijn, MT Kreutzer

Researchtheme
Complex dynamics of fluids

Participants
M Musterd

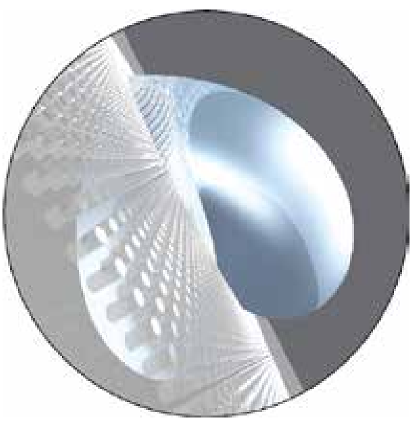
Cooperations
JM van Beek (UT), L Lefferts (UT), Shell, DOW, ECN, Sulzer

Funded
ISPT

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

Start of the project
2010

Information
M Musterd
015 278 7084
m.musterd@tudelft.nl
http://cheme.nl/tp/musterd



Project Aim

In this project we aim to develop a CFD model to predict multiphase flow in micro- and millifluidic channels under partial wetting conditions. The partial wetting condition introduces additional fluids-solid interactions, which have a significant influence on the flow behaviour due to the dominance of capillary forces. A quantitative understanding of the fluids-solid interactions is of importance to accurately model the surface tension dominated multiphase flow. Therefore, the focus is on understanding and controlling the dynamics of the fluids-solid interface.

Progress

In order to understand the complex interaction between a partially wetting liquid and a solid we have translated the two-phase micro/milli-fluidic system into a model system of a liquid droplet on a solid substrate. We tilt the substrate until the droplet sets in motion and at this moment we determine the pinning force of the substrate from the balance with gravity. The pinning force arises from a difference in interaction energy between the front and the back of the droplet which can be seen from the difference in contact angles (see figure below).

We use the finite element package Surface Evolver to minimize the energy of a droplet on an incline. Our numerical results show that even droplets with a low Bond are flattened by gravity and this needs to be accounted for in the calculations of the pinning force. Additionally we find that the way in which the droplet deforms when tilted, depends to a large extend on the difference between the initial contact angle of the droplet and the equilibrium contact angle.

Dissertations

-

Scientific Publications

1. Improved Reproducibility of Droplet Pinning Measurements on Microscopically Heterogeneous Surfaces, M. Musterd, V. van Steijn, C. R. Kleijn, and M.T. Kreutzer. In Proceedings of the 3rd European Conference on Microfluidics, 3-5 Dec 2012, Heidelberg, 2012.

Prof.dr.ir. ThJJ van der Hagen

MISSION

The reactor physics 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
   - Experimental research on stability of natural circulation Boiling Water Reactors with enhanced safety features.
   - Numerical analyses of thermal-hydraulic phenomena in new reactors like the SBWR and others. This also includes method and code development.
   - Thermo-Siphon research.
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.

Investigation of heat transfer to turbulent supercritical fluids by means of direct numerical simulation

Project Aim

Heat transfer to supercritical fluids shows exotic behaviour, due to sharp fluid property changes. As a result, it is difficult, if not impossible, to accurately predict heat transfer to such fluids. The goal of this project is to investigate the complex physics involved and to develop an accurate design correlation for the prediction of heat transfer to supercritical fluids. With Direct Numerical Simulations, it is possible to investigate the physics involved in great detail. These investigations will then be used for the design of a heat transfer relation.

Progress

A 6th order precision finite difference/spectral code has been developed to solve the low-Mach number Navier-Stokes equations in an annular geometry. The code has been validated against various analytical cases (heat transfer to laminar fluids with variable fluid properties), as well as turbulent Direct Numerical Simulation cases (heat transfer to fluids with constant fluid properties) with good results. The code is currently being validated against experimental results (heat transfer to strongly heated gas).

Dissertations

-

Scientific Publications

-

Projectleaders

M Rohde

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

JWR Peeters, BJ Boersma, R Pecnik, THJJ van der Hagen, M Rohde

Cooperations

-

Funded

STW-OTP

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

Start of the project

2012

Information

JWR Peeters
015 278 6628
j.w.r.peeters@tudelft.nl
http://pe.tudelft.nl/node/603

Heat transfer in non-unity Prandtl number flows (part of THINS project)

Projectleaders
M Rohde

Researchtheme
Complex dynamics of fluids

Participants
NGW Warncke, V Valori,
DW de Haas, P van der Baan,
M Rohde

Cooperations
University of Pisa, PSI, KTH

Funded
Euratom (EU)

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

Start of the project
2010

Information
N Warncke
015 278 3811
n.g.w.warncke@tudelft.nl

Project Aim

The aim of the project is twofold: The primary goal is to understand turbulent heat transfer in a supercritical fluid, in particular the so-called Onset of Heat Transfer Deterioration due to a re-laminarizing boundary layer in an upward flow. The second aim is to study the effect of turbulent mixing in a supercritical fluid on the temperature fluctuations in walls (thermal fatigue).

Progress

The experimental facility was finished in early 2012. It consists of a closed loop filled with supercritical Trifluoromethane at 57 bar, with an annular flow around a cylindrical heating rod in the rising section. During Summer 2012, several first flow measurements were done using LDA, but these tests showed a high loss of seeding material which was later found to be caused by settling of seeding particles on the surface of the heating rod. After the removal, cleaning and polishing of the heating rod, the facility was operational again in October. Some more tests using different measurement equipment have been done afterwards. A design for a new experiment on mixing of supercritical jets in a plenum has been completed.

Dissertations

-

Scientific Publications

-

AERODYNAMICS

Prof.dr.ir. H Bijl

Prof.dr. F Scarano

Prof.dr.ir. PG Bakker

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 is a continuation of previous research on flapping-wing propulsion in the flight regime of insects (Re ~ 100 to 1000). The present interest lies in the particular application of experimental and computational analysis tools to investigate flapping-wing Micro Aerial Vehicles (MAVs). Specific challenges are the wing-wing interaction, the high amount of wing flexibility, and the higher Reynolds number regime (10,000 - 100,000) which requires transitional and/or turbulent flow modeling.

PROGRESS

Computational activities compare the relative performance for deforming mesh strategies (ALE) and IBM (immersed boundary methods). Specific topics that were investigated were the interaction between single or biplane flapping wings and tail effects. Further activities were undertaken to extend the IBM approach for the simulation of 3D clap-and-fling wing interactions.

The experimental work has two major fields of attention: 1) the study of generic aeroelastic phenomena relevant to MAV propulsion and 2) a more detailed characterizationof the aerodynamics of the DelFly MAV itself (wake structure; forward flight regime).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. G.C.H.E. de Croon, M.A. Groen, C. De Wagter, B. Remes,R. Ruijsink, B.W. van Oudheusden: Design, Aerodynamics, and Autonomy of the DelFly, Bioinspiration & Biomimetics, vol. 7 (2012), no. 2, article 025003.
2. Shuanghou Deng, Bas van Oudheusden, Tianhang Xiao, Hester Bijl: A Computational Study on the Aerodynamic Influence of a Propeller on an MAV by Unstructured Overset Grid Technology and Low Mach Number Preconditioning, Open Aerospace Engineering Journal, vol 5 (2012), 11-21.
3. M.Perçin, Y.Hu, B.W.van Oudheusden, B.Remes, F.Scarano: Wing flexibility effects in clap-and-fling, International Journal of Micro Air Vehicles, Volume 3, Number 4, December 2011, pp. 217-227.
4. W.B. Tay, H.Bijl, B.W. van Oudheusden: Analysis of biplane flapping flight with tail, AIAA Aerodynamics Conference, 25-28 June 2012, New Orleans, AIAA 2012-2968.
5. M. Perçin, H.E. Eisma, B.W. van Oudheusden, B. Remes, R. Ruijsink, C. de Wagter: Flow visualization in the wake of the flapping-wing MAV "DelFly II" in forward flight, AIAA Aerodynamics Conference, 25-28 June 2012, New Orleans, AIAA 2012-2664.
6. Mustafa Percin, H.E. Eisma, B.W. van Oudheusden, B. Remes , R. Ruijsink , C. de Wagter: Wake Reconstruction of Flapping-Wing MAV 'DelFly II' in Forward Flight. International Micro Air Vehicle Conference and Flight Competition (IMAV 2012), 3-6 July 2012, Braunschweig.
7. Shuanghou Deng, Tianhang Xiao, Wee-Beng Tay, B.W. van Oudheusden, Hester Bijl: Numerical Investigation of Flexible Flapping Wing Propulsion at Low-Reynolds Numbers. International Micro Air Vehicle Conference and Flight Competition (IMAV 2012), 3-6 July 2012, Braunschweig.
8. W.B. Tay, B.W. van Oudheusden and H. Bijl: Validation and Numerical simulation Using the Immersed Boundary Method Solvers for Flapping Wing Flight. International Micro Air Vehicle Conference and Flight Competition (IMAV 2012), 3-6 July 2012, Braunschweig.

PROJECTLEADERS
H Bijl, BW van Oudheusden

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
WB Tay, M Percin, S Deng

COOPERATIONS
Univ. Lund, Univ. Michigan, AFRL

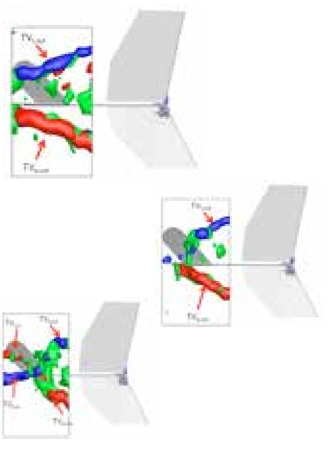
FUNDED
STW

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

START OF THE PROJECT
2010

INFORMATION
BW van Oudheusden
015 278 5349
B.W.vanOudheusden@tudelft.nl
http://www.tudelft.nl/

Experimental vortex-wake visualization behind the flapping wings of the DelFly MAV in forward flight configuration (flow speed 3 m/s; angle of attack 0 degrees); the flapping phase is just before the end of outstroke; the different diagrams show the effect of flapping frequency on the vortex-wake structure (top to bottom: 6, 8 and 12 Hz)



PIV-based non-intrusive determination of unsteady aerodynamic loads

Projectleaders
BW van Oudheusden, F Scarano, FFJ Schrijer

Researchtheme
Complex dynamics of fluids

Participants
R de Kat, D Ragni, K Lynch

Cooperations
DNW, NLR

Funded
STW

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

Start of the project
2006

Information
BW van Oudheusden
015 278 5349
B.W.vanOudheusden@tudelft.nl
http://www.tudelft.nl/

Project Aim

Novel non-intrusive experimental approaches are developed and applied to determine the 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 principles. Apart from looking at the fundamental principles (notably 3D flow effects) the project will also address the development of practical procedures. The primary area of application is for low-speed aerodynamics and industrial fluid dynamics, but the extension of the method to the high-speed flow regime will also receive attention, in view of its relevance for industrial aeronautics.

Progress

1) Completion of the comparative assessment of the computation of instantaneous pressure from time-resolved PIV velocimetry data (Thesis of R de Kat).

2) Determination of pressure fields and integral loads in application to operating propellers (Thesis of D Ragni)

3) Extension of PIV-based determination of mean pressure in a transonic base flow investigation with relevance to launcher-afterbody buffeting.

Dissertations

1. D.Ragni, PIV-based load determination in aircraft propellers, TU Delft, 10-02-2012 (promoter: prof. F.Scarano, co-promotor: dr.ir. B.W. van Oudheusden).
2. R. de Kat, Instantaneous planar pressure determination from particle image velocimetry, TU Delft, 05-03-2012 (promoter: prof. F.Scarano, co-promotor: dr.ir. B.W. van Oudheusden).

Scientific Publications

1. D.Ragni, B.W. van Oudheusden, F.Scarano: 3D pressure imaging of a propeller blade tip region by phase-locked stereoscopic PIV, Exp. Fluids, vol. 52 (2012), pp. 463-477.
2. R. de Kat, B.W. van Oudheusden: Instantaneous planar pressure determination from PIV in turbulent flow, Exp. Fluids, vol. 52 (2012), pp. 1089-1106.
3. D.Ragni, B.W. van Oudheusden, F.Scarano: Stereoscopic particle image velocimetry-based integral load determination on an aircraft propeller, Journal of Aircraft, vol.49 (5), 2012, pp. 1497-1506.
4. R. de Kat, B.W. van Oudheusden: Instantaneous volumetric pressure determination from particle image velocimetry, Int. Workshop on the Application of PIV for Aeroacoustics and Noise, Delft, The Netherlands, 16-17 April 2012.
5. D.Ragni, B.W. van Oudheusden, F.Scarano: PIV-load determination in aircraft propellers, 16th Int Symp. on Applications of Laser Techniques to Fluid Mechanics, Lisbon, Portugal, 09-12 July, 2012.

Trailing edge aeroacoustics

Project Aim

The aim of the research project on trailing edge aeroacoustics are twofold: On one hand, the applicability and limitations of available methods for quantitative broadband trailing edge noise estimiation in conjunction with state of the art 4D measurement techniques (high-speed tomographic PIV) is investigated. On the other hand, the advantage of high-speed PIV systems, namely the time-resolved description of the velocity and aeroacoustic source field, is used for quantitative analyses of source mechanisms relevant to airfoil self noise.

Progress

In cooperation with the NLR high-speed tomographic PIV and phased-array acoustic measurements have been performed on a flat plate with a sharp trailing edge. Various methodologies for estimation of the noise level based on the 4D PIV data have been applied by the partners (TUD, NLR, VKI) and compared to the results of the acoustic measurements, providing the first example for the estimation of broadband noise generated by turbulent flows based on PIV. In a separate project the source mechanism responsible tonal noise observed for airfoils at low to moderate Reynolds numbers has been studied. Access to time-resolved velocity field data in the source region and simultaneously microphone measurements allowed to advance the understanding of this particular airfoil self noise mechanism.

Dissertations

-

Scientific Publications

1. Pröbsting, S., Scarano, F., Bernardini, M., & Pirozzoli, S. (2012). A comparative study of turbulent boundary layer wall pressure fluctuations obtained from high-speed tomographic PIV and DNS. 16th Int Symp on Appl of Laser Tech to Fluid Mech. Lisbon.

Projectleaders

F Scarano

Researchtheme

Complex dynamics of fluids

Participants

S Pröbsting

Cooperations

NLR, VKI

Funded

FP7 AFDAR

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

Start of the project

2011

Information

S Probsting
s.probsting@tudelft.nl

Instabilities of the separated wake flow in the base region of a space launcher

Projectleaders
F Scarano

Researchtheme
Complex structures of fluids

Participants
F Scarano, F Schrijer, B van Oudheusden, V Gentile

Cooperations
-

Funded
Tinkerbell Scholarship

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

Start of the project
2012

Information

F Scarano
015 278 5902
F.Scarano@TUDelft.NL

F Schrijer
015 278 6386
f.f.j.schrijer@tudelft.nl

BW van Oudheusden
015 27 85349
B.W.vanOudheusden@tudelft.nl

V Gentile
V.Gentile@tudelft.nl

Project Aim

Investigation of the effects of boundary conditions on the instabilities caused by separation phenomena in the base region and on the afterbody of a space launcher. Particular attention is given to the buffeting phenomena affecting the flow past Ariane5 launcher during its ascent through the atmosphere at transonic speeds.

Progress

An experiment dealing with a simple blunt-based rocket model has been lately performed at uncompressible regime; then afterwards the effects of geometric boundary conditions will be considered adding different after- bodies to the base of the model and/or modifying the base region of the model performing an experiment at transonic speed.

Dissertations

-

Scientific Publications

-

Multiscale and reduced-order modeling of turbulence

Project Aim

To develop efficient prediction methods for wall-bounded turbulent flows using variational multiscale large-eddy simulation (VMS-LES) and goal-oriented reduced-order modelling techniques. In addition, to develop numerical models for conventional and nanopulse plasma flow control.

Progress

1) Near-wall models using reduced-order models based on enrichment functions have been shown to be highly effective for stochastically-forced burgers cases. Implementation for Navier Stokes using XFEM techniques nearly complete.

2) The semi-continuous formulation for goal-oriented reduced-order modeling was further developed and applied to non-linear equations and multi-dimensional problems

3) Models of plasma transition control for shear layers and transitional boundary layers have been developed and compared with experiment.

Dissertations

-

Scientific Publications

1. Correale, G, Popov, IB, Starikovskii, A & Hulshoff, SJ (2010). Flow Separation Control on Airfoil With Pulsed Nanosecond Discharge Actuator. In B Graham (Ed.), Proceedings of the 63rd Annual Gaseous Electronics conference and 7th International Conference on Reactive Plasmas (pp. 1-1). sn. (TUD).
2. Popov, IB & Hulshoff, SJ (2012). Numerical Investigation of Instabilities in Free Shear Layer Produced by NS-DBD Actuator. In s.n. (Ed.), WASET proceedings (pp. 1601-1609). Paris: WASET. (TUD).

Projectleaders

SJ Hulshoff, H Bijl

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

L Chen, L Cheng, I Popov

Cooperations

University of Texas, Austin

Funded

Chinese Scholarship Council (CSC)

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

Start of the project

2008

Information

SJ Hulshoff
015 278 1538
S.J.Hulshoff@TUDelft.NL
www.lr.tudelft.nl/aerodynamics

Aerodynamic measurement of high-speed base flows

PROJECTLEADERS
F Scarano
RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
K Lynch
COOPERATIONS
FLOVIST
FUNDED

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

START OF THE PROJECT
2011
INFORMATION
K Lynch
k.p.lynch@tudelft.nl
015 278 2629

Project Aim

The project aims at a greater understanding of the unsteady aerodynamic phenomena occurring in the wake of cylindrical bodies, as often encountered in launch vehicles and missiles. Related to this problem is the complimentary challenge of three-dimensional measurement. The project thus investigates advances in tomographic PIV for performing measurements of not only velocity characteristics, but derived quantities such as acceleration and pressure.

Progress

In the past year, it has been identified that for high-speed flow, instantaneous pressure evaluation is unfeasible using standard high-speed laser and camera systems. This forces the development of a burst type tomographic PIV system capable of arbitrary timing and control. Besides hardware aspects, the use of unique processing algorithms for four-pulse data was explored and has been published in related work as it applies to fully time-resolved image data. A first set of experiments have been conducted with the system operating in a low speed flow, which will appear in the upcoming PIV13 conference at TUDelft, followed by experiments in the high speed regime.

Dissertations

-

Scientific Publications

1. K. Lynch, F. Scarano “Enhancing the velocity dynamic range and accuracy of time-resolved PIV through fluid trajectory correlation.” 16th Int Symp on Applications of Laser Techniques to Fluid Mechanics. Lisbon, Portugal, 09-12 July, 2012.
2. K. Lynch, F. Scarano “A high-order time-accurate interrogation method for time-resolved PIV,” Meas Sci. Technol 24:035305.

Environmental Fluid Mechanics

Prof.dr.ir. GS Stelling

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 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. An example is the software package SWAN (Simulating Waves Nearshore). 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 with topics such as: Generation and prediction of squall oscillations and harbour seiches, dynamics of surf beat and the Wave model SWAN
- Shallow flows, transport and sedimentation 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 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.

Numerical model for simulatig the propagation of and inundation by tsunami waves

Project Aim

Since the Indian Ocean Tsunami many countries have contributed to the development of tsunami warning systems in the Indian Ocean. A German-Indonesian Tsunami Early Warning System (GITEWS) (www.gitews.de, is currently under active development. One of the aims of this project is the development of accurate numerical models with which to simulate the propagation, flooding and drying, and run-up of a tsunami. This is done not only for forecasting purposes, but also for detailed scenario studies, in order to assess the regions most at risk from future tsunamis.

Progress

The model H_2Ocean has been extended to non-hydrostatic. A lumping scheme has been introduced to improve the efficiency of the model. Both the memory requirement and number of floating point operations required to solve the Poisson equations has been reduced. The CPU time is reduced by around 30%. To improve the accuracy and efficiency of the model further, a reduced two-layer formulation has been developed. When applying the method in a two-layer model, the reduced model takes the same computational effort as the depth-integrated model, but achieves much higher dispersion accuracy. The project has been ended. A dissertation based on this project will be published in 2013.

Dissertations

-

Scientific Publications

1. Cui, H., Pietrzak, J.D. and Stelling, G.S., 2012. Improved efficiency of a non-hydrostatic, unstructured grid, finite volume model. Ocean Modeling, 35, 16-30.
2. Hooper, A.; Pietrzak, J.; Simons, W.; Cui, H.; Riva, R.; Naeije, M.; Terwisscha van Scheltinga, A.; Schrama, E.; Stelling, G.; Socquet, A., 2012. Importance of horizontal seafloor motion on tsunami height for the 2011 Mw=9.0 Tohoku-Oki earthquake. arth and Planetary Science Letters, Volume 361, p. 469-479.

Projectleaders

GS Stelling, JD Pietrzak

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

H Cui, JD Pietrzak, GS Stelling

Cooperations

Alfred Wegener Institute for Polar and Marine Research

Funded

Alfred Wegener Institute, Water Research Center Delft

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

Start of the project

2008

Information

Haiyang Cui
015 278 85433
H.Cui@tudelft.nl

Sediment nourishment as a solution to autonomous bed degradation of the Rhine river : response to sediment overloading

Projectleaders
WSJ Uijttewaal, A Blom

Researchtheme
Complex dynamics of fluids

Participants
C Orrú

Cooperations
Geotechnology Laboratory group, Applied Geophysics and Petrophysics section, Faculty of Civil engineering and Geosciences, TU Delft. Remote sensing group, Faculty of Aerospace Engineering, TU Delft.

Funded
NWO, Regional Government of Sardinia (Italy) (Regione Autonoma della Sardegna-Programma Master&Back)

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

Start of the project
2011

Information
C Orrú
015 278 4070
C.Orru@tudelft.nl

Project Aim

The main goal is to provide insights on the development of the morphodynamic pattern of rivers dominated by bedforms with sand-gravel mixtures during unsteady conditions. More specifically we study the influence of the evolution of bedform geometry, stochastics of bedform geometry and sorting on morphodynamic changes. This will be reached by creating a new experimental data set for calibration of analytical and numerical models of morphodynamics of sand/gravel rivers. In the flume experiments we will focus on the response of the river bed to dredging and sediment nourishment.

Progress

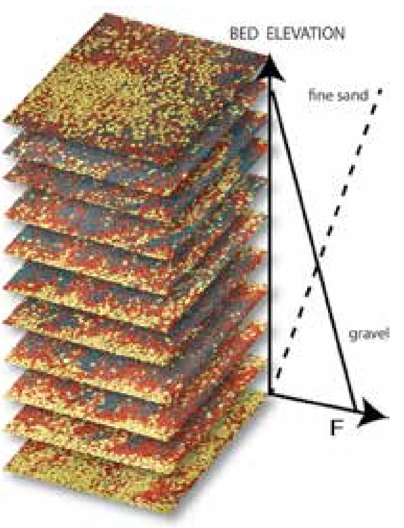
Over the past year the research has focused on developing measurements techniques to be applied in the upcoming flume experiments. These methods are needed for characterizing the bed surface grain size distribution and bed stratigraphy, which is needed to gain new insights in grain size selective processes. The assessment of the image analysis combined with particle coloring, reconstruction of bed samples using a micro CT scanner 3D and the Multibeam echosounder survey were performed in an experiment. Additionally, the technique of image analysis was applied to determine the stratigraphy of a Gilbert delta deposit in a flume experiment (Figure1). Furthermore the work has concentrated on the design and program of the upcoming flume experiments.

Dissertations

-

Scientific Publications

1. Conference proceedings: Orrú, C, Blom, A, Uijttewaal, W.S.J. (2012). Image analysis techniques used to determine the grain size distribution of a sand-gravel bed surface and substrate. NCR days 2012, Arnhem, Book of abstracts (pp.53-54). http://www.ncr-web.org/images/publications/NCR%202012%20%20Book%20of%20Abstracts.pdf%20.pdf.



Example of vertical sorting profile measuring the bed stratigraphy with image analysis.

Project Aim

The objectives of the proposed study are:

- Quantify the effects of this sediment-turbulence interaction in general, and in particular with respect to the vertical turbulent mixing processes,
- Quantify the transport by sediment-driven density currents and establish the conditions under which these currents contribute significantly to the overall siltation rate in harbor basins,
- Implement the relevant physical processes in a three-dimensional numerical model and test this model against field data.

Progress

The formation of turbidity maxima in the Rotterdam Waterway and their relation to harbor siltation was studied with surveys and 3D RANS simulations. The gradient of the tidal water level dominates the water motion, while the trapping of SPM and siltation are mainly determined by the baroclinic pressure gradient and the stratification caused by salinity. The salinity structure generates currents and damps turbulent mixing. The trapped SPM at the head of the salt wedge determines the exchange of SPM with harbors. Therefore, baroclinic currents dominate the transport of SPM in the harbors. The saltwater intrusion length varies continuously due to water level gradients caused by tidal periodicities, wind, and variations of the river discharge. This length controls the location of significant siltation and the trapping efficiency of the system. Uncertainties in the prediction of the salinity structure determine the quality of the predicted distribution of SPM in the system.

Dissertations

1. de Nijs, M.A.J., 2012, On sedimentation processes in a stratified estuarine system, pp. 1-302, doi:10.4233/uuid:fb0ec18d-dcfd-468d-af4a-45bfb02cac1c, ISBN: 9789461915627.

Scientific Publications

1. de Nijs, M.A. J.; Pietrzak, J.D., 2012, On total turbulent energy and the passive and active role of buoyancy in turbulent momentum and mass transfer, Ocean Dynamics, Volume 62, Issue 6, pp.849-865 DOI: 10.1007/s10236-012-0536-6
de Nijs, M.A. J.; Pietrzak, J.D., 2012, Saltwater intrusion and ETM dynamics in a tidally-energetic stratified estuary, Ocean Modelling, Volume 49, p. 60-85.

.

Projectleaders

GS Stelling, JD Pietrzak, JC Winterwerp

Researchtheme

Complex dynamics of fluids

Participants

MAJ de Nijs

Cooperations

Port of Rotterdam, Public Works Directorate South-Holland

Funded

STW

University	-
FOM	-
STW	93 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	7 %
Scholarships	-

Start of the project

2004

Information

JD Pietrzak
015 278 9455
J.D.Pietrzak@tudelft.nl
www.fluidmechanics.tudelft.nl

PROJECTLEADERS
GS Stelling, JD Pietrzak

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
O Kleptsova, JD Pietrzak, GS Stelling

COOPERATIONS
-

FUNDED
TU Delft

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

START OF THE PROJECT
2005

INFORMATION
O Kleptsova
O.Kleptsova@TUDelft.nl

PROJECT AIM

The project ams to develop a new coastal model based on unstructured grids. The model is to be suitable for the investigation of flow phenomena, such as the development and behavior of river plums and associated transport processes in the Dutch and other coastal zones. New discretization of the shallow water equations are being developed and deeper insight gained into the numerical properties and modeling capabilities of this new class on models.

PROGRESS

The project has ended and resulted in the dissertation named On Techniques for Modelling Coastal and Ocean Flow with Unstructured Meshes (2013).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Kleptsova, O , Pietrzak, JD & Stelling, GS (2012). On a momentum conservative z-layer unstructured C-grid ocean model with flooding. Ocean Modelling, 54-55(September), 18-36.

Project Aim

Present state of the art wave models are still insufficiently accurate regarding shallow water dissipation and non-linear interactions in the coastal zone. This project will focus on three main areas; improvement of modelling capabilities of physical processes in the coastal zone, procurement, utilisation and dissemination of high quality datasets and the development, testing and dissemination of new source terms for third generation wave models.

Progress

A new source term formulation for depth-induced breaking; the beta-kd model (based on the previous n-kd model) has been developed and is being calibrated and verified to account for normalized wave length, local slope and directional spreading over an extensive selection of laboratory and field cases. An alternative to the LTA source term for triads; the DCTA is being developed which provides superior results at the high frequency end of the spectrum. Analysis of spectral evolution is being carried out by USACE and Shell IEP.

Dissertations

-

Scientific Publications

-

Projectleaders
G van Vledder, J Hanson, LH Holthuijsen, K Ewans

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
D Hurdle, M Zijlema, M Christou, K Hathaway, J Salmon

Cooperations
Arcadis NL/Alkyon Hydraulic Consultancy & Research, US Army Corps of Engineers, Shell International Exploration and Production

Funded
Office of Naval Research, USA

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

Start of the project
2010

Information
G Ph van Vledder
015 278 3255
g.p.vanvledder@tudelft.nl

Projectleaders
A Blom

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
G Stecca

Cooperations
-

Funded

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

Start of the project
2012

Information
G Stecca
06 219 84189
G. Stecca@tudelft.nl

Project Aim

The aim of the project is to numerically model the morphodynamic response of rivers where sediment sorting plays a dominant role to unsteady flow and sediment supply conditions. The focus is on the development of a numerical tool which shall be generally applicable to different sediment regimes (with and without dunes) and include different phenomena such as abrasion and selective transport.

Progress

During the last year G. Stecca focused on recasting the coupled system formed by the shallow water equations for free-surface flows and the Hirano active layer equations for mixed sediments in matrix-vector form and solving them by finite-volume path-conservative methods. He also numerically studied the celerity of the additional waves induced by the inclusion of the active layer equations. This activity is currently in progress.

Dissertations

-

Scientific Publications

-

Simulating waves till shore (SWASH)

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

The following features have been implemented in SWASH:

- Partial reflection and transmission through porous structures, like rubble-mound breakwaters in harbors, can be specified.
- The nonlinear k-ε model for secondary flows is included.
- Periodic boundary conditions to be able to do simulations of large field cases along coasts.
- Adding bound long waves to multidirectional waves obtained from linear wave theory at the wave maker to take into account the nonlinear effects.

SWASH can be downloaded from http://swash.sf.net. There were about 1,000 downloads by the end of 2012 since the launch of SWASH at the website (as of February 9, 2011).

Dissertations

-

Scientific Publications

1. Vilani, M., Bosboom, J., Zijlema, M. and Stive, M.J.F. (2012). Circulation patterns and shoreline response induced by submerged breakwaters, in: P.J. Lynett and J.M. Smith (Eds.), Proc. 33th Int. Conf. on Coast. Engng., ASCE, World Scientific Publishing, Singapore, paper no. structures.25.
2. Rijnsdorp, D.P., Smit, P.B. and Zijlema, M. (2012). Non-hydrostatic modelling of infragravity waves using SWASH, in: P.J. Lynett and J.M. Smith (Eds.), Proc. 33th Int. Conf. on Coast. Engng., ASCE, World Scientific Publishing, Singapore, paper no. currents.27.
3. Zijlema, M. (2012). Modelling wave transformation across a fringing reef using SWASH, in: P.J. Lynett and J.M. Smith (Eds.), Proc. 33th Int. Conf. on Coast. Engng., ASCE, World Scientific Publishing, Singapore, paper no. currents.26.
4. Suzuki, T., Verwaest, T., Veale, W., Trouw, K. and Zijlema, M. (2012) A numerical study on the effect of beach nourishment on wave overtopping in shallow foreshores, in: P.J. Lynett and J.M. Smith (Eds.), Proc. 33th Int. Conf. on Coast. Engng., ASCE, World Scientific Publishing, Singapore, paper no. waves.50.

Projectleaders

G Stelling, M Zijlema

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

PB Smit, DP Rijnsdorp, T Bogaard

Cooperations

-

Funded

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

Start of the project

2010

Information

M Zijlema
015 278 3255
m.zijlema@tudelft.nl
http://swash.sf.net

Development of a quasi-3D morphodynamic model and its application to meander processes at high curvature

Projectleaders
WSJ Uijttewaal, HJ de Vriend

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
W Ottevanger, K Blanckaert, CJ Sloff

Cooperations
Deltares (Netherlands), EPFL (Switzerland), IGB (Germany)

Funded
STW, NWO, Deltares

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

Start of the project
2008

Information
W Ottevanger
015 278 4069
w.ottevanger@tudelft.nl

Project Aim

Development of a quasi-3D morphodynamic model which is valid for sharply curved river bends, such that high spatial and temporal scales may be simulated. Subsequently, the quasi-3d model will be validated using laboratory and field measurements, as well as more detailed software models (LES, RANS), Finally the model will be used for fundamental research into the processes (momentum redistribution, secondary flow, bank and bed shear stresses) and the dynamics (river bed adaptation, bank erosion and accretion, planform development) of meandering rivers (at high curvature).

Progress

The processes governing velocity redistribution in sharp river bends were analyzed for three sharply curved flume and field measurement data sets using a 1D flow model valid for high curvature. An extension of Delft3D for hydrodynamic modeling in sharp bends using a quasi-3D approach has been developed and validated. The new approach includes the saturation of secondary flow at high curvature, increased roughness due to curvature and the bed shear stress angle adaptation. These processes are important with regards to the morphological development in sharply curved meander bends. A parameter study using axi-symmetric fully developed Large-eddy simulations was performed and bank shear stresses were related to 1D and quasi-3D model quantities. The bank shear stresses are higher than would be expected based on the depth-averaged velocity alone. Furthermore, for large increasing width-to-depth ratio the bank shear stresses no longer increase, whereas the bed shear stresses do continue to increase. This behavior suggests that sharply curved meander bends tend to deepen, rather than migrate laterally.

Dissertations

-

Scientific Publications

1. Ottevanger,W.,Blanckaert,K.,Uijttewaal,W.S.J. (2012),,Processes governing the flow redistribution in sharp river bends, Geomorphology http://dx.doi.org/10.1016/j.geomorph.2011.04.049.

An environmental fluid dynamics laboratory in the field; hydrodynamics, morphodynamics and invertebrate ecology in river meanders

Project Aim

This project combines laboratory experiments, detailed numerical simulations and field measurements on river bends in order to link the physical processes related to hydrodynamics and morphodynamics to the biological processes. It is aimed at extending the ecological modelling approach with hydrodynamic parameters.

Progress

Field studdies have been performed on three different river bends.
Bed levels, detailed velocity patterns and distribution of invertebrates and vegetation over the width of the bend have been obtained. Parallel to this the numerical modelling of flow and transport is being adapted to include ecological parameters.

Dissertations

-

Scientific Publications

1. Schnauder, I.; Sukhodolov, A. N. (2012) Flow in a tightly curving meander bend: effects of seasonal changes in aquatic macrophyte cover EARTH SURFACE PROCESSES AND LANDFORMS 37(11): 1142-1157 DOI: 10.1002/esp.3234.
2. Sukhodolov, Alexander N. (2012) Structure of turbulent flow in a meander bend of a lowland river. WATER RESOURCES RESEARCH 48: W01516 DOI: 10.1029/2011WR010765.

Projectleaders

WSJ Uijttewaal

Researchtheme

Complex dynamics of fluids

Participants

W Ottevanger, K Blanckaert, I Schnauder, A Sukhodolov

Cooperations

IGB Berlin Germany

Funded

NWO-DFG

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

Start of the project

2009

Information

WSJ Uijttewaal
015 278 1371
W.S.J.Uijttewaal@tudelft.nl

Bed and form resistance in rivers at high water stages

Projectleaders
WSJ Uijttewaal, GS Stelling
Researchtheme
Complex dynamics of fluids
Participants
Shahid Ali
Cooperations
Deltares, RWS
Funded
NUFFIC

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

Start of the project
2007
Information
Shahid Ali
015 278 5974
S.Ali@tudelft.nl

Project Aim

The River flow within flood plains is difficult to forcast because of the complex flow geometry founded by main channel and groyne fields. In the flood plane there are many obstacles and landforms, which requires high demand for numerical modeling. Due to large computational domain and limitation of computer capacity, complete details can generally not be resolved. This study focuses on correct representation of resistance elements in a numerical simulation and consistent behavior towards high water stages. A number of prosesses related to vegetation, weirs and bed- forms will be studied experimentally in great detail in order to come to an improved implementation of physical processes.

Progress

The energy head loss due to submerged and emerged vegetated dikes and groynes has been modeled by The expansion loss form drag model and has been compared with the experimental data. A series of Experiments have been performed. In these experiments blockage due to vegetation has been varied and different shapes of vegetation and groynes have been tested. Experiments to investigate the structure of the flow over the oblique vegetated groynes and other complex phenomena related to it have been performed. A 2-d numerical study of flow over plain weir-like obstacles has been conducted by using RANS mathematical model including free surface variations. A non-linear k-ε model has been applied for turbulence closure. The flow conditions under which the undulations occur and the wave characteristics of the undular hydraulic jump caused by the weir-like obstacles have been also investigated. 3-d numerical simulations have been performed for flow over oblique weir-like obstacles to investigate the flow features in the vicinity of the oblique obstacles.

Dissertations

-

Scientific Publications

1. Ali, S. and Uijttewaal, W. S. J. 2013. Flow resistance of vegetated weir-like obstacles during high water stages. Journal of Hydraulic Engineering, ASCE, Vol. (139), No. (3). pp. 325-330.
2. Ali, S., Uijttewaal, W. S. J. and Kimura. I. 2012. Numerical modeling of rapidly varying flow over weir-like obstacles during high water stages. Proceedings of River flow, Costa Rica, pp. 123-130.
3. Ali, S. and Uijttewaal, W. S. J. 2010. Flow resistance of vegetated weir-like obstacles during high water stages. Proceedings of River flow, Braunschweig Germany, pp. 293-299.
4. Ali, S. and Uijttewaal, W. S. J. 2009. Form drag due to vegetated weir-like obstacles interpreted as expansion loss. 33rd IAHR world congress Vancouver Canada, pp. 139-146.

A study on wave-induced responses of moored floating bodies embedded in a large scale wave model

Project Aim

An accurate prediction of the body responses under different wave conditions is of great importance for the safe operation of a ship in a harbor. The long term goal of this study is to predict the response of a moored floating structure in a complex wave environment (e.g. a harbor or coastal region) using a numerical model. For this purpose, SWASH, a far field wave model recently developed at the TU Delft, will be extended by nesting floating bodies in such large scale regions. This allows to predict the body motions and resulting fluid motions and hence the pressure at the hull of the body.

Progress

At present, a numerical code is developed to simulate the wave transformation around a fixed (i.e. non moving) floating body. Preliminary results indicate that the model correctly predicts wave transmission and reflection coefficients. This approach will be extended by including wave-induced motions of the floating body. Low frequency waves (also known as Infragravity waves) can have a significant impact on moored vessel motions. This requires an accurate generation of these waves at the off-shore boundary. Therefore, on short term, a second order accurate boundary condition is implemented, which provides an accurate forcing of infragravity waves at the 'wave maker'. This boundary condition is validated using both analytical solutions and flume experiments. At present effort is made to verify the model for simulating infragravity waves in a coastal region. For this purpose model results are compared with a field experiment.

Dissertations

-

Scientific Publications

1. Rijnsdorp, D.P. , P.B. Smit, and M. Zijlema, Non-hydrostatic modelling of infragravity waves using SWASH, 2012, Proceedings of the 33rd Coastal Engineering Proceedings.

Projectleaders

GS Stelling, M Zijlema

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

DP Rijnsdorp

Cooperations

Sichuan University, Chengdu, China

Funded

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

Start of the project

2011

Information

DP Rijnsdorp
d.p.rijnsdorp-1@tudelft.nl

A spectral shallow-water wave model with nonlinear energy- and phase evolution

Projectleaders
LH Holthuijsen

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
GS Stelling, LH Holthuijsen, M Zijlema, TT Janssen, PB Smit

Cooperations
-

Funded

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

Start of the project
2006

Information
LH Holthuijsen
015 278 4803
L.H.Holthuijsen@tudelft.nl

Project Aim

The project aim is to develop a conceptual extension of spectral energy wave models to be able to capture spatial inhomogeneity in the wave field (due to diffraction, refraction) and to improve present formulations for the triad wave-wave interactions. Furthermore, to allow for an extreme flexibility in spatial resolution, the present spectral wave model SWAN is implemented on an unstructured computational grid (SWANus). The first application of such a grid is, in cooperation with the University of Notre Dame, a coupling with the ocean circulation model ADCIRC to improve the hurricane prediction capability for New Orleans.

Progress

Based upon a formal multiple scales analysis, we have derived an approximate transport equation for the evolution of the second order wave statistics over variable topography. The derived model, as is demonstrated by comparison to observations, includes effects such as coherent interference and diffraction. Conceptually, the model is formulated in terms of the Wigner-Ville spectrum which is akin, and for quasi-homogeneous conditions reduces to, the variance density spectrum used in modern stochastic wave models. As such, the model is a natural extension of existing third-generation wave models to include effects such as diffraction and coherent interference induced by the topography. Previously the spectral energy wave model SWAN was made applicable for unstructured grids and the code has been released to the public domain.

Dissertations

-

Scientific Publications

1. Smit, P.B, Janssen, T.T. and Herbers, T.H.C. "Topography-induced Focusing of Random waves". Proceedings of 33rd Conference on Coastal Engineering, Santander, Spain, 2012.

Project Aim

Besides the characterization of clays through their behavior in electric fields, which is an on-going study, new related topics are developed: RioTinto has given funding for a new challenging topic related to the separation of iron ore and clay; A new electroacoustic device is under construction in collaboration with Cordouan Tech. and PECSA.

Progress

New findings have been achieved in the characterization of montmorillonite (2 articles submitted); new models are developed for the electrokinetic response of non-ideal particles (1 article submitted); these models will be at the onset of the software developed for Cordouan tech.

Dissertations

-

Scientific Publications

-

Projectleaders

C Chassagne

Researchtheme

Complex structures of fluids

Participants

C Chassagne, M Ibanez

Cooperations

PECSA, Université Paris-Sorbonne, Cordouan Tech., Deltares

Funded

Allocation Nationale de Recherche (ANR), RioTinto

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

Start of the project

2011

Information

C Chassagne
c.chassagne@tudelft.nl
www.citg.tudelft.nl/index.php?id=72915

PROJECTLEADERS
GS Stelling, BC van Prooijen
RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
ND Volp
COOPERATIONS
NIOZ, Deltares, Rijkswaterstaat, BAW
FUNDED
Building with Nature, Ecoshape

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

START OF THE PROJECT
2009
INFORMATION
ND Volp
015 278 4069
n.d.volp@tudelft.nl

PROJECT AIM

The objective of the project is to improve the morphodynamic modeling of intertidal areas, focusing on model improvement and better model usage. Morphodynamic and hydrodynamic processes are strongly coupled and cover a wide range of time and length scales. Therefore, a multiple-scale approach is required. Typical challenges in model improvement are the proper computation of velocities in shallow water areas, the coupling between hydrodynamics and morphodynamics on the different length and time scales.

PROGRESS

The subgrid method of Casulli,2009 uses small scale bathymetry information for simulations on a coarser grid. Based on a similar approach, a momentum conservative formulation for the advection is derived and a formulation of the friction that accounts for velocity variations within a cell. These variations are due to bathymetric and roughness changes such cell. The hydrodynamic results show a significant increase in accuracy, with only a slight increase in computation cost. It also allows for an accurate reconstruction of a velocity field on subgrid scale, which is used to compute sediment transport and bed updates on a small horizontal scale. The initial morphodynamic results based on the velocity reconstruction are very promising.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Hydraulic impact of overtopping waves on a multifunctional dike

Project Aim

Multifunctional dikes can be designed in an infinite number of ways. The most relevant hydraulic issues are related to the impact of waves on various parts of the structure. So the aim of this project is to quantify the hydraulic impact of overtopping wave on residential buildings or other structures that are part of a multi-functional flood defence. The impact is related to the strength of the structures and various failure mechanisms are assessed.

Progress

Literature study and preparation of tests are being executed.

Dissertations

-

Scientific Publications

1. Chen, X., Hassan, W., Uijttewaal, W., Verwaest, T., Verhagen, H., Suzuki, T., & Jonkman, S. (2012). HYDRODYNAMIC LOAD ON THE BUILDING CAUSED BY OVERTOPPING WAVES. Coastal Engineering Proceedings, 1(33), structures.59. doi:10.9753/icce.v33.structures.59.

Projectleaders

WSJ Uijttewaal

Researchtheme

Complex dynamics of fluids

Participants

X Chen, B Jonkman

Cooperations

Deltares, STOWA, Flanders Hydraulic Res., RWS. Waterdienst

Funded

STW

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

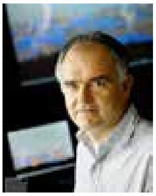
Start of the project

2011

Information

X Chen
06 864 49343
X.Chen-2@tudelft.nl

Geoscience & Remote Sensing



Prof.dr.ir. H Jonker

Prof.dr.ir. AP Siebesma

This group studies an entirely new research field using existing expertise in fluid mechanics and turbulence at TU Delft to address important questions in the field of weather and climate. Special attention is payed to the role of clouds, of which relatively little is known. It is believed that clouds could have a considerable impact on the size of the estimated enhanced greenhouse effect.

Project Aim

A realistic representation of deep cumulus clouds remains one of the most challenging problems in atmospheric modeling. Numerical Weather Prediction and climate models, in which deep convection is parametrized, tend to predict the onset of deep convection too early during the day. We will investigate the transition from shallow clouds to deep convection using the Dutch Atmospheric Large Eddy Simulation (DALES) model. The simulation results of DALES will be used to determine the relative roles of gradual moistening of the cloud layer and the organization of the boundary layer below cloud base.

Progress

A previous study regarding the role of organization in the subcloud layer has been published in the Journal of Atmospheric Sciences. Another study of the sensitivity of continental deep convection to environmental humidity and atmospheric stratification has been published in Geophysical Research Letters. Recent work has focused on an explanation for the cloud thermodynamic properties (temperature and water content) found in Large Eddy Simulations. Whereas previous studies proposed that downdrafts are responsible for the observed properties of cumulus clouds, we find that the strong correlation between (equivalent) temperature and water content are in agreement with horizontal mixing. Variations between the mixing rates that cloud parcels experience explain the differences between their thermodynamic properties. Horizontal mixing is also observed in the trajectories of Lagrangian particles in the Large Eddy Simulations, whereas organized downdrafts are virtually absent.

Dissertations

-

Scientific Publications

1. Böing, S. J., H. J. J. Jonker, A. P. Siebesma and W. W. Grabowski (2012), “Influence of the subcloud layer on the development of a deep convective ensemble.” J. Atmos. Sci., 69, 2682–2698.
2. Böing, S.J., A. P. Siebesma, J. D. Korpershoek and H. J. J. Jonker (2012), “Detrainment in deep convection.” Geophysical Research Letters, 39:20.

Projectleaders

HJJ Jonker, AP Siebesma

Researchtheme

Complex dynamics of fluids

Participants

SJ Böing, HJJ Jonker, AP Siebesma, SR de Roode

Cooperations

KNMI, Dr. W.Grabowski (NCAR, Boulder,Colorado,U.S.A)

Funded

TU Delft

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

Start of the project

2009

Information

S Böing
015 278 3478
s.j.boing@tudelft.nl
www.grs.citg.tudelft.nl

Cloud-climate feedback: the role of boundary layer clouds

Projectleaders
SR de Roode, HJJ Jonker, AP Siebesma

Researchtheme
Complex dynamics of fluids

Participants
J van der Dussen, SR de Roode, HJJ Jonker, AP Siebesma

Cooperations
KNMI, + 12 other EU partners involved in EUCLIPSE

Funded
EU

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

Start of the project
2010

Information
J van der Dussen
015 278 4720
J.J.vanderDussen@tudelft.nl
www.grs.citg.tudelft.nl

Project Aim

The cloud response due to the enhanced greenhouse effect remains the largest source of uncertainty in climate model projections of a future climate. The EU-funded Cloud Intercomparison, Process Study & Evaluation Project (EUCLIPSE) aims to reduce the uncertainty in the representation of cloud processes and feedbacks in the new generation of Earth System Models (ESMs). This sub-project will use the Dutch Atmospheric Large-Eddy Simulation model to study in detail turbulent flows in cloudy atmospheres. Central question is how the vertical atmospheric stability controls the spatial coverage and depth of low clouds like stratocumulus and shallow cumulus.

Progress

In total 6 large-eddy simulation (LES) modeling groups participated in the model intercomparison study of the Lagrangian transition of a solid marine stratocumulus case to broken shallow cumulus clouds. It has been found that all models agree very well with the observed mean state and turbulence structure of the atmospheric boundary layer. Various sensitivity experiments on the role of precipitation on the break-up of stratocumulus have been performed which show that low cloud droplet concentrations cause larger drizzle rates which, in turn, diminish the entrainment rate. Because the reduced entrainment drying and removal of water by drizzle have opposing effects on the total amount of cloud liquid water the timing of the cloud break up appears to be not very sensitive to the cloud droplet concentration. A manuscript that discusses the results of the LES model intercomparison case has been submitted.

To better understand the role of various physical processes on the evolution of a solid cloud deck a budget equation for the vertically integrated liquid water content has been derived. With this approach a criterion can be derived which predics whether a cloud layer thickens or thins. It nicely explains why clouds can be persistent in case some theoretical studies suggest a rapid break up. The manuscript will be submitted in March 2013.

In a third study with the Dutch Atmospheric LES (DALES) model several sensitivity studies have been performed based on the model intercomparison case, which shows that the timing of stratocumulus cloud break-up is subtly controlled by the large-scale divergence of the horizontal mean wind velocity.

The fourth study will be dedicated to calculating with the LES model equilibrium states of stratocumulus clouds as a function of the thermodynamic properties above the thermal inversion layer capping the stratocumulus cloud top.

Dissertations

-

Scientific Publications

-

Droplet-turbulence dynamics under heterogeneous conditions

Project Aim

The focus will be on the evolution of droplet size distributions under a sharp gradient in the mean gas velocity, the droplet concentration and the background humidity. The goal of this project is to understand the interplay between the turbulence dynamics, and the droplet distribution. The two key questions to be addressed are: What is the influence of shear in the mixing layer on the droplet distribution and dispersion, droplet collisions and coalescence efficiency. How are the dispersion, collision frequency and coalescence efficiency influenced by the orientation of the mixing layer with respect to gravity?

Progress

Last year we investigated the role of dissipation en vorticity on both the droplets and the collisions. Our key finding is that droplets statistically do not collide where they preferentially concentrate. We also have tried to construct a physical picture of how collisions occur. Droplets first preferentially cluster under the influence of enstrophy. They do, however, not collide yet since the increase in velocity coherence yields a decrease in relative velocity. Once clustered, dissipative events are found to precede collisions, because they appear vital for decorrelating the droplet velocities. These findings where written and submitted in a first paper. We also started investigating the role of the eigenvalues of the deformation tensor, and defined a categorization based on whether rotation is present and the strength of the convergence. We also developed a simple model to compute the effect of eigenvalues on the collision probability. We have found that flow regions with a high convergence are favorable to collisions. We also developed a 3d visualization tool to visualize droplet and collisions in a turbulent flow.

Dissertations

-

Scientific Publications

-

Projectleaders

HJJ Jonker

Researchtheme

Complex dynamics of fluids

Participants

V Perrin, HJJ Jonker

Cooperations

Prof W. vd Water (TUE)
Humberto Bocanegra Evans (TUE)

Funded

FOM

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

Start of the project

2010

Information

V Perrin
015 278 9174
v.e.perrin@tudelft.nl
www.grs.citg.tudelft.nl

Predictive Large-Eddy-Simulations: Improving cloud and precipitation forecasting

Projectleaders
HJJ Jonker, AP Siebesma
Researchtheme
Complex dynamics of fluids
Participants
J Schalkwijk, HJJ Jonker,
AP Siebesma, RAJ Neggers
Cooperations
KNMI
Funded
KNMI, TU Delft

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

Start of the project
2010
Information
J Schalkwijk
015 278 9174
J.Schalkwijk@tudelft.nl
www.grs.citg.tudelft.nl

Project Aim

Current weather and climate models do not have sufficient resolution to explicitly resolve low cloud evolution, and therefore use statistical models for this purpose. While these models are reasonably successful in forecasting statistical estimates of relevant weather properties like precipitation and cloud amount, any local quantitative prediction (where exactly is a cloud developing) is outside their reach. This program aims to improve prediction accuracy by using Large Eddy Simulations (LES) to perform the needed high-resolution calculations and integrate this in large-scale prediction models to create a multi-scale model hierarchy. Excessive computational requirements always forced reasonable domain LES to run on supercomputing facilities, whose batch queuing protocols inhibit interaction. This program aims to solve this using Graphical Processing Units (GPUs) to provide the necessary computational power.

Progress

The group's Atmospheric Large Eddy Simulation has been ported to be performed on the computer's GPU, with the help of the Mathetmatics&Computer Sciences group. The GPU-implemented version has been verified with the help of LES intercomparison case studies. The LES has been adapted to run in forecasting mode in a model hierarchy, i.e. surface models and communication with other models has been added. Moreover, the LES has been adapted to simulate deep convective clouds, as it can now handle a domain of dozens of kilometers in the vertical direction and can simulate rain/snow formation. The surface model was found to be inadequate and was extended to perform consistent with current forecasting models.
The GPU-LES was also extended using MPI to make use of multi-GPU hardware in order to perform simulations covering extremely large domains (i.e. the Netherlands). State-of-the-art simulations have been performed in this 'forecasting mode', some covering a large domain (the Netherlands) and others covering a large time frame (a full year). This provides a unique dataset to evaluate the performance of LES in simulating real-weather situations.
The dataset provides extensive validation and comparison possibilities with available observations from the CESAR observatory and other models from the KNMI Testbed

Dissertations

-

Scientific Publications

1. J. Schalkwijk, Griffith, E.J., Post, F.H. And Jonker, H.J.J., "High-Performance Simulations of Turbulent Clouds on a Desktop PC : exploiting the GPU", Bulletin of the American Meteorological Society, March 2012.

Urban climate at street scale: analysis and adaptation

Project Aim

The aim of this project is to simulate climate adaptation in neighbourhoods and districts of cities, with a main emphasis on heat. Issues like temperature effects and surface heat balances for building facades are taken into account. The model is coupled to a meso-scale model for large scale effects of the urban heat island effect.

Progress

A 3D Monte Carlo radiation model has been developed and implemented in the simulation program.The surface energy balance is implemented and coupled to the radiation and CFD model. Validation tests are performed for the individual models which show good agreement.

Dissertations

-

Scientific Publications

-

Projectleaders

HJJ Jonker, S Kenjeres, SR de Roode

Researchtheme

Complex dynamics of fluids

Participants

PJC Schrijvers, S Kenjeres, SR de Roode, HJJ Jonker

Cooperations

WUR, TNO

Funded

Kennis voor Klimaat

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

Start of the project

2010

Information

P Schrijvers
015 278 9174
P.J.C.Schrijvers@tudelft.nl
www.grs.citg.tudelft.nl

Projectleaders
D Crommelin (CWI), AP Siebesma, HJJ Jonker

Researchtheme
Complex dynamics of fluids

Participants
J Dorrestijn, D Crommelin (CWI), F Selten (KNMI) AP Siebesma, HJJ Jonker

Cooperations
CWI, KNMI

Funded
NWO/ALW

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

Start of the project
2010

Information
HJJ Jonker
015 278 6157
H.J.J.Jonker@tudelft.nl
www.grs.citg.tudelft.nl

Project Aim

Stochastic parameterization is an exciting new topic at the intersection of applied mathematics and climate science. Because of the shortcomings of currently used, deterministic parameterizations and the pivotal role of clouds and convection in climate change uncertainties, stochastic methods for convection parameterization have become a hot research theme in recent years. In this project we will develop a stochastic approach to convection parameterization, combining new mathematical ideas on hybrid stochastic-deterministic models and multiscale systems with results from Large Eddy Simulation (LES) of atmospheric moist convection. The overall goal is to formulate a stochastic parameterization scheme that is suitable for practical use in climate models, and to evaluate the impact of such a scheme on cloud-climate feedbacks.

Progress

As reported last year (2011) we successfully constructed a stochastic parameterization from high-resolution data of Large-Eddy Simulation of shallow cumulus convection. This has now been published in a scientific journal.
In 2012 we constructed a similar parameterization based on LES-data of a simulation of deep convection. This work, done in cooperation with Joseph Biello, (Davis, University of California, USA) has been accepted for publication in a scientific journal. At this moment we are exploring the usage of radar-data from Darwin in Australia, to construct a similar stochastic parameterization of deep convection.We also made a step towards testing in the ensemble prediction model of the ECMWF: Dorrestijn got experience with running the model. We plan to test the influence of a stochastic parameterization in the ensemble prediction model and eventually in the similar climate model EC-Earth.

Dissertations

-

Scientific Publications

1. Dorrestijn, J., Crommelin, D.T., Siebesma, A.P., Jonker, H.J.J. 2012 Stochastic parameterization of shallow cumulus convection estimated from high-resolution model data. Theor. Comput. Fluid Dyn. 27, 133-148. (doi:10.1007/s00162-012-0281-y)

Local precipitation extremes derived from non-hydrostatic modeling

Project Aim

Events of extreme precipitation have a huge influence on society. They are associated with flooding, erosion, and water damage and may impact transport and safety. It is commonly expected that precipitation extremes will increase as the climate warms, as a warmer atmosphere has a larger capacity for moisture. With this study, we aim to increase the understanding of underlying causes of extreme precipitation, as well as anticipate how events of extreme precipitation will react to a warming climate. To this end, observational data, as well as Large Eddy Simulations (LES) are used. Furthermore, we will explore local precipitation extremes over the Netherlands within HARMONIE, a non-hydrostatic high resolution model.

Progress

Using KNMI precipitation data, the dependence of extreme precipitation to temperature and humidity has been analyzed. These results have been further assessed using a conceptual 1D model. This work is presented in “Understanding convective extreme precipitation scaling using observations and an updraft model ”, which has been submitted to the Journal of Atmospheric Sciences. In the current research stage, we use LES to further develop our understanding of earlier findings.

Dissertations

-

Scientific Publications

-

Projectleaders

AP Siebesma

Researchtheme

Complex dynamics of fluids

Participants

J Loriaux, AP Siebesma,
G Lenderink, SR de Roode

Cooperations

KNMI

Funded

Knowledge for Climate

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

Start of the project

2011

Information

J Loriaux
030 220 6376
j.m.loriaux@tudelft.nl
www.grs.citg.tudelft.nl

Mesoscopic Transport Phenomena

Prof.dr.ir. AA Darhuber

Prof.dr.ir. MEH van Dongen (em)

In 2006 prof. M.E.H. (Rini) van Dongen retired as head of the research group Gas Dynamics and obtained emeritus status. In 2007 prof. Anton Darhuber was appointed as his successor. Prof. A. (Mico) Hirschberg was interim leader of the group Gas Dynamics in 2006 and 2007. On January 1, 2008 the research group Gas Dynamics was officially renamed into Mesoscopic Transport Phenomena (MTP). On January 1, 2009 the head of the group Low-Temperature Physics (LTE) prof. A.T.A.M. (Fons) de Waele retired and LTE became a part of MTP. Therefore, currently three major lines of research coexist in MTP: the first corresponds to the activities of the former group Gas Dynamics, i.e. research on aero-acoustics and condensation phenomena; the second involves fluid dynamics at small lengthscales, where interfacial typically dominate over inertial effects. The third corresponds to the activities of the former group Low-Temperature Physics, i.e. research on thermo-acoustics.

In September 2008, prof. Federico Toschi was appointed professor in the Department of Applied Physics and became a member of MTP. He is working in the field of statistical physics, fluid dynamical turbulence and micro-/ nanofluidics. In February 2009, Jens Harting was appointed Assistant Professor in the group MTP. His expertise rests with large-scale Lattice Boltzmann simulations of suspension dynamics as well as micro- and meso-scale flows.

The research activities related to gas dynamics concern the study of wave phenomena in gases. Aero-acoustics is the study of the interaction between sound and flows. The research concerns the study of wave generation by elementary processes in flows, with the focus on confined flows and sound generation by vortices. This work has many important industrial applications. Condensation phenomena are studied using gas-dynamical devices such as expansion wave tubes to obtain fundamental information about the physics of nucleation and droplet growth in complex gas mixtures. This involves the development of models for the properties of molecular clusters in the nanometer range at extreme conditions far below the freezing point, for which bulk liquid properties are unknown.

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, as well as flows involving phase changes.

Research activities of the former group LTE concern pulse-tube refrigeration, thermoacoustics, and vortex cooling. These topics have a common thermodynamic and hydrodynamic background. They provide cooling without moving parts in the cold regions of the system. All topics address new physical questions in gas dynamics with the aim of unraveling basic working principles.

Diagnostics of voice and respiration pathologies

Project Aim

Using in-vitro experiments we study the effects of the interaction between air flow and oscillations of flexible walls at conditions relevant for speech and cough. Goal is the development of physical models which can support the diagnostics of pathologies by means of signal analysis.

Progress

A review paper has been written for Annual Review of Fluid Mechanics.

Dissertations

-

Scientific Publications

-

Projectleaders

AA Darhuber

Researchtheme

Complex dynamics of fluids

Participants

A Hirschberg, X.Pelorson, A.M. van Hirtum (Gipsa, IPG); J. Gilbert (LAUM, Université du Maine)

Cooperations

Institut Polytechnique de Grenoble (Gipsa), Université du Maine (LAUM).

Funded

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

Start of the project

1998

Information

A Hirschberg
040 2547 21 63
A.Hirschberg@tue.nl

Flow-induced pulsations in gas transport systems: prediction, prevention and influence on volume flow measurements

Projectleaders
AA Darhuber

Researchtheme
Complex dynamics of fluids

Participants
A Hirschberg, G Nakiboglu, O Rudenko, MEH v Dongen, H Manders, F v Uittert, AP Holten, E de Cocq, HWM Hoeijmakers (Utwente), SPC Belfroid (TNO), J Golliard (TNO), HK Nienhuys (ASML), R Henkes (Shell), H Riezebos (Kema)

Cooperations
Gasunie, TNO, ASML, Shell, UT, VKI,Philips, Kema, LMS(Be),EDF (Fr), LAUM (Univ.du Maine, Fr), Univ. Cambridge (UK), Cerfacs (Fr),TUMunchen, KU Leuven (Be), LTU(Lulea, SW), IST(Lisbon, Pt), Rolls Royce (UK), Alstom (Ch), Polyu(Hong Kong)

Funded
European Community (Marie-Curie), STW

University	20 %
FOM	-
STW	50 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	30 %
Scholarships	-

Start of the project
2002

Information
A Hirschberg
040 2547 21 63
A.Hirschberg@tue.nl

Project Aim

The quantitative prediction of unsteady shedding of vortices in confined flows and the interaction of these vortices with acoustic waves. Prediction of self-sustained flow-instabilities in high-pressure gas transport systems and impact of such instabilities on volume-flow measurements. The focus of the project is presently on fundamental aspects of the design of mufflers and the whistling of corrugated pipes.

Progress

Within the frame work of the European project Aether, the study of on grazing/bias flow along perforated walls has been completed. Also the aero-acoustical response of complex pipe systems has been finalized. The focus has been on a multiple side-branch system with up to 20 side-branches. Within the framework of a STW project the whistling of corrugated pipes has been studied. A predictive model has been obtained for the flow conditions at which whistling occurs. A model for the prediction of the pulsation amplitude has been validated. A linear model for the prediction of the onset of pulsations has been developed. The sound radiation from musical instruments/toys has been studied.

Dissertations

1. G. Nakiboglu, Aeroacoustics of Corrugated Pipes, PhD thesis, Eindhoven University of Technology, Eindhoven, The Netherlands.

Scientific Publications

1. Nakiboglu, G. and Hirschberg, A. Aeroacoustic Power Generated by Multiple Compact Axisymmetric Cavities: Effect of Hydrodynamic Interference on the Sound production, Physics of Fluids 24, 067101, 2012 .
2. Nakiboglu, G., H.B.M. Manders and Hirschberg, A. Aeroacoustic Power Generated by A Compact Axisymmetric Cavity: Prediction of Self-Sustained Oscillation and Influence of the depth, Journal of Fluid Mechanics 73, pp. 163-191, 2012.
3. Nakiboglu G., Rudenko O., Hirschberg A., Aeroacoustics of the swinging corrugated tube: voice of the dragon, Journal of the Acoustical Society of America 131, pp. 749-765, 2012 DOI: 10.1121/1.3651245.
4. Fabre B., Gilbert J., Hirschberg A., Pelorson X., Aeroacoustics of musical instruments, Annual Review of Fluid Mechanics, 44, pp. 1-25, 2012. DOI: 10.1146/annurev-fluid-120710).
5. Rudenko, O., Nakiboglu, G. and Hirschberg, A, On the whistling of pipes with a corrugated pipe segment, 10th International Conference on Flow-Induced Vibration & Flow Induced Noise, Trinity College Dublin, Ireland, 2012.
6. Nakiboglu, G., Rudenko, O., Hirschberg, A, Golliard, J. and Belfroid S. P. C. On the effect of a swirl on the self-sustained oscillations in compact axisymmetric cavities, 10th International Conference on Flow-Induced Vibration & Flow Induced Noise, Trinity College Dublin, Ireland, 2012.

Project Aim

Colloidal particles are commonly used as stabilizers for fluid-fluid interfaces. In this project a system of colloidal particles suspended in two immiscible fluids (water and oil) is being considered. The lattice Boltzmann method is used to simulate the two fluids, while the suspended particles are simulated by molecular dynamics. A particular focus of this PhD project is on anisotropic particles such as rods, cylinders, platelets and ellipsoids, where the role of capillary and electrostatic particle-particle interactions shall be investigated.

Progress

The effect of the particle anisotropy on some properties of the emulsions are studied. To get a further understanding the studies at model systems (such as one or many particle st a flat or spherical interface) are continued. Furthermore the effect of hydrodynamics for particles at the interface were studied.

Dissertations

-

Scientific Publications

1. Lattice Boltzmann simulations of anisotropic particles at liquid interfaces F. Günther, F. Janoschek, S. Frijters, J. Harting. Computers and Fluids, in press (2012).
2. Effects of nanoparticles and surfactant on droplets in shear flow. S. Frijters, F. Günther, J. Harting. Soft Matter 8, Number 24, 6542 - 6556 (2012).
3. Numerical simulations of complex fluid-fluid interface dynamics. T. Krüger, S. Frijters, F. Günther, B. Kaoui1, J. Harting. Submitted for publication (2012)

Projectleaders

J Harting

Researchtheme

Complex dynamics of fluids

Participants

F Günther

Cooperations

-

Funded

STW

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

Start of the project

2010

Information

FS Günther
040 247 5140
f.s.guenther@tue.nl

Blood in motion

Projectleaders
F Toschi, J Harting
Researchtheme
Complex dynamics of fluids
Participants
F Janoschek
Cooperations
TU/e: FN van de Vosse (Biomed. eng.); PD Anderson, HEH Meijer (Mech. Eng.). KTH Stockholm: L Brandt
Funded
TU/e High Potential Research Program (2009)

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

Start of the project
2009
Information
J Harting
040 247 3766
j.harting@tue.nl
http://mtp.phys.tue.nl

F Toschi
040 247 3911
f.toschi@tue.nl
http://mtp.phys.tue.nl

Project Aim

Blood may be treated as a dense suspension of red blood cells in blood plasma. Typical length scales vary over several orders of magnitude. Current computational models treat blood as a homogeneous fluid or model a limited number of cells at high resolution. Our aim is to bridge the gap between both approaches with a simplified yet still particulate method of high efficiency. We will develop phenomenological cell-cell and cell-wall interaction models based on experimental and numerical work done by other groups on the single-cell level and provide a link to flow properties at larger scales which might be used to improve continuous blood models.

Progress

Continuing the estimates made in the previous period, plasma velocity fluctuations in our empirical coarse-grained blood model were compared with the self-diffusion of cells and plasma found in the literature and in our simulations. For this sake, massless tracer particles were implemented. We thereby convinced ourselves of the importance of hydrodynamic short-range interactions for microscopic suspension dynamics. In the mean time, our code was made ready for the simulation of rigid and anisotropic particles as a natural starting point for the development of a consistent model for red blood cells which requires an efficient generation of non-overlapping particle packings as initial conditions, the decoupling of cell and fluid time steps to allow for stiff interaction forces, and a lubrication and contact model. The work already enabled a collaboration with scientists from KTH Stockholm on the rheology of suspensions of rigid particles.

Dissertations

-

Scientific Publications

1. Coupled Lattice Boltzmann and Molecular Dynamics simulations on massively parallel computers. J. Harting, S. Frijters, F. Janoschek, F. Günther. NIC Symposium 2012 – Proceedings (NIC Series, 45), ed. K. Binder, G. Münster, M. Kremer, Forschungszentrum Jülich GmbH Zentralbibliothek, Verlag, 243-250 (2012).

Lattice Boltzmann simulations of multiphase flows in microfluidics

Project Aim

Development and application of the software LB3D for problems of fluid flows of multiple phases as well as multiple components in confined, complex geometries. Research focuses on a better understanding of models for non-ideal and complex fluid mixtures and the implementation and improvement of boundary conditions to enable more realistic simulations of contact line dynamics.

Progress

Applications of a high Knudsen enabled LB scheme to dilute gas flows in complex geometries. Implementation of a hybrid DSMC model for intermediate Knudsen numbers, preparation of publication. Simulations of binary and ternary mixtures in porous media, implementation and preparation of publication.

Simulations of super-hydrophobic model systems, publication.

Implementation work in debugging and code optimization.

Dissertations

-

Scientific Publications

1. S. Schmieschek, A. Belyaev, J. Harting, O. Vinogradova, Phys. Rev. E 85 (1), 016324 (2012).

Projectleaders

J Harting

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Schmieschek

Cooperations

-

Funded

Eindhoven University of Technology

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

Start of the project

2009

Information

S Schmieschek
040 247 4215
s.m.p.schmieschek@tue.nl
mtp.phys.tue.nl

Detection and guidance of nanoparticles for enhanced oil recovery

Projectleaders
J Harting, S Luding, H Steeb

Researchtheme
Complex structures of fluids

Participants
SCJ Frijters

Cooperations
Shell-FOM IPP

Funded
Shell-FOM IPP

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

Start of the project
2010

Information
J Harting
040 247 3766
jharting@tue.nl

Project Aim

To find out whether ferromagnetic particles can be a suitable alternative to conventional EOR techniques, and whether pulsed electromagnetic fields could be used to drive these particles to preferred regions. To have control over the movement of the particles will be a major advantage of the proposed method.

Progress

Research on the subject of nanoparticles as stabilizers of a single droplet has been concluded: intertial effects have been shown to play a dominant role in increased deformation properties of particle-stabilized droplets. Currently under investigation is the behaviour of particle-stabilized emulsions, and in particular the possibility of inducing a transition from a bijel to Pickering emulsion state or vice versa by changing the contact angle of the stabilizing particles. Additionally, the rheology of emulsions is considered, as well as an extension of our simulation model to include effects of electrostatics.

Dissertations

-

Scientific Publications

1. Coupled Lattice Boltzmann and Molecular Dynamics simulations on massively parallel computers, J. Harting, S. Frijters, F. Janoschek, F. Günther. NIC Symposium 2012 – Proceedings (NIC Series, 45), ed. K. Binder, G. Münster, M. Kremer, Forschungszentrum Jülich GmbH Zentralbibliothek, Verlag, 243-250 (2012)
2. Effects of nanoparticles and surfactant on droplets in shear flow, S. Frijters, F. Günther, J. Harting. Soft Matter 8, Number 24, 6542 - 6556 (2012)
3. Numerical simulations of complex fluid-fluid interface dynamics, T. Krüger, S. Frijters, F. Günther, B. Kaoui, J. Harting Submitted for publication (2012) .

Dewetting of thin liquid films on partially wetting surfaces

Project Aim

The aim of this project is to study the physics of dewetting of thin liquid layers on partially wetting surfaces. The evaporation of these films causes technological difficulties, as cooling due to the large latent heat of evaporation of water leads to inhomogeneous thermal contractions of substrates. At the focus is the question whether the dewetting and break-up process of the water layer into droplets can be influenced regarding the size distibution and arrangement of the resulting droplets.

Progress

A numerical model for the dynamics of spontaneous and induced break-up of model liquids has been developed. An experimental setup for dry-spot nucleation induced by an air-jet has been built and systematic experiments have been performed. A second setup for temperature-gradient-induced dry-spot nucleation has been designed and built and is currently being used for a systematic study. A third setup for moving airjets has been designed and built. A complete study of the influence of all relevant parameters on the deformation of the thin liquid film and the resulting break-up behavior and residual droplet distributions has been performed.

Dissertations

-

Scientific Publications

1. C. W. J. Berendsen, J. C. H. Zeegers, G. C. F. L. Kruis, M. Riepen, and A. A. Darhuber, Langmuir 2012, 28, 9977–9985.

Projectleaders

AA Darhuber

Researchtheme

Complex dynamics of fluids

Participants

C Berendsen, J Zeegers, AA Darhuber

Cooperations

ASML

Funded

FOM-IPP met ASML en Oce

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

Start of the project

2010

Information

AA Darhuber
a.a.darhuber@tue.nl

Energy and light : How microfluidics can make a difference

Projectleaders
AA Darhuber
Researchtheme
Complex dynamics of fluids
Participants
AA Darhuber, M Hanyak, D Sinz
Cooperations
Shell International Exploration and Production B.V
Funded
STW, TU/e, Shell

University	25 %
FOM	-
STW	65 %
NWO Other	-
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2008
Information
AA Darhuber
a.a.darhuber@tue.nl

Project Aim

Systematic investigation and modeling of the surfactant induced flows at micro- and nanoscales. Quantification of the spreading dynamics of surfactants on liquid films in various geometries, ranging from simple test cases to natural porous media. Development of strategies how to use surfactants to increase oil recovery rates.

Progress

Using both experiments and numerical simulations, we studied surfactant spreading on thin liquid films deposited on chemically patterned surfaces. On liquid rivulets, upon which a droplet of surfactant is deposited, a rim develops in the rivulet height profile that is moving away from the deposited surfactant droplet. It is located just behind the leading edge of the surfactant, and to good approximation the rim position xrim(t) follows a power law behavior xrim ~ ta, where the spreading exponent a quantifies the displacement efficiency of a given surfactant. Experiments conducted for both soluble and insoluble surfactants spreading along liquid-air interfaces are in quantitative agreement with numerical simulations. A detailed study of spreading along liquid-liquid interfaces has been performed.

Dissertations

1. Myroslava Hanyak, Marangoni flows induced by non-uniform surfactant distributions, PhD thesis, Eindhoven University of Technology, Eindhoven, The Netherlands.
2. David K. N. Sinz, Surfactant induced flows in thin liquid films - An experimental study, PhD thesis, Eindhoven University of Technology, Eindhoven, The Netherlands.

Scientific Publications

1. Myroslava Hanyak, David K. N. Sinz and Anton A. Darhuber. Soft Matter, 2012, 8, 3660.
2. David K. N. Sinz and Anton A. Darhuber. Lab Chip, 2012, 12, 705.

.

Engineering the morphology of organic (semi-) conductor layers

Project Aim

The investigation and optimization of the hydrodynamics of die-coating to fabricate active layers of organic light emitting diodes (OLEDs) of uniform thickness and composition based on solution-processing. Means to enhance the influence of surface energy patterns at high coating speeds will be explored as well as methods for mitigation and elimination of evaporation-driven material redistribution.

Progress

An experimental system for structured infrared illumination has been developed. A numerical model coupling heat transfer, gas-phase and liquid-phase transport has been developed and simulation results quantitatively agree with experimental results. The dewetting dynamics of thin liquid films on chemically patterned substrates has been studied. Evaporative instabilities have been characterized and a numerical model agrees qualitatively with the measurements.

Dissertations

1. B.J. Brasjen, Coating and stability of thin liquid films on chemically patterned substrates, PhD thesis, Eindhoven University of Technology, Eindhoven, The Netherlands.

Scientific Publications

1. J. A. Vieyra Salas, J. M. van der Veen, J. J. Michels, and A. A. Darhuber J. Phys. Chem. C 2012, 116, 12038−12047.

Projectleaders

AA Darhuber

Researchtheme

Complex dynamics of fluids

Participants

AA Darhuber, BJ Brasjen, JA Vieyra Salas

Cooperations

Holst Centre Eindhoven

Funded

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

Start of the project

2007

Information

AA Darhuber
a.a.darhuber@tue.nl

PROJECTLEADERS
J Zeegers
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
R Liew, J Zeegers
COOPERATIONS
-
FUNDED

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

START OF THE PROJECT
2009
INFORMATION
J Zeegers
040 247 4212
j.c.h.zeegers@tue.nl

PROJECT AIM

Developing a vortex tube swirling flow system to separate condensate out of gas flow.

PROGRESS

In the past two years the phenomenon of temperature separation with vortex tubes has been unraveled via a thorough experimental study which was combined with an analytical model, leading to a good description. This work was published in Phys. Rev. Lett. in 2012 and will be published in a more comprehensive paper in 2013. Detailed velocity and droplet size measurements have been made in the vortex tube using PDPA and Laser Doppler techniques, part of which was recently published in a paper in Experiments in Fluids. This has become possible using the advanced TSI equipment that was purchased in the first year of the project. Since july 2012 ongoing research has demonstrated the first results of separation of water droplets using vortex tubes. This is a first step towards the end goal of the project. The PhD student is currently preparing his thesis and finishing the last measurements. From April 1 and onwards the project will be carried out by a postdoc who will focus on the separation study.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Physical Review Letters (2012) 109, 054503. Maxwell's Demon in the Ranque-Hilsch Vortex Tube. R. Liew, J.C.H. Zeegers, J.G.M. Kuerten and W.R. Michalek.
2. Journal of Physics Conference Series (2012) 395, 012066. Temperature, Pressure and Velocity measurements on the Ranque-Hilsch Vortex Tube R. Liew, J.C.H. Zeegers, J.G.M. Kuerten and W.R. Michalek.

Towards Green Inks (TGInk)

Project Aim

Waterborne inks are the future in the area of inkjet printing, since the use of organic solvents has to be reduced for environmental reasons. The particles, dissolved in the ink, should agglomerate and stick at a certain depth in the paper. This agglomeration is steered by the liquid concentrations of the ink, which themselves are determined by sorption and evaporation. This project aims to develop a mathematical model that describes the particle penetration into paper in relation to the ink composition.

Progress

Literature study. Getting involved with TU/e simulation package LB3D. Investigation of fluctuating Lattice Boltzmann.

Dissertations

-

Scientific Publications

-

Projectleaders

J Harting, O Adan, H HuininK

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Dennis Hessling, Kees Kuijpers

Cooperations

Océ

Funded

M2i

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

Start of the project

2012

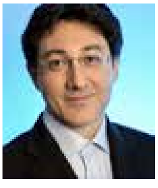
Information

D Hessling
040 247 3154
D.M.Hessling@tue.nl
mtp.phys.tue.nl

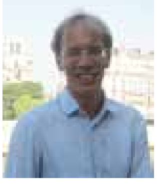
Vortex Dynamics and Turbulence

Prof.dr. HJH Clercx

Prof.dr.ir. GJF van Heijst



Prof.dr. F Toschi



Prof.dr.ir. BJ Geurts

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.

Project Aim

The objective of this project concerns the quantification of the vertical turbulent transport of phytoplankton by DNS and the associated process of scum formation at the free surface. This part concerns a combined study involving numerical simulations (TU/e) and field observations (Deltares).

Progress

The spatial distribution of biologically active particles was studied by coupling Direct Numerical Simulations and Lagrangian particle tracking. The biologically active particles represent colonies of a species of phytoplankton (Microcystis aeruginosa). This species changes its density in time as a response to its light environment. The intrinsic gap between biological and flow time-scales makes the modeling exercise non-trivial. In order to conceal time scales of flow and biology we implemented a scaling procedure. Our results show that our model is effective in representing the vertical daily migration of Microcystis Aeruginosa, in a sense that realistic characteristics are simulated as compared to nature. A paper is being prepared with the description of the scaling methodology.

Dissertations

-

Scientific Publications

-

Projectleaders

HJH Clercx

Researchtheme

Complex dynamics of fluids

Participants

E Aparicio Medrano, BJH van de Wiel, HJH Clercx

Cooperations

V Armenio (Univ Triest, Italy), RE Uittenbogaard (Deltares)

Funded

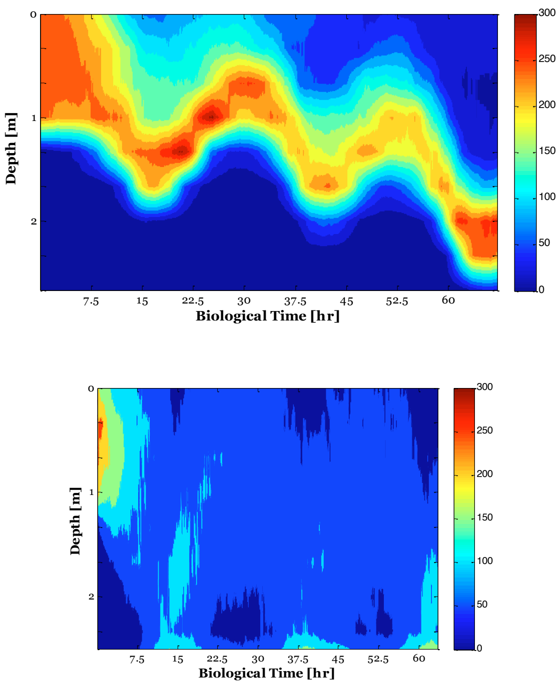
Deltares	
University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	100 %
EU	-
Scholarships	-

Start of the project

2009

Information

HJH Clercx
040 247 2680
h.j.h.clercx@tue.nl
www.fluid.tue.nl



Variation of colony concentration in time. Top figure: Lower turbulence intensity, (turbulent energy dissipation ε = O (10-8 m2 s-3)), the vertical migration of Microcystis depends mainly on its buoyant status. Bottom figure: Higher turbulence intensity, (ε = O (10-5 m2 s-3)), supersede the buoyant ability of the algae and distribute them more uniformly within the domain.

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

Projectleaders
HJH Clercx

Researchtheme
Complex dynamics of fluids

Participants
O Baskan, HJH Clercx

Cooperations
MFM Speetjens (TU/e-Wbt),
Demissie (TU/e-Wbt),
G Metcalfe (CSIRO, Australia)

Funded
STW

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

Start of the project
2010

Information
HJH Clercx
040 247 2680
h.j.h.clercx@tue.nl
www.fluid.tue.nl

Project Aim

Principal objective of the proposed study is an in-depth analysis of the Kenics static mixer by Lagrangian mixing analysis of heat transfer. The study is divided into two subprojects: (1) Topological mixing analysis of heat transfer in the Kenics mixer (Esubalew Demissie; Wbt) and (2) Experimental heat-transfer and mixing analysis of the Kenics mixer (Ozge Baskan, Applied Phys.). The project at Applied Physics focuses on the experimental characterisation of Lagrangian mixing properties in case studies by measurement of 3D fluid trajectories and the evolution of 3D concentration fields using advanced optical measurement techniques. Benchmarking of numerical thermal mixing analyses and testing of the prototype thermal-analysis tools for advanced data processing. Experimental performance tests of optimised Kenics mixers in the laboratory set-up and in industrial test facilities.

Progress

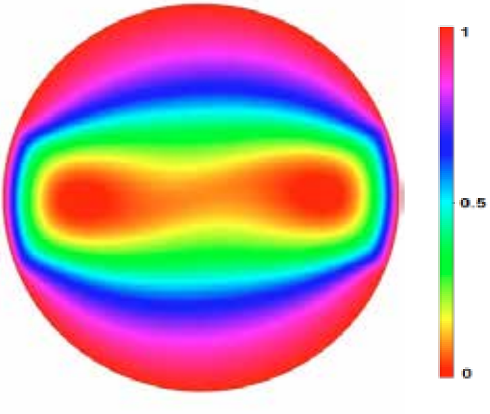
An experimental facility of the 2D representation of the Rotated Arc Mixer (RAM), as an experimentally more accessible alternative to the Kenics mixer, has been built and made operational for 2D Particle Image Velocimetry (PIV) and Infrared Thermography (IRT) to acquire velocity fields and temperature fields, respectively. Experimental results, notwithstanding 3D flow field effects and heat losses in the facility, are in good agreement with 2D numerical simulations in terms of flow and thermal patterns. This implies that the laboratory facility is representing the 2D RAM well. First results exposed a strong correlation between temperature and flow fields: thermal patterns evolve in accordance with the time-periodic flow patterns and become persistent ultimately. These persistent patterns are called dominant eigenmodes and the experiments are believed to offer the first visualisations of such fundamental thermal features in a realistic industrial device. Further investigation of the evolution of the temperature and its connection with the Lagrangian flow properties is in progress. Moreover, first steps towards a Lagrangian thermal analysis are underway.

Dissertations

-

Scientific Publications

-



Persistent (or repeating) thermal patterns form during the evolution of temperature fields due to time-periodic flow fields. This picture shows the asymptotic time-periodic temperature field at end of thermal transient for Pe=10^3.

PROJECT AIM

We study the dynamics of droplets in a turbulent flow and concentrate on preferential concentration. The idea is to tag selected droplets in a turbulent air flow by making them glow. This is done by dissolving Europeum chelate molecules in the droplets, illuminating them with a strong laser, and following the phosphorescent droplets using a fast intensified camera.

PROGRESS

At timescales on the order of the Kolmogorov timescale, a linear dispersion is expected, i.e. width Δ(t) □ t, but inertial particles deviate from this prediction. Using the recently developed phosphorescent tagging technique, we study the dispersion of heavy particles in homogeneous, isotropic turbulence by laser-tagging a thin volume within a cloud of phosphorescent droplets and monitoring its evolution in time. A faster dispersion of heavy droplets than of fluid tracers can be readily observed. The data shows a considerable increase in the dispersion of heavy droplets. The aforementioned technique can also be used to study the phenomenon of preferential concentration. This is done by tagging a sheet-like volume and quantifying the inhomogeneity of the spatial distribution of particles. This is done by comparing the local droplet concentration against the average concentration over the entire field.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS

W van de Water, GJF van Heijst

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

H Bocanegra Evans, GJF van Heijst, W van de Water

COOPERATIONS

NJ Dam (TU/e-Wbt)

FUNDED

FOM

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

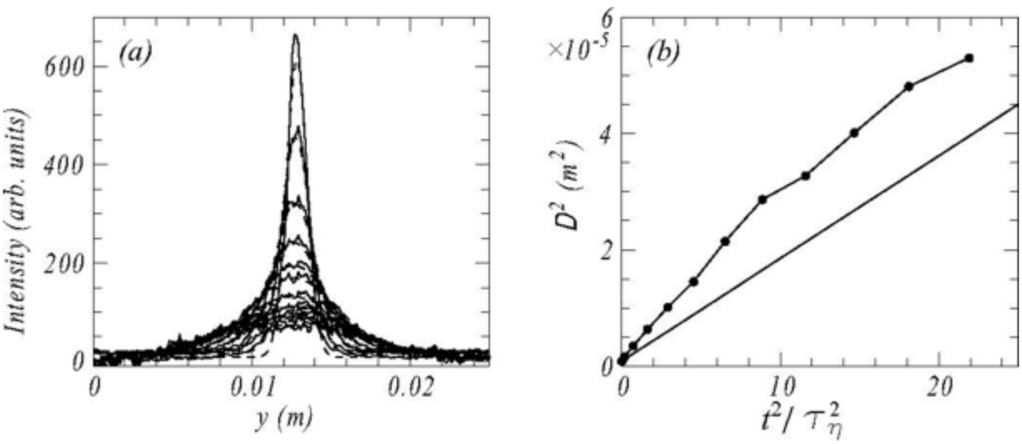
START OF THE PROJECT

2009

INFORMATION

W van de Water
040 247 3443
w.v.d.water@tue.nl
www.fluid.tue.nl

Panel (a): Time progression of the intensity profile of the tagged volume. The widening of the tagged volume is a result of the droplets being dispersed and advected by the turbulent flow. Panel (b): Volume width Δ2 as a function of time. The solid line represents the predicted theoretical width.



Effects of rotation in quasi-two-dimensional turbulence in a thin fluid layer

Projectleaders
GJF van Heijst

Researchtheme
Complex dynamics of fluids

Participants
M Duran Matute, LPJ Kamp,
RR Trieling, GJF van Heijst

Cooperations
Z Kizner (Bar-Ilan University, Israel)

Funded

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

Start of the project
2006

Information
GJF van Heijst
040 247 2722
g.j.f.v.heijst@tue.nl
www.fluid.tue.nl

Project Aim

The aim of the project is to gain insight in the dynamics of vortex structures in a shallow fluid layer under the influence of background rotation. The project combines laboratory experiments and numerical flow simulations.

Progress

This project has been concluded with the PhD thesis of M. Duran Matute (Nov. 2010).

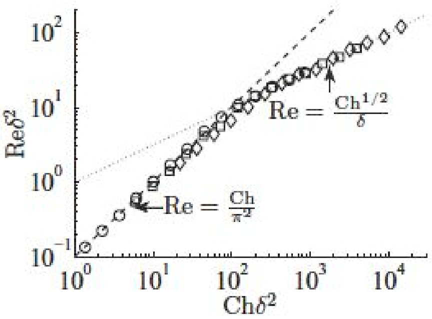
Dissertations

-

Scientific Publications

1. M. Duran Matute, G. Di Nitto, R.R. Trieling, L.P.J. Kamp & G.J.F. van Heijst. The break-up of Ekman theory in a flow subjected to background rotation and driven by a non-conservative body force. Phys. Fluids 14, 116602 1-15 (2012.

Magnitude of the response (Reδ2) of an electromagnetically forced dipolar flow as a function of the forcing parameter Chδ2), with δ the layer aspect ratio. Viscous and advective regimes can be clearly distinguished



A new way of understanding chaotic wind bursting at night

Project Aim

The project aims to find the physical mechanism that drives intermittent (discontinuous) turbulence in the nocturnal atmospheric boundary layer. During intermittency, periods with 'laminar' flow are interrupted by chaotic bursts of turbulence and a significant transport of heat, moisture and momentum occurs. Key tools are theoretical analyses combined with Direct Numerical Simulation (DNS) techniques.

Progress

Currently, the collapse of turbulence in the evening atmosphere is studied by means of DNS. As physical properties of the land surface play a crucial role in either stimulating or moderating the collapse process, emphasis lies on the coupling of the flow model to a realistic surface model. The response of the atmosphere to weak mechanical forcing is studied for various surfaces like: short grass, snow covered surfaces, bare soil and water. Besides numerical simulation also theoretical and experimental analysis is used to understand the dynamic feedbacks between the lower stratified atmosphere and the underlying surface.

Dissertations

-

Scientific Publications

1. B.J.H. van de Wiel, A.F. Moene & H.J.J. Jonker – The cessation of continuous turbulence as precursor of the very stable nocturnal boundary layer. J. Atmos. Sci. 69, 3097-3115 (2012).
2. B.J.H. van de Wiel, A.F. Moene, H.J.J. Jonker, P. Baas, S. Basu, J. M.M. Donda, J. Sun & A.A.M. Holtslag – The minimum wind speed for sustainable turbulence in the nocturnal boundary layer, J. Atmos. Sci. 69, 3116-3126 (2012).

Projectleaders

BJH van de Wiel , HJH Clercx, GJF van Heijst

Researchtheme

Complex dynamics of fluids

Participants

JMM Donda, BJH van de Wiel, HJH Clercx, GJF van Heijst

Cooperations

A Moene (WUR), H Jonker (TUD), P Baas (KNMI)

Funded

Vidi NWO-ALW

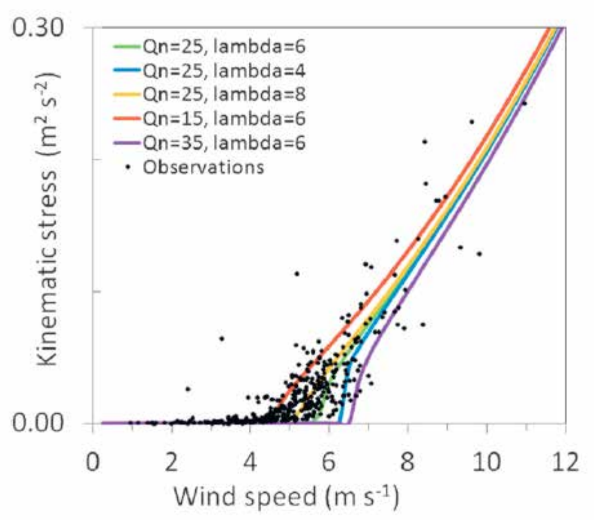
University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2010

Information

BJH van de Wiel
040 247 4285
b.j.h.v.d.wiel@tue.nl
www.fluid.tue.nl



Predicting the minimum wind speed for sustainable turbulence in the atmospheric evening boundary layer: turbulent stress (at 5m) versus wind speed (40m) at the KNMI Cabauw observatory (4-hour averages of 20Hz data). Predictions by conceptual model are given by the colored lines representing various classes of net radiative cooling Qn [Wm-2] and different values of soil–vegetation conductivity [Wm-2K-1]. Observe that the 'hockey-stick' shape of the curve appears a robust feature.

Population dynamics in turbulent flows: numerical simulations

Projectleaders
F Toschi, HJH Clercx

Researchtheme
Complex dynamics of fluids

Participants
P Perlekar, F Tesser, HJH Clercx, F Toschi, JCH Zeegers

Cooperations
R Benzi (Univ. Tor Vergata, Italy) DR Nelson (Harvard University, USA), S Pigolotti (Universidad Politécnica de Cataluña, Spain) MH Jensen (Niels Bohr Institute, Denmark)

Funded
FOM

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

Start of the project
2011

Information
F Toschi
040 247 3911
f.toschi@tue.nl
www.fluid.tue.nl

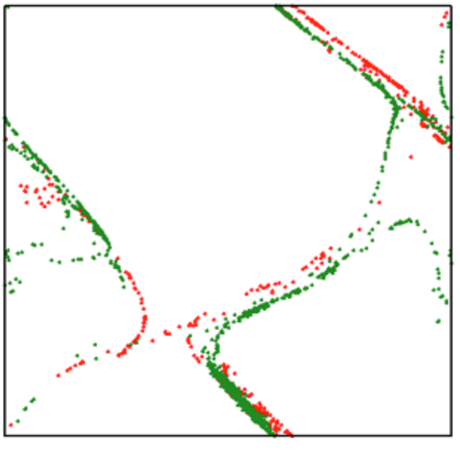
Project Aim
Population dynamics deals with the study of birth, death and growth processes of biological species. These processes are severely affected by the local ecosystems, by the presence of nutrients, and by the local population density. Turbulence is known to increases mixing and diffusion; but, remarkably, population dynamics in a (compressible) turbulent environment shows strong localization (e.g. patchy regions of planktons on the ocean surface). The aim of the present project is to study the interplay of these two mechanisms to understand population dynamics of species in turbulent environments.

Progress
We study population dynamics of two species in a chaotic two-dimensional surface flow. The confinement of the organisms in thin layers leads to an effective compressibility that we model using inertia on individual entity. For simplicity, we choose the species to be biologically identical but with different inertia. We find that there exists a possibility of coexistence of species with comparable but not exactly same inertia. As a prelude to our current study, we also developed and implemented discrete population rules. The results of these studies were published in various journals.

Dissertations
-

Scientific Publications

1. R. Benzi, M.H. Jensen, D.R. Nelson, P. Perlekar, S. Pigolotti & F. Toschi. Population dynamics in compressible flows. European Physical Journal: Special Topics 204, 57-73 (2012).



Population dynamics of two species. Notice how the competition takes place at the interface of the two populations.

How gravity, shear and coalescence modify the droplet size distribution

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

A new fast method has been developed for the computation of the Basset force. An article on the implementation of the Basset history force computation has been published (J. Comput. Phys. 230, 1465 (2011)). A new interpolation method for application in spectral codes has been proposed and successfully compared with several standard interpolation methods. The new interpolation method has been implemented in the spectral code. Additionally, an alternative version for the hydrodynamical forces has been implemented. Some test simulations have been performed. The code has been extended to integrate homogeneous shear flows and to evolve Lagrangian particles in homogeneous shear turbulence.

Dissertations

-

Scientific Publications

1. M.A.T. van Hinsberg, J.H.M. ten Thije Boonkkamp, F. Toschi & H.J.H. Clercx. On the efficiency and accuracy of interpolation methods for spectral codes. SIAM Journal on Scientific Computing, 34(4), B479-B498 (2012).
2. M.A.T. van Hinsberg, J.H.M. ten Thije Boonkkamp, F. Toschi & H.J.H. Clercx On optimal interpolation schemes for particle tracking in turbulence. CASA Report, No. 12-40. Eindhoven University of Technology, 8 pp. (2012).

Projectleaders

HJH Clercx, F Toschi, GJF van Heijst

Researchtheme

Complex dynamics of fluids

Participants

MAT van Hinsberg, HJH Clercx, F Toschi

Cooperations

L Biferale (Rome, Italy), P Perlekar (TU/e), J ten Thije Boonkkamp (TU/e).

Funded

FOM

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

Start of the project

2011

Information

HJH Clercx
040 247 2680
h.j.h.clercx@tue.nl

F Toschi
040 247 3911
f.toschi@tue.nl
www.fluid.tue.nl

PROJECTLEADERS
HJH Clercx, GJF van Heijst
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
VH Fernandes, LPJ Kamp,
GJF van Heijst, HJH Clercx
COOPERATIONS
N Lopes Cardozo (TU/e-TN),
R Jaspers (TU/e-TN),
M Steinbuch (TU/e-Wbt),
M de Baar (FOM; TU/e-Wbt)
FUNDED
TUE

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

START OF THE PROJECT
2010
INFORMATION
HJH Clercx
040 247 2680
h.j.h.clercx@tue.nl

GJF van Heijst
040 247 2722
g.j.f.v.heijst@tue.nl
www.fluid.tue.nl

PROJECT AIM

Large-scale coherent flows play an important role both in geophysical fluids and in fusion since they interact with the turbulence and can give rise to transport barriers. It turns out that these phenomena in fluids and plasmas can be described by the same equation. Therefore a relatively simple fluid dynamics experiment is proposed with the aim to study how zonal flows affect turbulence and turbulent transport and how these flows are sustained in the improved confinement mode. Comparison of fluids and plasmas by experiments and numerical simulations are an integral part of this research. In this project visualisation of the effect of flow on turbulence is a key element, whereas the fluid dynamics experiment will also serve as a test bed for control methods (link with project "Control of plasma transport by plasma flow" which is being conducted at Dept. Mech. Engineering, TU/e).

PROGRESS

We have focused on getting a better understanding of the basic mechanisms behind the interaction of two-dimensional (2D) turbulence with a shear flow. Therefore we started a numerical investigation where we considered a decaying vortex interacting with a steady 2D confined (channel) shear flow. Several vortex types (like monopoles and dipoles - being the building blocks of 2D turbulence) and two types of shear flows (Couette and Poiseuille) have been considered. Generic behavior is identified by exploring parameter space that is spanned by three dimensionless parameters. Preliminary results are obtained for the simplest problem, i.e. a monopole in a shear flow. Next we will consider the interaction of dipoles and clusters of vortices with the shear flow in order to mimic more realistically the interaction of velocity shear with a turbulent flow field. Also some modifications in the experimental setup were finalized in order to pursue this investigation experimentally.

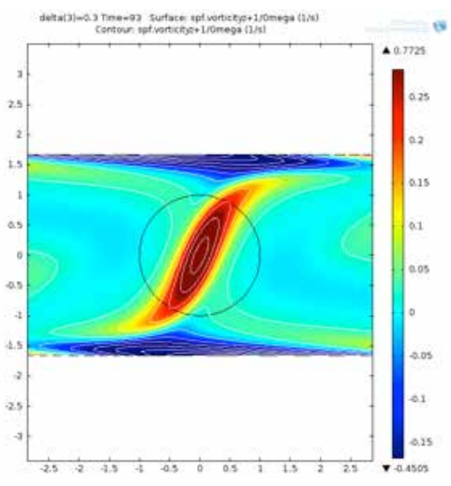
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Vorticity field of a time decaying Lamb monopole in a plane Couette flow in a channel. The relative vorticity is shown.



Spinodal decomposition in homogeneous, isotropic turbulence

Project Aim

We study the coarsening of symmetric binary mixtures below their critical temperature in presence of turbulence. Turbulence is known to result in effective mixing whereas a binary mixture phase-separates (demixing). The competition between these two opposite competing mechanisms leads to an arrest of the coarsening process. The binary mixture is numerically modeled by means of a multicomponent Lattice-Boltzmann method.

Progress

We have completed a study of coarsening arrest of a binary mixture in a turbulent flow. Our study clearly brings out the interplay between the surface tension and turbulence that govern the size of the domains (see figure below). The next step is to study the additional effects of density and/or viscosity contrasts on this dynamics.

Dissertations

-

Scientific Publications

1. P. Perlekar, L. Biferale, M. Sbragaglia, S. Srivastava & F. Toschi – Droplet size distribution in homogeneous isotropic turbulence, Phys. Fluids 24, 065101 (2012).
2. L. Biferale, P. Perlekar, M. Sbragaglia & F. Toschi – Convection in multiphase flows using Lattice Boltzmann methods, Phys. Rev. Lett. 108, 104502 (2012).

Projectleaders

F Toschi

Researchtheme

Complex dynamics of fluids

Participants

P Perlekar, HJH Clercx

Cooperations

R Benzi (Univ. of Tor Vergata, Italy), L Biferale (Univ. Tor Vergata, Italy), DR Nelson (Harvard University, USA), M Sbragaglia (Univ. Tor Vergata, Italy)

Funded

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

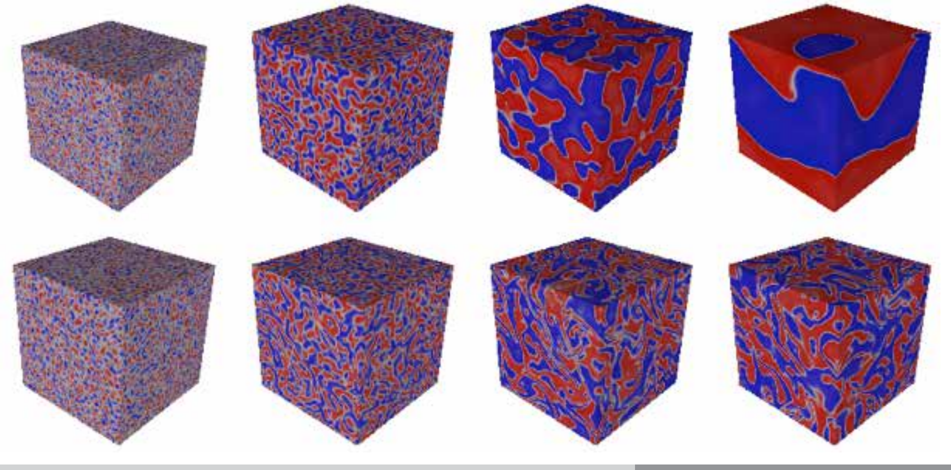
Start of the project

2012

Information

F Toschi
040 247 3911
f.toschi@tue.nl
www.fluid.tue.nl

Pseudocolor plots of the concentration fields with the two symmetric fluids indicated in red and blue. Top panel, left-right: Time evolution of the concentration field undergoing coarsening process from an initially well-mixed state. Notice the formation of ever-larger concentration patches as time evolves. Bottom panel, left-right: Time evolution of the concentration field undergoing coarsening process from a well-mixed state in presence of turbulence generated by an external driving. The last two panels indicate that a statistically steady state has developed. The coarsening process goes on uninhibited until arrested by the turbulence.



Projectleaders
F Toschi, L Biferale (Tor Vergata, Italy)

Researchtheme
Complex dynamics of fluids

Participants
R Scatamacchia

Cooperations
L Biferale (Tor Vergata, Italy),
AS Lanotte (ISAC, SNR),
M Sbragaglia (Tor Vergata, Italy)

Funded
University of Tor Vergata

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

Start of the project
2012

Information
F Toschi
040 247 3911
f.toschi@tue.nl
www.fluid.tue.nl

Project Aim

The project is a dual-degree collaboration between TU/e and University of Tor Vergata (Italy). The goal of the project is to study the behavior of few prototypal examples of complex flows and complex fluids.

Progress

In the first part of the project the focus was on the dynamics of tracers and inertial particles dispersed by point sources in homogenous and isotropic turbulence velocity fields. The system is the simplest model for dispersion in the atmosphere (e.g. ashes from volcanic sources or pollutants from industrial chimneys). The massively parallel simulation with extraordinary high statistics allowed to measure, for the first time, deviations from Richardson dispersion due to finite flow velocity.

Dissertations

-

Scientific Publications

1. R.Scatamacchia, L.Biferale & F.Toschi – Extreme events in the dispersion of two neighboring particles under the influence of fluid turbulence. Phys. Rev. Lett. 109, 144501 (2012).
2. L. Biferale, A.S. Lanotte, R. Scatamacchia & F. Toschi – Extreme events for two-particles separations in turbulent flows. Progress in Turbulence 2012.

A sketch illustrating the dispersion of a bunch of tracers released from a point wise source and dispersing in a homogenous and isotropic velocity field.

Unravelling 3D mixing near the surface of actuated beads

Project Aim

This project is part of a larger research program on magneto-active mixing and catching by small beads for microfluidic biosensor applications. It concerns the full exploitation of the scavenging properties of magnetic beads in microfluidic devices, control of fluid mixing, and the enhancement of the capture of (biological) targets by the beads. Key in this process is knowledge of the unsteady streamline pattern around a translating and rotating sphere and a detailed understanding of the local mixing properties nearby the sphere surface. Quantitative information, obtained from a laboratory experiment (on macroscopic scale), combined with numerical modeling will be used to optimize the mixing and capturing processes. Actuation protocols will be devised to enhance the capture probability of target particles by the bead.

Progress

We have extended the numerical/analytical study on the fundamental transport phenomena and associated mixing processes around a piecewise-steadily rotating spherical bead. The formation and origin of coherent structures was further explored. It was found that these structures are intimately linked to the presence of isolated periodic points and their associated invariant manifolds. The results of this study have been summarized in a paper which has been submitted to the Journal of Physics of Fluids. Parallel to the above study, preliminary experiments were carried out in order to benchmark the numerical findings and to search for the motion protocol that optimizes the capture efficiency of target molecules by measuring the target flux to the sphere surface. Here, heat is used as a passive tracer and the working fluid is silicone oil. First benchmark tests have been performed.

Dissertations

-

Scientific Publications

-

Projectleaders

HJH Clercx

Researchtheme

Complex dynamics of fluids

Participants

NR Moharana, RR Trieling,
GJF van Heijst, HJH Clercx

Cooperations

M Prins (TU/e-TN; Philips),
AM de Jong (TU/e-TN),
J den Toonder (TU/e-Wbt; Philips),
MFM Speetjens (TU/e-Wbt).

Funded

STW

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

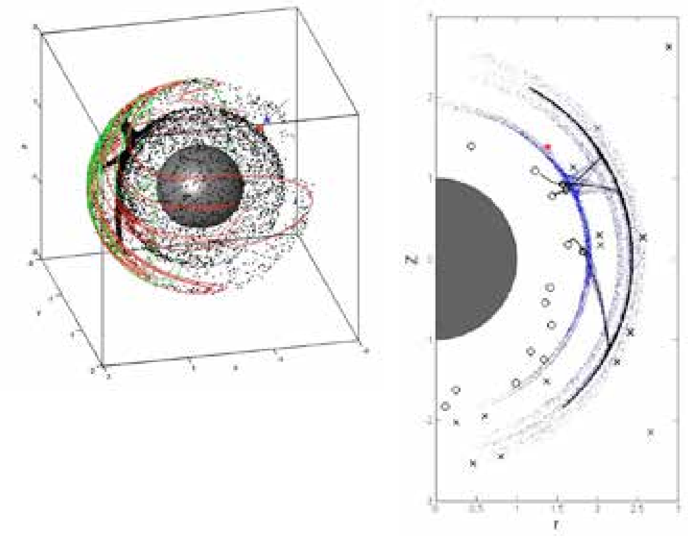
Start of the project

2010

Information

HJH Clercx
040 247 2680
h.j.h.clercx@tue.nl

RR Trieling
040 247 2673
r.r.trieling@tue.nl
www.fluid.tue.nl



3D Poincaré map (left panel) and its corresponding projection in the rz-plane (right panel) for a single tracer released at the position of the (red) bullet for a piecewise-steadily rotating sphere subject to artificial (nonlinear) perturbations. Corresponding period-3 foci and nodes are indicated by circles and crosses, respectively. The lines represent the 1D and 2D manifolds associated with specific triplets of period-3 foci and nodes.

PROJECTLEADERS
HJH Clercx

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
RJAM Stevens, V Lavezzo, P Perlekar, F Toschi, GJF van Heijst, HJH Clercx

COOPERATIONS
BJ Geurts (TU/e & UT), R Verzicco (Univ. Bari, Italy), D Lohse (Univ. Twente), G Ahlers (UCSB, USA), RPJ Kunnen (TU/e-TN)

FUNDED
FOM

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

START OF THE PROJECT
2008

INFORMATION
HJH Clercx
040 247 2680
h.j.h.clercx@tue.nl
www.fluid.tue.nl

PROJECT AIM

The aim of this research project is threefold: 1) understanding of the effect of background rotation on Rayleigh-Bénard convection (RBC) and the role of Ekman boundary layers on the emergence of coherent structures in the flow, 2) heat transport measurements in (rotating) RBC in cylindrical convection cells, and 3) analysis of the dispersion of particles with (thermal) inertia and its subsequent feedback on the flow. For this purpose both laboratory experiments and direct numerical simulations are performed (both cylindrical geometry and channel geometry).

PROGRESS

This project has been finished with the thesis of R.J.A.M. Stevens (2011).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. R.J.A.M. Stevens, H.J.H. Clercx & D. Lohse – Breakdown of the large-scale circulation in Gamma=1/2 rotating Rayleigh-Bénard flow. Phys. Rev. E 86, 056311-1/9 (2012).

Lattice Boltzmann method for contact line dynamics

Project Aim

The project aims at the development, validation and use of the lattice Boltzmann method (LBM) for the numerical study of flows in various simple model geometries where contact line dynamics is relevant. The method allows for the investigation of flows where the complexity of the geometry also plays a role, e.g. in the immersion lithography and ink-jet print head setups.

Progress

We study numerically the dynamics of the interface between two immiscible fluids in contact with a smooth, partially wetting and moving solid plate by means of the lattice Boltzmann method (LBM) and compare with an extension to finite viscosity ratio of the generalized lubrication theory (GL). We consider the generic case of two fluids with arbitrary viscosity ratio and of a plate moving either pulled or pushed in the bath. Both methods (LBM and GL) allow resolving, in different ways, the viscous singularity at the triple contact between the two fluids and the wall. When the solid plate moves fast enough the entrainment of one fluid inside the other one can occur. The LBM and GL results very well supports and complement each other for different physical parameters (contact angle, viscosity ratio and capillary number). The results and findings of this study will soon be published in a scientific journal.

Dissertations

-

Scientific Publications

1. P. Perlekar, L. Biferale, M. Sbragaglia, S. Srivastava & F. Toschi – Droplet size distribution in homogeneous isotropic turbulence, Phys. Fluids 24, 065101. (2012).

Projectleaders

F Toschi

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Srivastava

Cooperations

ASML, Océ

Funded

FOM

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

Start of the project

2009

Information

F Toschi
040 247 3911
f.toschi@tue.nl
www.fluid.tue.nl

Attributing the sources of tropospheric ozone from space: Constraining biogenic VOC emissions and emissions from biomass burning

Projectleaders
KF Boersma, GJF van Heijst
Researchtheme
Complex dynamics of fluids
Participants
MHA van Geel, GCM Vinken, WW Verstraeten, KF Boersma
Cooperations
KNMI, BIRA, Harvard-Smithsonian
Funded

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

Start of the project
2010
Information
KF Boersma
040 247 2160
k.f.boersma@tue.nl
www.fluid.tue.nl
www.knmi.nl/~boersma

Project Aim

Ozone is produced in the troposphere by photochemical oxidation of volatile organic compounds (VOCs) and CO in the presence of nitrogen oxides. These precursors have large and changing anthropogenic sources and some natural sources may be perturbed by climate change. In this project, we use satellite data as top-down constraints on emissions of isoprene, and derive emissions of HCHO and NOx from biomass burning. We focus on three tasks: the first two involve biogenic emissions, the third involves biomass burning. We will first evaluate isoprene chemistry in TM5. We then proceed and apply satellite observations of HCHO columns from the GOME(-2), SCIAMACHY, and OMI instruments to better estimate isoprene emissions from biogenic sources and fires.

Progress

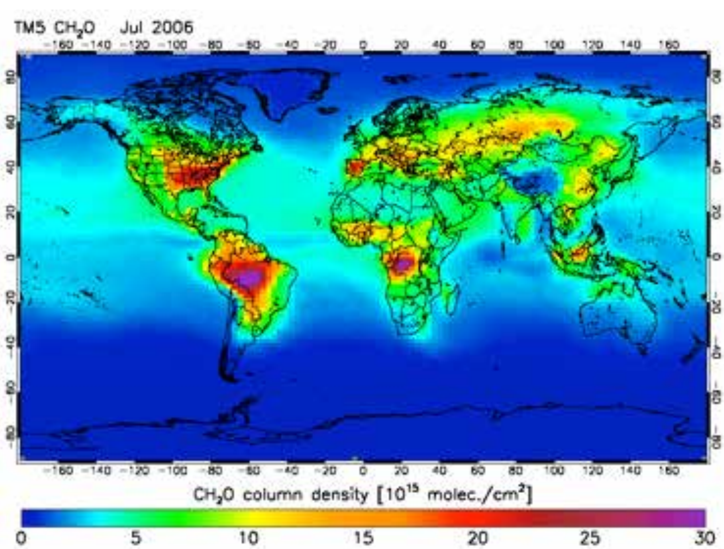
The PhD candidate has successfully implemented two new isoprene oxidation schemes in the global 3D chemistry transport model TM5 in order to simulate atmospheric concentrations of isoprene and HCHO. The new schemes lead to a much improved agreement between the simulations and aircraft observations from the AMMA campaign. The aircraft observations have also been used to validate the satellite retrievals of HCHO columns over the tropics. These activities constitute the building blocks for a successful inversion of satellite measurements to isoprene emission estimates.

Dissertations

-

Scientific Publications

-



Average Formaldehyde (CH2O) columns simulated with the TM5 chemistry transport model for July 2005. Enhanced values over vegetated regions of the world reflect oxidation of isoprene emitted by plants.

Attributing the sources of tropospheric ozone from space: Mapping NO2 emissions with satellite observations

Project Aim

Ozone is produced in the troposphere by photochemical oxidation of volatile organic compounds (VOCs) and CO in the presence of nitrogen oxides. These precursors have large and changing anthropogenic sources and some natural sources may be perturbed by climate change. In this project, we will exploit NO2 column data from SCIAMACHY, OMI, and GOME(-2) as top-down constraints on emissions of NOx, building on earlier work with GOME and OMI. We will first improve the description of a number of physical and chemical processes relevant to NOx emissions in the global models we will use (TM5, GEOS-Chem). We then apply satellite observations of NO2 columns from the GOME(-2), SCIAMACHY, and OMI instruments to better estimate NOx emissions from different categories, including international shipping, lightning, biomass burning, and anthropogenic emissions.

Progress

NO2 columns for Europe were simulated using an updated, high-resolution (0.5°x0.67°) version of the GEOS-Chem chemistry transport model. This model accounts for non-linear chemistry in ship plumes (Vinken et al., 2011). These simulated columns were averaged seasonally and then compared to satellite NO2 observations of OMI to provide constraints for 2005-2006 on major ship routes in Europe (Spain-France and Med. Sea). This work was presented at the annual European Geosciences Union General Assembly 2012, and the annual American Geophysical Union Fall Meeting 2012, as well as two workshops on (ship) emissions in Hamburg and Toulouse. This work will be extended by constraining other major ship tracks in Europe and by covering more years.

Dissertations

-

Scientific Publications

1. K. F. Boersma, G. C. M. Vinken, P. Castellanos, M. de Ruyter de Wildt & H. J. Eskes – Minder stikstofdioxide boven Europa door milieubeleid en economische recessie. Tijdschrift Lucht, jaargang 8, nummer 3, juni 2012.
2. M. de Ruyter de Wildt, H. Eskes & K.F. Boersma – The global economic cycle and satellite-derived NO2 trends over shipping lanes. Geophys. Res. Lett. 39, L01802 (2012).

Projectleaders

KF Boersma, PF Levelt, GJF van Heijst

Researchtheme

Complex dynamics of fluids

Participants

GCM Vinken, MHA van Geel, WW Verstraeten, KF Boersma

Cooperations

KNMI, Harvard University

Funded

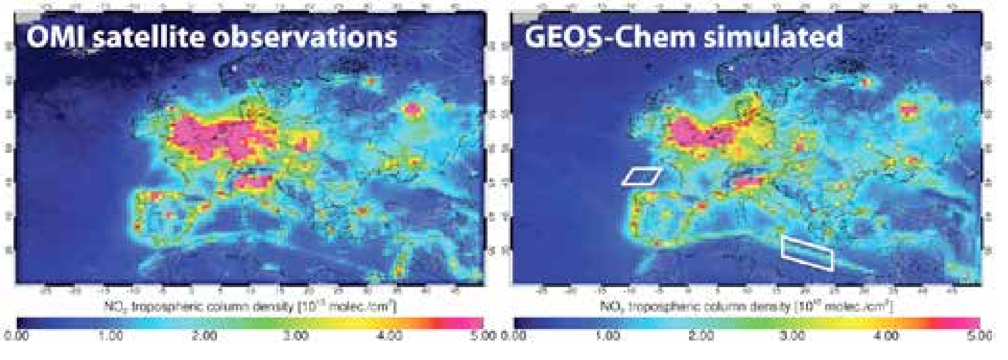
NWO-VIDI	
University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2010

Information

KF Boersma
040 247 2160
k.f.boersma@tue.nl
www.fluid.tue.nl
www.knmi.nl/~boersma



OMI observed (left) and GEOS-Chem simulated (right) NO2 columns for 2005, averaged on a 0.5° x 0.667° resolution. The parallelograms (right) indicate the parts of the ship tracks that are used in the constraint.

Attributing the sources of tropospheric ozone from space: Evaluating time series of free tropospheric ozone observed from space with a chemical transport model

Projectleaders
KF Boersma, GJF van Heijst

Researchtheme
Complex dynamics of fluids

Participants
WW Verstraeten, GCM Vinken, MHA van Geel, KF Boersma

Cooperations
KNMI, JPL

Funded
NWO-VIDI

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

Start of the project
2011

Information
WW Verstraeten
040 247 2160
w.w.verstraeten@tue.nl
www.fluid.tue.nl

Project Aim

Tropospheric ozone is an important greenhouse gas and a global air pollutant. The fact that ozone in the troposphere reflects the complex interplay of varying spatio-temporal emissions of precursors together with meteorological conditions and atmospheric transport patterns, challenges in-depth interpretation of ozone observations. Spaceborne sensors are excellent tools to map tropospheric ozone patterns thanks to their extensive spatial coverage and frequent overpasses, but understanding and attributing tropospheric ozone concentrations and sources to the observations requires advanced chemical transport models.

Progress

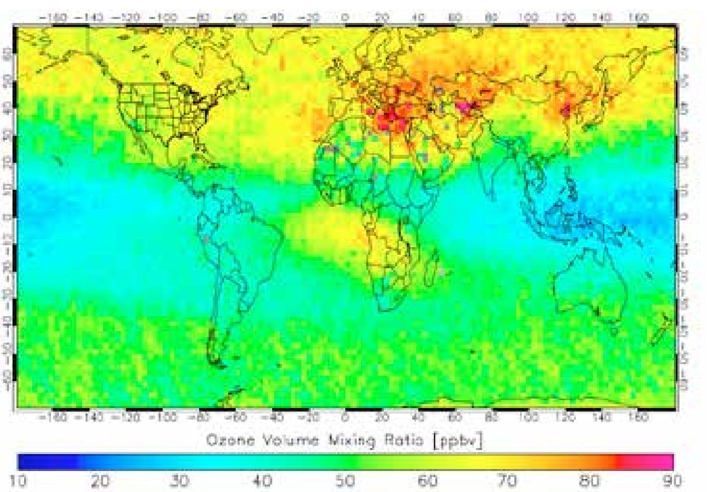
V004 nadir ozone profiles from the Tropospheric Emission Spectrometer (TES) onboard NASA's EOS-Aura satellite were processed and validated with ±4400 coinciding ozone balloon sonde measurements taken across the world from WOUDC data base during the period 2005-2010. Generally, TES ozone retrievals are biased high by 2-7 ppbv in the troposphere, consistent with validation results from earlier studies. Trend analysis on the TES ozone time series for the region of Eastern Asia showed a clear increase of tropospheric ozone in this region from 2005 on. This increase was also reproduced by the TM5 chemistry transport model using anthropogenic NOx emissions updated with OMI derived tropospheric NO2 columns. This suggests that the observed increase in tropospheric ozone is likely to reflect a combination of increasing anthropogenic emissions of ozone precursors as well as more favorable regime for ozone formation over Asia.

Dissertations

-

Scientific Publications

-



June-July-August average of ozone concentrations at 464 hP.

Dynamics, collisions and coalescence of droplets in turbulence

Project Aim

In this experimental project the motion of droplets with diameter of 10 to 50 micrometer in an air-filled turbulence chamber are tracked with 3D particle tracking velocimetry (PTV). The focus is on interactions between droplets (collision or coalescence) and the effect of gravity. We also study the evolution in time of the droplet size distribution with phase-Doppler anemometry (PDA). Turbulence-induced droplet coalescence is the process responsible for rapid precipitation formation; it is, however, not well understood.

Progress

The assembly of the experimental facility is nearly finalized. The first experiments will be done in March. First, PIV measurements will be used to quantify homogeneity and isotropy of the turbulence in the chamber. Then we will start experiments on droplet motion in turbulence in which we employ 3D PTV. Droplet generation using a spinning disk is operational. We can generate droplets with a tunable diameter between 15 and 50 micrometers.

Dissertations

-

Scientific Publications

-

The 'soccer ball' turbulence chamber.

Projectleaders

HJH Clercx, GJF van Heijst

Researchtheme

Complex dynamics of fluids

Participants

AM Yavuz, MAT van Hinsberg, RPJ Kunnen, HJH Clercx, F Toschi

Cooperations

BJ Geurts (UT), D Lohse (UT), BJ Boersma (TUD), RF Mudde (TUD), L Portela (TUD), J Westerweel (TUD)

Funded

FOM

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

Start of the project

2011

Information

HJH Clercx
040 247 2680
h.j.h.clercx@tue.nl

RPJ Kunnen
040 247 3194
r.p.j.kunnen@tue.nl
www.fluid.tue.nl.

Population dynamics under flow: experiments with bacteria

Projectleaders
F Toschi, HJH Clercx

Researchtheme
Complex dynamics of fluids

Participants
F Tesser, P Perlekar, HJH Clercx, F Toschi, JCH Zeegers

Cooperations
R Benzi (Univ. Tor Vergata, Italy), L Brunsveld (BMT, TU/e), MH Jensen (Niels Bohr Institute, Denmark), DR Nelson (Harvard University, USA), S Pigolotti (Universidad politécnica de Cataluña, Spain)

Funded
FOM

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

Start of the project
2012

Information
F Toschi
040 247 3911
f.toschi@tue.nl
www.fluid.tue.nl

Project Aim

Population dynamics deals with the study of birth, death and growth processes of biological species. These processes are severely affected by the local ecosystems, by the presence of nutrients, and by the local population density, moreover all these factors can be strongly influenced in a liquid environment by the presence of a flow. Effects can be visible at macroscales in terms of strong non homogeneities. The aim of the present project is to validate the continuum model for the growth of populations extending it to flow conditions, using a combination of dedicated experiments of growth of bacteria in microfluidic devices and numerical discrete particle simulations.

Progress

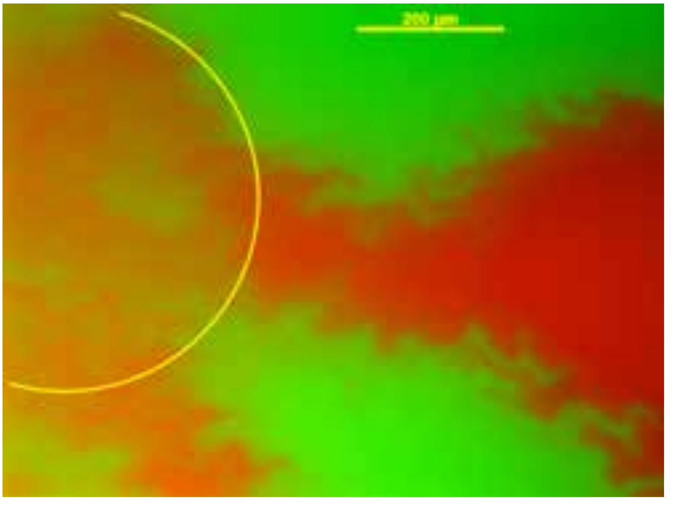
The first part of the first year has been spent on the general study of the problem, on knowledge acquisition from literature and then on the implementation of the experimental set up, including the fabrication of some PDMS trial devices and the optical structure.

Dissertations

-

Scientific Publications

1. R. Benzi, M.H. Jensen, D.R. Nelson, P. Perlekar, S. Pigolotti & F. Toschi – Population dynamics in compressible flows. European Physical Journal: Special Topics 204, 57-73 (2012).



A 50:50 mixture of two identical species of bacteria radially growing on agar plate shows segregation of genes due to fluctuations at expanding frontiers.

Prof.dr.ir. K Kopinga

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. Transport and phase change processes in porous building materials, rocks and coatings are studied. The studied phenomena play a key role in the durability of building materials. Much research is done in close cooperation with TNO. The work is funded by the Dutch Technology Foundation (STW), Materials innovation institute (M2i), the European Commission and various industrial partners. In our research Magnetic Resonance Imaging techniques is one of the major working horses.

Influence of water-polymer interactions on water transport in multilayer coatings

Projectleaders
OCG Adan, HP Huinink

Researchtheme
Complex dynamics of fluids

Participants
V Baukh

Cooperations
AkzoNobel Automotive & Aerospace Coatings, TNO

Funded
AkzoNobel

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

Start of the project
2011

Information
V Baukh
040 247 3231
v.v.baukh@tue.nl

Project Aim

The aim of the current project is to understand how compositions of multilayer coatings influence water transport. Different compositions may induce different water-polymer interactions in layers of coatings. As a result, different sorption characteristics and water transport kinetics will be observed. The focus of the study is on the influence of additives in waterborne layers on their sorption and transport properties.

Progress

It was shown that high resolution NMR imaging is a versatile tool for studying such processes. Besides imaging of how water distributes in multilayer coatings during transport, this technique is capable of evaluating water-polymer interactions in individual layers. Furthermore, a theoretical model for water transport in multilayer coatings was developed and verified. The theory shows that water transport is determined by the permeability of the barrier layer to water and the sorption isotherms of a base layer, which is sensitive to water. The following steps are to gain understanding of the layer composition influence on these parameters.

Dissertations

-

Scientific Publications

1. V. Baukh, H.P. Huinink, O.C.G. Adan, S.J.F. Erich and L.G.J. van der Ven (2012) Predicting Water Transport in Multilayer Coatings, Polymer, Vol.53, Issue 15, p. 3304-3312.

Open time of glue mortar

Project Aim

The aim of the project is to understand the parameters that determine the open time of glue mortars. The open time is a crucial parameter for the performance of (glue) mortars for joining material components, such as tiles and bricks. The open time is the time during which tiles can be fixed with a sufficiently good adhesion to the substrate. Exceeding this so-called open time would give a huge reduction in adhesion, because of processes taking place at the surface layer, e.g. drying and hardening. Empirically it is known that the open time has an optimum at specific concentration of specific types of modified cellulose Obviously, optimizing the adhesive strength plays a central role in product development.

Progress

NMR is used to obtain moisture profile during drying of mortar. Experiments were performed on mortar and mortar in presence of different weight percentage of Methylhydroxylethylcellulose (MHEC). We observed homogeneous drying behaviour in mortar without (MHEC) and a front receding drying in polymer added mortar. The observed shift of drying from homogeneous to front receding is due to the influence of viscosity on flow process. Addition of MHS increased the viscosity of pore liquid and hence decreased the evaporation rate of mortar as described by a shift from Darcy's flux to diffusive flux. The future work in this project will be focused on the development of mathematical model that describe drying. To do so experiments on brick and porous aluminum, will enable to discriminate between hydration processes, and flow processes.

Dissertations

-

Scientific Publications

-

Projectleaders

SJF Erich, HP Huinink, OCG Adan

Researchtheme

Complex dynamics of fluids

Participants

APA Faiyas

Cooperations

Materials Innovation Institute (M2i),TNO

Funded

TNO

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

Start of the project

2010

Information

APA Faiyas,
040 247 4853
a.p.a.faiyas@tue.nl

Water assisted transport of inhibitors for corrosion protection

Projectleaders
SJF Erich, HP Huinink

Researchtheme
Complex structures of fluids

Participants
M van Soestbergen

Cooperations
TNO

Funded
Materials innovation institute

University	-
FOM	-
STW	-
NWO Other	-
Industry	40 %
TNO	60 %
GTI	-
EU	-
Scholarships	-

Start of the project
2010

Information
M van Soestbergen
040 247 3830
m.vansoestbergen@m2i.nl

Project Aim

The aim of this project is to obtain knowledge on the physical and chemical processes that underlie the transport of corrosion inhibitors through organic coatings and their subsequent leaching into an aqueous environment. The in this project obtained knowledge is useful to improve the design methodology of future coating systems.

Progress

We have currently determined accurate detection methods for the corrosion inhibitors, both in the organic coating system as well as in aqueous solution. These methods are used for leaching and diffusion cell experiments. During the leaching experiments the coatings, in which we incorporated up till 10 w% inhibitor, are exposed to demi-water and the increase in inhibitor concentration in the water phase is monitored. The diffusion cell consist of two compartment separated by a coating film, while the transport of inhibitors is determined from the increase in the compartment that initially contained a zero concentration. All this information will be combined in the numerical model that we have developed for the corrosion of aluminum substrates.

Dissertations

-

Scientific Publications

1. M. van Soestbergen, S.J.F.Erich, H.P.Huinink and O.C.G.Adan (2012) Dissolution properties of cerium dibutylphosphate corrosion inhibitors, Corrosion Engineering Science and Technology http://dx.doi.org/10.1179/1743278212Y.0000000069.

Project Aim

The aim of this project is to understand the fundaments of crystallization in porous media, in connection to damage mechanism. In this project the focus is on NaCl. The objective is to come to better understanding in order to develop new method to prevent salt damage in cultural heritage objects.

Progress

Experiments were done with potassium ferrocyanide (K4 [Fe (CN)6].3H2O) as crystallization inhibitor by spaying against NaCl damage to see the effect of use in situ. These results show that this inhibitor does work and could be used as such. Experiments were done on the use of effect of inhibitor on the various mixtures of salts, i.e., ternary mixtures of NaCl + KCl + water; NaCl + LiCl + water. These show that the inhibitor can still have an effect on the crystallization. A model has been developed to explain the difference in drying behavior for materials saturated with a NaCl solution.

Dissertations

-

Scientific Publications

1. Sonia Gupta, Kristina Terheiden, Leo Pel, and Alison Sawdy, Influence of ferrocyanide inhibitors on the transport and crystallization processes of sodium chloride in porous building materials, Crystal Growth & Design, 2012 (DOI: 10.1021/cg3002288) 2012, 12 (8), pp 3888–3898.
2. Sonia Gupta, Leo Pel, Alison Heritage, Effect of spraying Ferrocyanide on NaCl contaminated samples12th International Congress on the Deterioration and Conservation of Stone, New York 2012.

Projectleaders

K Kopinga, L Pel

Researchtheme

Complex dynamics of fluids

Participants

S Gupta

Cooperations

TNO

Funded

STW

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

Start of the project

2009

Information

L Pel
040 241 9742
l.pel@tue.nl
www.phys.tue.nl/nfcmr

Measuring, modelling and monitoring chloride ingress in cracked concrete

Projectleaders
OCG Adan, L Pel

Researchtheme
Complex dynamics of fluids

Participants
Vacancy

Cooperations
TNO, INTRON, BAM

Funded
STW

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

Start of the project
2008

Information
L Pel
040 241 9742
l.pel@tue.nl
www.phys.tue.nl/nfcmr

Project Aim

The objective of this project is to determine the effect of cracks on the chloride ingress in concrete. This project focuses on the effect of cracks, voids and compaction defects in concrete on chloride transport and on the effect of boundary conditions on the transport processes. The aim is to develop a model which can give a better prediction of the chloride transport over a longer time, i.e., years.

Progress

The objective of this project is to determine the effect of cracks on the chloride ingress in concrete. This project focuses on the effect of cracks, voids and compaction defects in concrete on chloride transport and on the effect of boundary conditions on the transport processes. Some first experiments were done to measure the ion diffusion in porous media. For the first time simultaneously both the Cl and Na distributions in a sample were determined. These measurements have to be extended to samples with cracks. The aim is to use this date to verify a model which can give a better prediction of the chloride transport over a longer time, i.e., years.

Dissertations

-

Scientific Publications

1. J.J.A.M. Borgharts and L. Pel, Non-destructive measurements of chloride in concrete by NMR, the 2nd International Conference on Microstructural-related Durability, of Cementitious Composites, Microdurability 2012, Amsterdam, The Netherlands, April 11 – 13, 2012.

Electrokinetic desalination of porous building materials

Project Aim

The objective of this project is to determine the effect of electro kinetics on the drying and desalination of porous building materials. This project also focuses on the effect of boundary conditions on the transport processes. The aim is to develop better methods which could be used.

Progress

The NMR measurements have shown that initially the salt (Na) ions transport by electro-migration is proportional to the strength of an applied electric field. These measurements showed that at later stages the salt transport by electro migration is halted and Na depletion front stagnates. It is shown that this front stagnates precisely at the same position, where the collision of acidic and alkaline fronts and a sharp variation in electrical potential in the brick was observed. A model based on the Poisson-Nernst-Planck equation was developed and agreed well within the experimental accuracy achieved in this study.

Dissertations

1. K. Kamran, Electro kinetic desalination of porous building materials, Ph.D. thesis, Eindhoven University of Technology, the Netherlands (2012).

Scientific Publications

1. Kashif Kamran, Leo Pel, Alison Sawdy, Henk Huinink, Klaas Kopinga, Desalination of porous building materials by electro kinetics: an NMR study, Materials and Structures 45:297–308 (2012).
2. K. Kamran, M. van Soestbergen, H.P. Huinink, L. Pel, Inhibition of electro kinetic ion transport in porous materials due to potential drops induced by electrolysis, Electrochimica Acta 78 229– 235 (2012).
3. K. Kamran, M. van Soestbergen, L. Pel, Electro kinetic Salt Removal from Porous Building Materials Using Ion Exchange Membranes, Transport in Porous Media, 2012 (DOI 10.1007/s11242-012-0083-0).

Projectleaders
K Kopinga, L Pel

Researchtheme
Complex dynamics of fluids

Participants
K Kamran

Cooperations
-

Funded
HEC Pakistan

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

Start of the project
2008

Information

L Pel
040 241 9742
l.pel@tue.nl
www.phys.tue.nl/nfcmr

PROJECTLEADERS
OCG Adan, L Pel
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
Vacancy
COOPERATIONS
TNO, NEBEST, Strukton
ENCI, Cosensor
FUNDED
STW

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

START OF THE PROJECT
2010
INFORMATION
L Pel
040 241 9742
l.pel@tue.nl
www.phys.tue.nl/nfcmr

PROJECT AIM

The objective of this project is to model the chloride transport at the pore level in concrete, i.e., to describe the transport in the capillary and gel pores. Here fore it is needed to measure the transport of the ions non-destructively and the aim is to develop a NMR setup which will be able to measure nondestructively the transport in concrete.

PROGRESS

The objective of this project is to model the chloride transport at the pore level in concrete, i.e., to describe the transport in the capillary and gel pores. Here fore it is needed to measure the transport of the ions non-destructively and the aim is to develop a NMR setup which will be able to measure nondestructively the transport in concrete. Some first experiments were performed using a 1.5T scanner, which showed the feasibility of the technique for measuring Cl. A new setup is now under development which should operate at 4.7T, giving an improved signal-to-noise ratio.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. J.J.A.M. Borgharts and L. Pel, Non-destructive measurements of chloride in concrete by NMR, the 2nd International Conference on Microstructural-related Durability, of Cementitious Composites, Microdurability 2012, Amsterdam, The Netherlands, April 11 – 13, 2012.

TGInk (Towards Green Ink)

Project Aim

Waterborne inks are the future in the area of inkjet printing, since the use of organic solvents has to be reduced for environmental reasons. In an inkjet process droplets are jetted from the nozzle, hit the paper and start to spread, penetrate the paper and evaporate. This all happens on time scales between 0.001 and 1 s. At present water based inks have three main constituents beside water:

1. pigment particles for giving color to the image,
2. polymer particles to create continuous films needed for fixating the pigments and gloss,
3. co-solvent used to prevent evaporation at the tip of nozzle of the inkjet.

Water based inks have much in common with the waterborne coatings. When ink droplets hit paper the polymeric phase has to form a continuous layer on top of the paper sheet. Since in copiers and printers paper gets a heat treatment after being covered with ink, the actual fusion of the polymeric particles is not a problem. It is the arrangement of particles on the paper before the heat treatment which is the critical factor for obtaining a proper film. Little ingress (order of microns) of the polymeric phase promotes adhesion, but deep penetration prevents the formation of a polymeric layer on top of paper and leads to loss in quality of the image. The penetration depth seems to reduce with increasing evaporation rate and is therefore tightly connected with the addition of the co-solvents mentioned before. For the jetting process itself low evaporation rates are required to prevent blockage of the nozzle and for a good quality of the image high evaporation rates are desired. As this project aims for understanding the penetration of the ink constituents in paper in relation to the evaporation rate of water, the knowledge gained within this project could be used as a tool for improving ink formulations.

Progress

-

Dissertations

-

Scientific Publications

-

Projectleaders

HP Huinink, OCG Adan

Researchtheme

Complex dynamics of fluids

Participants

CJ Kuijpers

Cooperations

Materials Innovation Institute (M2i), Oce

Funded

M2i, Oce

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

Start of the project

2012

Information

CJ Kuijpers
040 247 4063
c.j.kuijpers@tue.nl

Thermo chemical heat storage for the future

Projectleaders
L Pel, OCG Adan
Researchtheme
Complex dynamics of fluids
Participants
PAJ Donkers
Cooperations
Materials Innovation Institute (M2i), TNO
Funded
TNO

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

Start of the project
2011
Information
PAJ Donkers
040 247 5612
p.a.j.donkers@tue.nl

Project Aim

Renewable energy is of increasing importance in our modern society. In the Netherlands the main sources of renewable energy are windmills, solar panels and solar collectors. Systems that buffer the energy are needed to match the demand and supply. New systems of heat storage are needed which can store energy with a high energy density and low or no energy loss, for instance, a compact heat storage system which can be introduced in the Dutch building industry. One particular heat storage method with a high potential uses the (hydration) crystallization energy of salts. By using thermo chemical energy storage the energy needed for heating in the Netherlands could be reduced by around 50 PJ per year. The aim is to find the most viable salts which are stable over repeated cycles of absorption and release of energy.

Progress

To use crystalline hydrate salts as the working media for thermal energy storage their phase transitions should be understood in detail. To this end we have studied the phase transition of Mirabilite into Thenardite, where we have monitored both the crystal structure and water content. With the help of NMR, XRD and Raman a homogenous drying of Mirabilite over the entire crystal was observed. According to the drying behavior, the mobility of water molecules within the crystal structure has to be high, which was checked and observed in separate NMR diffusion measurements. Raman spectroscopy showed that the transition of Mirabilite into Thenardite most likely occurs via a disordered phase. The impact of this disordered phase decreases when the water content is decreasing. Preliminary experiments suggest that this is caused by a non-symmetric crystal phase.

Dissertations

-

Scientific Publications

-

Water transport through coatings on wood

Project Aim

An important reason to apply coatings on wood is to protect wood against water. In order to use waterborne coatings for wood care the main factors determining transport through these coatings have to be understood. Waterborne coatings are intrinsically more sensitive to water. Further, the influences of wood on the coating structure and permeability have to be understood. In this project the migration of water through waterborne coatings on wood will be studied with NMR imaging tools. NMR imaging is very suitable tool for visualizing water distributions in the wood and the coating. Further, NMR also gives information about the state of water (bound or free) and plasticization effects (polymer-water interactions).

Progress

-

Dissertations

-

Scientific Publications

-

Projectleaders

SJF Erich, HP Huinink

Researchtheme

Complex structures of fluids

Participants

O Gezici

Cooperations

TNO

Funded

AKZO/TNO

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

Start of the project

2012

Information

B Erich
040 247 3830
s.j.f.erich@tue.nl

Water transport in multilayer coatings

Projectleaders
OCG Adan, HP Huinink

Researchtheme
Complex dynamics of fluids

Participants
V Baukh

Cooperations
AkzoNobel Automotive & Aerospace Coatings, TNO

Funded
AkzoNobel, TNO

University	-
FOM	-
STW	-
NWO Other	-
Industry	40 %
TNO	60 %
GTI	-
EU	-
Scholarships	-

Start of the project
2007

Information
V Baukh
040 247 3231
v.v.baukh@tue.nl

Project Aim

The aim of the current project is to understand water transport in multilayer coatings, which consist of hydrophilic base coat and a hydrophobic top coat. The study focuses on investigation of water transport kinetics and its relationship with coating properties. As a key technique high resolution NMR imaging is used, which has a potential for monitoring water distributions during the process and for providing information about water-polymer interactions.

Progress

High resolution NMR imaging has provided water distributions during uptake and has given information about influence of water on coating and state of water in the layers. The observations have enabled to introduce a theoretical model for water transport. The model was experimentally verified and is able to predict water transport. For prediction only two key parameters are needed: the top coat permeability to water and the base coat sorption isotherm. These parameters can be easily measured with low-tech techniques, like gravimetry, enabling the possibility to design simple and cost-efficient test for water transport in such kind of systems.

Dissertations

1. V. Baukh, Water transport in multilayer coatings, March 5, 2012.

Scientific Publications

1. Huinink, H., Baukh, V., Erich, B., Adan, O., Van Der Ven, L., Keeping protection in the clear, (2012) European Coatings Journal, (11), pp. 38-42.

Combustion Technology

Prof.dr. LPH de Goey

Prof.dr. B Johansson

The goal of the research programme of the ‘Combustion Technology Group’ is to gain insight in and knowledge on reacting flows in order to develop new and improve existing models of combustion systems. The models are used to guide new developments in the struggle to come to more efficient and clean conversion systems of fossil and sustainable fuels for a sustainable society. The knowledge and models developed are based on thorough physical and chemical understanding of the processes. This means that the gap between fundament and application has to be bridged continuously by transforming models describing physical/chemical behaviour on the smallest scales to models for the macroscopic scale of the full system. The knowledge is based on ‘generic’ theoretical and numerical insights for the propagation and structure of idealised flames and their interaction with acoustic waves, turbulent structures and inert/reacting surfaces. Most models for the combustion chemistry are based on a combination of the so-called laminar flamelet concept and chemical reduction methods leading to new techniques like FGM.

There is also a close entanglement of theoretical/numerical and experimental research. Available diagnostic techniques are e.g. flame visualisation, absorption techniques, LDV, PIV, LIF and Rayleigh scattering. Validation with the available laser-diagnostic measurement systems in the laboratory and real applications is carried out to disentangle the processes taking place on the various length and time scales. These measurements are carried out in flat (non-)adiabatic flames stabilised on the Heat Flux burner, laminar flames on Bunsen-type burners, flat turbulent flames on a weak-swirl burner, biomass grid, tube and bed reactors, optically-accessible combustion vessels and optically-accessible engines. Application areas are: small-scale laminar combustion systems, combustion of bio-fuels, engines and gas turbines. The application area of combustion engines is of particular interest.

Suppression of thermo-acoustic instabilities in central heating equipment by burner design optimization

Project Aim

The aim of this project is to provide tools to suppress the thermo-acoustic instabilities by optimizing the design of the perforated burners. Within the scope of this project different methods (experimental as well as numerical) will be explored for a-priori calculation of acoustic response (the flame transfer function) of the perforated burners. This information of transfer function is then used for (in)stability prediction of a simplified boiler using acoustic network model approach.

Progress

The acoustic response of the perforated burner plate is calculated using FLUENT®. An excellent match between numerically and experimentally obtained transfer function is obtained. The correct chemical mechanism and burner deck temperature are the key elements to obtaining the TF numerically. The parameterization of the transfer function of perforated burner deck will be done in near future and will be submitted to the European combustion meeting.

Dissertations

-

Scientific Publications

1. LBW Peerlings, Manohar, M., Kornilov, V.N. & Goey, L.P.H. de (2011). Flame saturation current as a measure of the flame thermo-acoustic behavior. Proceedings of the 19th International congress on sound and vibration, Vilnius, Lithuania, 8-12 July 2012.

Projectleaders

I Lopez, V Kornilov, H Nijmeijer, LPH de Goey

Researchtheme

Complex dynamics of fluids

Participants

Manohar M, PGM Hoeijmakers, V Kornilov, I Lopez, H Nijmeijer, LPH de Goey

Cooperations

STW, Bekaert, Honeywell, ATAG, Remeha

Funded

STW

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

Start of the project

2011

Information

Manohar
040 247 3819
manohar@tue.nl
www.tue.nl/combustion

PROJECTLEADERS
JA van Oijen, LPH de Goey
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
SE Abtahizadeh
COOPERATIONS
University of Groningen, TATA Steel, NUMECA
FUNDED
STW, NVV, TATA Steel, NUMECA

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

START OF THE PROJECT
2010
INFORMATION
JA van Oijen
040 247 3133
j.a.v.oijen@tue.nl
www.tue.nl/combustion

PROJECT AIM

In this project, MILD combustion by using highly preheated and diluted oxidizer and/or fuel streams will be studied to provide lower peak temperatures and as a result, low NOx emissions. Towards this end, 1D simulations of counterflow diffusion flames will be done to study the consequences of the composition of the fuel and/or oxidizer on spatial flame structure. Two-dimensional simulations of a coflow burner will be performed to compare with measurements. Based on the computational results obtained, a reduced chemical model for MILD combustion will then be developed and implemented in codes for simulation of turbulent combustion in JHC burners.

PROGRESS

Simulations of the laminar coflow burner of RuG have been performed with a detailed chemistry and transport model and radiative heat losses. A body-fitted multi-block parallel code has been adopted to speed up the simulations. The numerical results show a very good agreement of flame temperature and major species against the experiments. NO concentrations are also predicted reasonably well. The impact of burned gases on autoignition and flame stabilization is also studied in a turbulent jet-in-hot-coflow (JHC) burner. In this burner, Dutch Natural Gas (DNG) is mixed with various amounts of H2. The FGM tabulation has been performed using igniting laminar counterflow diffusion flames. Due to the presence of H2 in the fuel, preferential diffusion effects should be included the FGM table. Current results show that the FGM table is capable of prediciting the autoignition of fuel mixtures containing H2.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Abtahizadeh, S.E., Oijen, J.A. van & Goey, L.P.H. de. Numerical study of mild combustion with entrainment of burned gas into oxidizer and/or fuel streams. Combustion and Flame, Vol. 159(6), 2155-2165 (2012).
2. Abtahizadeh, S.E., Oijen, J.A. van & Goey, L.P.H. de (2012). Numerical study of a jet-in-hot-coflow burner with hydrogen-addition using the Flamelet Generated Manifolds technique. Bulletin of the 65th American Physical Society (APS) Division of Fluid Dynamics, 18 - 20 November 2012, San Diego, CA, USA.
3. S.E. Abtahizadeh, A. Sepman, J.A. van Oijen, L.P.H. de Goey. Fuel flexibility and NO Formation in dilute combustion. Proceedings of the Combustion Research and Application (COMBURA 2012), 3 - 4 October 2011, Maastricht, The Netherlands.
4. F. Pouyandeh, S.E. Abtahizadeh, J.A. van Oijen, L.P.H. de Goey. Investigation of fuel flexibility on the autoignition behavior of MILD combustion in jet-in-hot-coflow burners. Proceedings of the Combustion Research and Application (COMBURA 2012), 3 - 4 October 2011, Maastricht, The Netherlands.

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, 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 will be employed.

Progress

Combustion at MILD conditions has been investigated in numerical simulations of one-dimensional laminar counterflow diffusion flames employing detailed chemistry and transport models. These so-called flamelets will be used to generate look-up tables for accurate and efficient modeling of chemical kinetics in direct numerical simulations (DNS) of turbulent jet-in-hot-coflow flames. DNS of mixing layers under MILD conditions are performed with detailed chemistry. The results show that preferential diffusion effects are of paramount importance for the ignition behaviour. In addition, a large-eddy simulation (LES) solver has been extended with transport equations for two conserved scalars and their variances, which are used in conjunction with flamelet-generated manifolds (FGM). Preliminary LES simulations of the Delft jet-in-hot-coflow (DJHC) burner have been performed.

Dissertations

-

Scientific Publications

-

Projectleaders
JA van Oijen

Researchtheme
Complex dynamics of fluids

Participants
FE Hernandez Perez, MU Göktolga, JA van Oijen

Cooperations
-

Funded
NWO (VIDI)

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

Start of the project
2010

Information
JA van Oijen
040 247 3133
j.a.v.oijen@tue.nl
www.tue.nl/combustion

CFD modeling for the optimization of a flame ionization sensor

Projectleaders
JA van Oijen, LPH de Goey
Researchtheme
Complex dynamics of fluids
Participants
N Speelman
Cooperations
Bosch Thermotechnik
Funded
Bosch Thermotechnik

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

Start of the project
2010
Information
JA van Oijen
040 247 3133
j.a.v.oijen@tue.nl
www.tue.nl/combustion

Project Aim

The purpose of this research is to develop a combustion control and diagnostics sensor based on flame ionization for condensing boiler applications. The flame ionization sensor measures the electrical conduction of the charged species generated during the combustion process to detect flashback and combustion instabilities, and to monitor equivalence ratio. In particular, the focus is on developing models to integrate the electric field emanating from the electrode with the lean premixed combustion process and ion reaction/transport submodels to simulate the electrode test results and optimize its position and shape.

Progress

The project was started in October 2010 and since then literature in the field of combustion in the presence of electrical fields has been studied. The electrical potential calculation has been incorporated into the existing one-dimensional model through Poisson's equation together with models for electrically charged species. The one-dimensional numerical model is currently being validated especially with regards to its boundary conditions. Furthermore a basic implementation of a flamelet-based chemistry model (FGM) in the commercial solver used by Bosch Thermotechnik has been realized. The theoretical extension to the inclusion of electric fields and charged species has been made, but furthering this awaits validation of the one-dimensional model.

Dissertations

-

Scientific Publications

-

Advanced low NOx flexible fuel gas turbine combustion, aero and stationary

Project Aim

In the current project detailed knowledge for modeling of combustion with alternative fuels will be developed. This is done by means of detailed descriptions in the framework of Computational Fluid Dynamics (CFD). The ultimate goal is to predict the combustion process of gas turbines, including complex physical real fuel phenomena (temperature-traverse, NOx, preferential diffusion, thermo diffusive effects, extinction etc.). To that end the promising flamelet generated manifolds (FGM) technique will be extended in this project. The technique is developed in its basic form at TU/e and has been continuously tested and extended to more general situations over the last years.

Progress

Andrea: Implementation of heat loss inclusion in the tool FGM construction. Ansys-CFX implementation of this technique for the 2D manifold. Testing in a simple 2D geometry. Inclusion of turbulence effects in the FGM construction tool. Ansys-CFX implementation of the 3D manifold. Begin with mixture fraction inclusion in the current implementation. Internship at Siemens Orlando (two months).

Sudipto: Development of Filtered FGM (FFGM) with correction factors, Internship at Rolls Royce Berlin (two months), Implementation of enthalpy as additional controlling variable in manifold generation tool at Rolls Royce. Validation of enthalpy as controlling variable in manifold, DNS of premixed Bunsen burner.

Dissertations

-

Scientific Publications

-

Projectleaders

RJM Bastiaans, LPH de Goey, JA van Oijen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Andrea Donini, Sudipto Mukhopadhyay

Cooperations

Siemens Power Generation (SPG)
Rolls Royce Deutschland (RRD)

Funded

University, STW, SPG, RRD

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

Start of the project

2010

Information

RJM Bastiaans
040 247 4836
r.j.m.bastiaans@tue.nl
www.tue.nl/combustion

Laminar burning velocity measurements and chemical reaction mechanism evaluation of H2 rich syngas at elevated pressures

Projectleaders
RJM Bastiaans

Researchtheme
Complex structures of fluids

Participants
M Goswami, AA Konnov,
RJM Bastiaans, LPH de Goey

Cooperations
H2-IGCC Consortium

Funded
EU-FP7 project

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

Start of the project
2010

Information
Mi Goswami
M.Goswami@tue.nl
www.tue.nl/combustion

Project Aim

The project aims to evaluate flame speed (laminar) of syngas-air mixtures with high H2 content at conditions of high pressure (30 bars) and temperature (200 ˚C) that are relevant for gas turbine applications. The heat flux burner will be used in the project. Based on results derived from these experiments a chemical reaction mechanism will be evaluated.

Progress

1. Laminar burning velocity measurements of pressure upto 9 atm with syngas mixtures (50:50% and 85:15% H2:CO) with a variety of oxidizers at lean conditions using heat flux method.
2. A high pressure setup has been setup in the laboratory for measurements up to 30 bar (conditions relevant for gas turbine applications). The system has been tested with a flame up to 5 atm.
3. Heat flux method was studied with thermophosphors to measure burner plate temperature by replacing thermocouples. The spectral ratio method was applied to relate intensity to temperature.

Dissertations

-

Scientific Publications

-

Numerical simulation using flamelet generated manifold technique on hydrogen combustion for gas turbines

Project Aim

The H2-IGCC project, co-funded by the European Union's 7th Framework Programme for Research And Development, is based on the initiative outlined in the European Turbine Network's (ETN). The subproject regarding TU Eindhoven is divided in two parts: Numerical (I) and Experimental (II). My tasks will cover the Numerical part: Development of RANS and LES models will be based on Flamelet Generated Manifold (FGM) techniques with a special focus on preferential diffusion effects, partial unpremixedness and local extinction. These effects govern thermodiffusive instabilities which interact with turbulence in a complicated way. The Simulations will be done with the use of the open source software Open FOAM.

Progress

- Extension of Flamelet Generated Manifold technique on Open FOAM from 1D to 2D case using either a laminar and a turbulent manifold
- Work in progress is now on the:
  - 3D/4D table case in order to include heat loss, turbulence and mixture fraction
  - Inclusion of beta PDF for turbulent combustion using a 3D geometry (DLR jet flame)
  - Addition of hydrogen effects in the mixture and investigation on preferential diffusion.

Dissertations

-

Scientific Publications

1. Alessio Fancello, R.J.M. Bastiaans, and L.P.H. de Goey – A Flamelet Generated Manifolds LookUp table tool for premixed turbulent combustion -7th OpenFOAM Workshop –Darmstadt (Germany) - June 2012.

Projectleaders

RJM Bastiaans

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

A Fancello, RJM Bastiaans, LPH de Goey

Cooperations

H2-IGCC Consortium

Siemens AG

Funded

EU-FP7 project

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

Start of the project

2010

Information

A Fancello

040 247 3621

a.fancello@tue.nl

www.tue.nl/combustion

MoST: Multi-scale modification of swirling combustion for optimized gas turbines combustion model

Projectleaders
RJM Bastiaans, LPH de Goey, BJ Geurts

Researchtheme
Complex dynamics of fluids

Participants
Thiago Cardoso de Souza

Cooperations
U Twente, Ansaldo-Thomassen

Funded
STW

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

Start of the project
2009

Information
Thiago Cardoso de Souza
040 247 3731
t.cardoso.de.souza@tue.nl
www.tue.nl/combustion

Project Aim

Considering the range of turbulent scales that occur in situations involving turbulent premixed combustion and the interaction of these scales with the flame front, the goal of this project is to investigate the response of a flame front embedded in a turbulent flow where certain conditions referred as ‘resonant turbulence are occurring. It is expected that an increase on the flame surface density can be achieved when the flow is subject to these ‘resonant’ conditions.

Progress

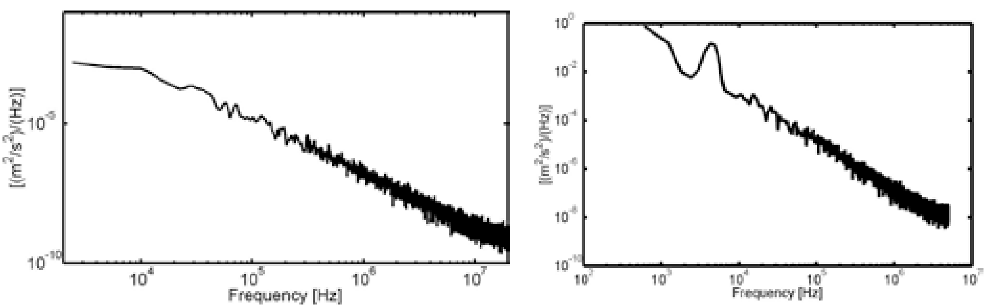
Currently, DNS simulations of resonant turbulence in premixed combustion are currently investigated considering a Bunsen flame subject to these forcing conditions. For such simulations, we use our in-house CFD code, which was also already applied in other situations associated with premixed combustion. The forcing is introduced at the inflow plane of our numerical grid using sinusoidal modes related with a given wave number and amplitude, then we characterize the flame response to these resonant flow by looking into the conversion rate and the effects of the turbulent scales in the flame structure, considering a situation with and without such flow perturbations.

Dissertations

-

Scientific Publications

1. Cardoso de Souza, T., Bastiaans, R.J.M., Geurts, B.J. & Goey, L.P.H. de (2012). DNS of large scale forcing in premixed Bunsen flames. Proceedings of the 9th International Ercoftac Symposium on Engineering Turbulence Modelling and Measurements (ETMM9), 6-8 June 2012, Thessaloniki, Greece.



Turbulent Kinetic energy spectrum: Left: spectrum obtained using random perturbations applied at the inflow plane to generate turbulence in the DNS simulations of the Bunsen flame. Right: Sinusoidal modes related with a certain length scale introduced jointly with the inflow random algorithm used to generate turbulence.

Numerical research of lean combustion in micro gas turbine

Project Aim

The aim of this project is to study the fluid and combustion in micro gas turbine to reduce NOx emission, improve combustion status and increase efficiency. Optimal injection location will be found to make air and gas mixed well and lean combustion in small scale combustor will be developed to achieve the low NOx emission of the value below 10 ppm.

Progress

Numerical methods (Fluent) are being explored to calculate the fluid status in the combustor to find optimal injection location which will reduce NOx emission.

Dissertations

-

Scientific Publications

-

Projectleaders

RJM Bastiaans, LPH de Goey

Researchtheme

Complex dynamics of fluids

Participants

Y Zhao, V Kornilov, RJM Bastiaans, LPH de Goey

Cooperations

-

Funded

China Scholarship Council (CSC)

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

Start of the project

2012

Information

Y Zhao
040 247 2877
Y.Zhao1@tue.nl
www.tue.nl/combustion

Crossing the combustion modes in diesel engines (XCiDE)

Projectleaders
LPH de Goey, LMT Somers, NJ Dam

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
U Egüz, CAJ Leermakers

Cooperations
DAF Trucks NV

Funded
STW, DAF, Delphi, Shell, Avantium

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

Start of the project
2009

Information
U Egüz
040 247 3286
u.eguz@tue.nl

C.A.J. Leermakers
040 247 2393
c.a.j.leermakers@tue.nl
www.tue.nl/combustion

Project Aim

The development of a well-established understanding of the processes occurring in the cylinder in different combustion regimes will be indispensable since new combustion concepts make diesel engines much more complex. The project aims to gain a better understanding of the new combustion concepts and develop numerical models that capture the complex combustion phenomena in these concepts. For the latter the FGM approach will be extended and applied in a CFD approach. To validate the models and even more to increase the fundamental knowledge of the new combustion concepts, high speed laser diagnostic techniques are developed. Application of these techniques to an optically accessible engine will help to understand and possibly explore new pathways for future engines and combustion concepts.

Progress

The FGM approach is implemented on an engine setup. The database for chemistry generation is created by homogeneous reactors and igniting counter-flow diffusion flamelets. The method is validated by comparing the ignition delay results with the experimental data. Many tests have been done on the metal engine, consisting of fuel tests with bio-derived oxygenates, low-reactive naphtha blends, and gasoline-diesel dual fuel combustion. Initial tests have been done for the high-speed visualization of minor combustion species and a start has been made with experiments on the optical engine.

Dissertations

-

Scientific Publications

1. Egüz, U., Ayyapureddi, S., Bekdemir, C., Somers, L.M.T. & Goey, L.P.H. de (2012). Modeling fuel spray auto-ignition using the FGM approach: effect of tabulation method. SAE Technical Papers 2012-01-0157.
2. Zhou, L., Boot, M.D., Luijten, C.C.M., Leermakers, C.A.J., Dam, N.J. & Goey, L.P.H. de (2012). Emission performance of lignin-derived cyclic oxygenates in a heavy-duty diesel engine. SAE Technical Papers 2012-01-1056.
3. Leermakers, C.A.J., Somers, L.M.T. & Johansson, B.H. (2012). Combustion phasing controllability with dual fuel injection timings. SAE Technical Papers, 2012-01-1575.
4. Wagemakers, A.M.L.M. & Leermakers, C.A.J. (2012). Review on the effects of dual-fuel operation, using diesel and gaseous fuels, on emissions and performance. SAE Technical Papers 2012-01-0869.
6. Bakker, P.C., Leermakers, C.A.J. & Johansson, B.H. (2012). Application of Partially Premixed Combustion using low octane fuels in a heavy duty engine. (pp. 34-35).
7. Corvers, M.M.H., Leermakers, C.A.J., Dam, N.J., Albrecht, B.A., Goey, L.P.H. de & Johansson, B.H. (2012). Development of optical diagnostics on Partially Premixed Combustion in a heavy-duty diesel engine. (pp. 36-37).
8. Leermakers, C.A.J., Somers, L.M.T. & Johansson, B.H. (2012). Combustion phasing controllability with dual fuel injection timings. (pp. 21-22).
9. Leermakers, C.A.J., Zegers, R.P.C., Somers, L.M.T., Dam, N.J., Johansson, B.H. & Goey, L.P.H. de (2012). Low Temperature Combustion Concepts: Full Metal and Optical Engine Experiments Compared.

10. Egüz, U., Ayyapureddi, S., Bekdemir, C., Somers L.M.T., & Goey, L.P.H. de (2012), ECN baseline n-heptane simulations with the FGM method.
11. Bakker, P.C. (2012). Application of partially premixed combustion using low octane fuels in a heavy duty engine. WVT No. 2012.11..
12 Wagemakers, A.M.L.M. (2012). Experimental study towards dual-fuel (gasoline-diesel) Reactivity Controlled Compression Ignition (RCCI) in a heavy duty diesel engine. No. WVT 2012.06.

Emission reduction in compression-ignition engines by fuel tuning

Projectleaders
LPH de Goey, NJ Dam, MD Boot

Researchtheme
Complex dynamics of fluids

Participants
L Zhou

Cooperations
Technical University of Munich,
Damark Technical University

Funded
TU/e, European Graduate School on Sustainable Energy

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

Start of the project
2009

Information
L Zhou
040 247 5995
L.Zhou@tue.nl
www.tue.nl/combustion

Project Aim

In order to adopt appropriate bio-fuels as alternatives of diesel for lower soot emission, this project is focused on the exploration of the mechanisms of soot formation by using advanced measurement methods by combining fundamental investigation and application research. The fundamental research is accomplished by a special designed High Pressure Vessel and Burner (HPVB) with an optical accessibility for laser diagnostic techniques. It provides capabilities of burning vaporized liquid fuels in laminar diffusion flames and research focuses on the impact of fuel molecular structures on the sooting tendencies of relevant fuels and bio-fuels. Besides, the HPVB setup is designed to allow measurements at elevated pressures. For the prospective of applications of relevant fuels in compression ignition engines, the research is focused on the effect of molecular structures on the soot-NOx emissions trade-off and corresponding engine performance. This is realized by means of experiments on a modified DAF heavy-duty diesel engine.

Progress

Soot volume fraction measurements in laminar diffusion flames of n-heptane from atmospheric to elevated pressure by Laser Induced Incandescence (LII) and Line-Of-Sight Attenuation (LOSA) have been finalized. Moreover, in order to evaluate the effect of molecular structures on the soot formation of laminar diffusion flames at elevated pressure, fuels with two kinds of molecular structures, straight line and cyclic, have been studied. Fuels in question here are from the non-oxygenates group: n-hexane and cyclohexane, and the oxygenates group: 1-hexanol and cyclohexanol. Using a particular designed “doped flame” system, sooting tendencies of laminar diffusion flames of these fuels blended in n-heptane at elevated pressure have been measured. In addition, the effect of the molecular structure of the bio-fuels on emission performance in a heavy-duty diesel engine, where the same group of the fuels which was studied in HPVB has been used. Then, as an extended research on bio-fuels from 2nd generation biomass, three lignin-derived aromatic oxygenates, including anisole, benzyl alcohol and 2-phenyl ethanol, have been presented, and the effect of the position of oxygen group to the aromatic ring on emission performance in a diesel engine has been investigated not only at one fixed engine operation points, but also on a wider engine operation range which is realized by (Exhaust Gas Recirculation) EGR sweeps and load sweeps.

Dissertations

-

Scientific Publications

1. ZHOU Lei, Boot, M.D. & Goey, L.P.H. de (2012). “The effect of the position of oxygen group to the aromatic ring to emission performance in a heavy-duty biodiesel engine”. SAE Int. J. Fuels Lubr. November 2012 5:1216-1239.
2. ZHOU Lei, Boot, M.D., Luijten, C.C.M., Leermakers, C.A.J., Dam, N.J. & Goey, L.P.H. de (2012). “Emission performance of lignin-derived cyclic oxygenates in a heavy-duty diesel engine”. SAE Technical Papers, 2012-01-1056.
3. ZHOU Lei, Dam, N.J. & Goey, L.P.H. de (2012). ‘Soot/PAHs Measurements in Laminar Diffusion Flames of Pre-vaporized Liquid Fuels”. Poster presented at the 34th International Symposium on Combustion, 29 July -3 August. 2012, Warsaw, Poland, (pp. W4P037). Warsaw. The Combustion Institute.

Developing comprehensive diesel combustion model for HDDI to predict heat release rate and emissions (mainly soot)

Project Aim

The prime aim of the current project is

- Enhance FGM methodology to model diesel engine combustion, in a way to reduce the cost and time involved in numerical simulations
- Accurate predictions of Ignition delay using counterflow diffusion flamelets
- Accounting pressure change, heatlosses using pressure and enthalpy as additional dimension in FGM
- Modeling diesel soot formation.

Progress

(1)CN Spray Modeling: The in-cylinder combustion process in engines is greatly influenced by the igniting characteristics of a single diesel spray. The auto ignition phenomenon in a conditioned constant volume combustion chamber has been modeled using FGM approach. A wide set of experimental data from Engine Combustion Network (ECN) at various ambient conditions of the chamber are used for model validation. Spray H and Spray A are the two target flames used with n-heptane and n-dodecane as diesel surrogate fuel, respectively.

(2)Engine Cycle Simulations: Engine cycle simulations performed with moving mesh in STAR-CD, by coupling FGM tables using subroutines. A priori study for enthalpy integration has been carried out to understand the various levels of enthalpy for both oxidizer and fuel during entire cycle. Pressure based FGM implemented and concluded that 5 pressure levels (between start of injection and peak cylinder pressure) are required to achieve converged ignition delay predictions for both Conventional and early injection timing. In order to account for the heat loss, enthalpy is used as additional dimension along with the pressure dependent FGM.

(3)Soot Modeling: With the recent norms on soot particle size along with the soot volume fraction, the detailed soot modelling is more focused to predict the size of soot accurately. In the current work, a soot model based on two (soot volume fraction, particle number density) equations is implemented and validated with equivalence-temperaure (φ-T) maps to evaluate the model at various φ-T conditions. The model results are validated with the published φ-T maps in literature.

Dissertations

-

Scientific Publications

1. Ayyapureddi, S., Egüz, U. , Bekdemir, C. , et al.,(2012). Application of the FGM method to Spray A conditions of the ECN database. ID1285, ICLASS 2012 (ISBN 978-88-903712-1-9), Heidelberg, Germany, September 2-6, 2012.
2. Egüz, U., Ayyapureddi, S., Bekdemir, C., Somers, L.M.T. & Goey, L.P.H. de (2012). Modeling fuel spray auto-ignition using the FGM approach : effect of tabulation method. SAE Technical Papers, 1-10.
3. U. Egüz, S. Ayyapureddi, C. Bekdemir, L.M.T. Somers, L.P.H.de Goey, Optimization of the FGM table resolution with Spray H cases. Submitted to Combustion Theory and Modeling, 2012.

Projectleaders
LMT Somers, LPH de Goey

Researchtheme
Complex dynamics of fluids

Participants
Sridhar Ayyapureddi

Cooperations
DAF Trucks Eindhoven, TNO

Funded

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

Start of the project
2009

Information

Sridhar Ayyapureddi
040 247 3731
s.ayyapureddi@tue.nl
www.tue.nl/combustion

Cracking diesel fuel chemistry

Projectleaders
LPH de Goey, LMT Somers

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
C Bekdemir, M Meijer

Cooperations
University of California, San Diego
Institut Français du Petrolé (IFPEN)

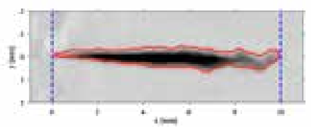
Funded
STW, DAF/PACCAR, Shell

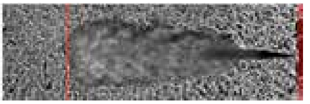
University	-
FOM	-
STW	90 %
NWO Other	-
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	-

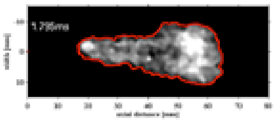
Start of the project
2008

Information
M Meijer
040 247 2877
m.meijer@tue.nl
www.tue.nl/combustion

ECN Diesel surogate fuel diagnostics from top to bottom:
(1) Liquid phase based on extinction.
(2) Gas and liquid phase basen on Schlieren.
(3) Spontanious OH emissions indicating the location of the flamefront.







Project Aim

Development, implementation and validation of a surrogate fuel concept for diesel engine combustion. The project combines both experimental and numerical work. The aim for the experimental part is to study surrogate fuels under engine relevant conditions in different fundamental set-ups with advanced optical diagnostics. The blend will be adapted such that both chemical and physical properties match the Diesel fuel as close as possible. The numerical work is performed by means of RaNS/LES and Flamelet Generated Manifold (FGM) based CFD in idealized and real engine conditions. Ultimately leading to a combined approach that can be applied to simulate fuel spray combustion and predict emission formation in engines, accurately and efficiently.

Progress

In modern diesel engines, spray formation and combustion are the main processes that challenge engineers. Several ways to model fuel sprays (flow and turbulence) exist starting using RaNS and LES approaches. The latter can be much more detailed in the sense that they resolve large eddies and therefore inherently introduce stronger in-homogeneity like observed in practice. The FGM method has been successfully implemented in the high-performance LES code AVBP. Results have been thoroughly validated against a n-heptane experiments available from the Engine Combustion Network. C. Bekdemir successfully defended his work in 2012 and obtained his degree with a Cum Laude. Since diesel fuel consists of many different hydrocarbon components it is a very complex fuel to model. Therefore surrogate fuels are of interest to use in realistic injection and combustion simulations and experiments. Experiments in a constant volume combustion chamber are executed in order to study the behaviour of n-heptane and n-dodecane fuel injections. Experiments are executed in close collaboration with the Engine Combustion Network (http://www.sandia.gov/ecn/). Where the aim is to minimize and clarify measurement uncertainties at well defined engine relevant conditions and to develop new measurement techniques suited for direct (CFD) modelling comparisons.

Dissertations

1. C. Bekdemir, Tabulated Chemical Kinetics for Efficient and Detailed Simulations of Diesel Engine Combustion, ISBN: 978-90-386-3255-1.

Scientific Publications

1. Egüz, U., Ayyapureddi, S., Bekdemir, C., Somers, L.M.T. & Goey, L.P.H. de (2012). Modeling fuel spray auto-ignition using the FGM approach : effect of tabulation method. SAE Technical Papers, 1-10 Meijer M., et al., 2013, Engine Combustion Network (ECN): Characterization and Comparison of Boundary Conditions for Different Combustion Vessels. Atomization and Sprays .
2. Meijer, M., et al., (2012). Engine combustion Network : “Spray A” basic measurements and advanced diagnostics. Proceedings of the 12th International Conference on Liquid Atomization and Spray Systems, ICLASS 2012, 2-6 September 2012, Heidelberg, Germany.

Project Aim

Conversely, in this PhD project we reverse engineer, from the engine's perspective, which compounds should ideally be added to conventional fossil fuels to arrive at a more favorable overall engine performance (i.e. in terms of fuel economy and emissions). Second, a production route from biomass should be developed to produce these desired compounds from biomass. This project builds further on existing knowledge that so-called cyclic oxygenates should be targeted, specifically from lignin, a renewable waste-stream available in large volumes in the paper industry.

Progress

Literature review on knock phenomenon and installation of Volvo test engine.

Dissertations

-

Scientific Publications

-

Projectleaders

LPH de Goey, MD Boot

Researchtheme

Complex dynamics of fluids

Participants

M Tian

Cooperations

-

Funded

CSC Chinese scholarship

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

Start of the project

2012

Information

MD Boot
M.D. Boot@tue.nl
www.tue.nl/combustion

Fuel(s)(spray) characterization and optimization for new engine combustion concepts

Projectleaders
CCM Luijten

Researchtheme
Complex dynamics of fluids

Participants
CCM Luijten, MD Boot, L Zhou, CAJ Leermakers, PJM Frijters

Cooperations
DAF Trucks NV, Lund University, Sweden, Radboud University of Nijmegen, Vialle Alternative Fuel Systems

Funded

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

Start of the project
2005

Information
CCM Luijten
040 247 5347
C.C.M.Luijten@tue.nl
Carlo.Luijten@asml.com
www.tue.nl/combustion

Project Aim

This project aims to make a cross-coupling between developments in fuels and engines. An important new engine combustion concept is PCCI: premixed charge compression ignition. PCCI, however, also puts new requirements to fuel formulation. With interest in alternative fuels booming, this offers a great opportunity for joint developments in engines and fuels. By studying “new” fuels in a variety of test setups (including a diffusion burner, a high pressure cell for spray studies and several engines), a broad spectrum of combustion data is gathered. These experimental data also enable verification of numerical simulations.

Progress

In 2012, a measurement campaign addressing fuel low cetane number fuels on the Cyclops engine was continued (effectively a one-cylinder test engine, driven by another 3-cylinder bank on the same engine; yet, the test-cylinder has fully decoupled fuel and air systems). This work led to 2 publications that were finalized in 2012 (one to be published in 2013). In the related area of fuel spray characterization, work on alternative FIE (fuel injection equipment) was continued, specifically investigations on a fuel injector with a porous tip (instead of the more conventional arrangement with multiple small holes). Such injectors currently experience lifetime problems, which was addressed in another SAE publication. Finally, a related project was finished in 2012 with the PhD defense of ir. P.J.M. Frijters.

Dissertations

1. Frijters, P.J.M. (2012, October 2). Fuel composition impact on heavy duty diesel engine combustion & emissions. TUE : Technische Universiteit Eindhoven (189 pag.) (Eindhoven: Technische Universiteit Eindhoven). Prom./coprom.: prof. dr.ir. R.S.G. Baert, dr.ir. L.M.T. Somers & dr.ir. C.C.M. Luijten.

Scientific Publications

1. Zhou, L., Boot, M.D., Luijten, C.C.M., Leermakers, C.A.J., Dam, N.J. & Goey, L.P.H. de (2012). Emission performance of lignin-derived cyclic oxygenates in a heavy-duty diesel engine. SAE Technical Papers,2012-01-1056.
2. Maes, N., Reijnders, J.J.E., Boot, M.D., Luijten, C.C.M., Goey, L.P.H. de & Dhaenens, M. (2012). Spray and Failure Analysis of Porous Injection Nozzles. SAE Technical Papers, 2012-01-1654.

Development and application of a laminar coflow burner to study combustion of modern automotive (bio-)fuels at high pressure, using advanced laser diagnostics

Project Aim

This project attempts to build a bridge between laminar flames and the much more complex and demanding environment found in practical combustion engines. This was accomplished by designing and constructing a High Pressure Vessel and Burner (HPVB) and integrating these with an evaporation system. This setup enables study of automotive (bio-) fuels, applying advanced optical diagnostics techniques. The latter are assessed in cooperation with the Lund Institute of Technology, shedding light on the applicability of these methods in sooty environments at high pressure.

Progress

The first half of 2012 was used for writing the PhD thesis. The experimental measurements and data analysis carried out with the HPVB setup had already been finalized in 2011. Laser diagnostic techniques were applied to characterize flames of gaseous fuels, doped with very small amounts (± 2000 ppm) of liquid compounds, and flames of vaporized liquid fuels. The data obtained with the doped flames approach was used by modelers involved in Computational Fluid Dynamics (CFD) at TU/e resulting in an article which was accepted for presentation at the International Combustion Symposium (2012, paper published in 2013). In May 2012, the project was finished with the PhD defense of Marcelo de Andrade Oliveira MSc. Early 2013 the last paper resulting from his PhD research was conditionally accepted (pending language revision) for publication in Fuel.

Dissertations

1. Andrade Oliveira, M.H. de (2012, May 8). Development and application of a laminar coflow burner for combustion studies at high pressure. TUE : Technische Universiteit Eindhoven (141 pag.) (Eindhoven: Technische Universiteit Eindhoven). Prom./coprom.: prof.dr. L.P.H. de Goey, prof. L.E.M. Aldén & dr.ir. C.C.M. Luijten.

Scientific Publications

-

Projectleaders

CCM Luijten, LPH de Goey, M Aldén

Researchtheme

Complex dynamics of fluids

Participants

MH de Andrade Oliveira

Cooperations

Lund Institute of Technology (Sweden)

Funded

TU/e, EU (Large Scale Facility at Lund University, optical diagnostic measurements)

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

Start of the project

2007

Information

MH de Andrade Oliveira
040 247 5995
M.H.Oliveira@tue.nl
www.tue.nl/combustion

Towards clean diesel engine combustion : PCCI spray combustion in high pressure cell)

Projectleaders
LPH de Goey

Researchtheme
Complex dynamics of fluids

Participants
M Yu, RPC Zegers, NJ Dam,
CCM Luijten

Cooperations
Lund University, Radbout University Nijmegen, DAF, Shell global solutions, Wärtsilä, TNO

Funded
STW

University	-
FOM	-
STW	85 %
NWO Other	-
Industry	15 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2007

Information
Miao Yu
040 247 5995
m.yu@tue.nl
www.tue.nl/combustion

Project Aim

Premixed charge compression ignition (PCCI) is a promising combustion strategy for engines, since it enables to realize very low soot and nitric oxide emissions while maintaining high fuel efficiency.

To obtain a more detailed understanding of the PCCI combustion process, we aim to investigate a limit set of fuel spray mixing/reacting events. The objectives include:

- Characterization of the temperature field prior to fuel injection (using thermographic phosphor)
- Characterization of the temperature field during/after injection (using toluene LIF)
- Build an experimental database for numerical models.

Progress

In November 2012, the sub project on PCCI Spray combustion in the Eindhoven High Pressure Cell (EHPC) was succesfully finished with the defense of Miao Yu, MSc. The temperature field in the EHPC prior to fuel injection has been studied using thermographic phosphors. It was the first time that this method was succesfully deployed in the gas phase. The temperature field during spray injection has been studied using toluene-LIF (laser induced fluorescence), in a joint effort with ir. R.P.C. Zegers, who studied the same technique for application in an optical engine. An assessment of the toluene-LIF method and first results were the subject of a second paper. Both papers were submitted for publication in Applied Physics B: lasers and optics, and have in the meantime been accepted for publication.

Dissertations

1. Yu, M. (2012, November 19). Two dimensional gas temperature measurements of fuel sprays in a high pressure cell. TUE : Technische Universiteit Eindhoven (125 pag.) (Eindhoven: Technische Universiteit Eindhoven). Prom./coprom.: prof.dr. L.P.H. de Goey, dr.ir. C.C.M. Luijten & dr. N.J. Dam.

Scientific Publications

-

Towards clean diesel engine combustion : characterization of PCCI combustion and mixture stratification in an optically accessible engine

Project Aim

Premixed charge compression ignition (PCCI) is a promising combustion strategy for engines, since it enables to realize very low soot and nitric oxide emissions while maintaining high fuel efficiency. To achieve PCCI combustion with limited heat release rates, the influence of charge stratification on combustion was investigated. The mixing process is investigated by measuring in-cylinder velocities during fuel injection using high speed particle image velocimetry (HS-PIV). In-cylinder temperatures are measured using Toluene Laser induced fluorescence. PCCI combustion has been further studied by determining flame position versus ignition delay using high speed OH chemiluminescence.

Progress

In 2012, the results of this project were finalized and described in the PhD thesis of ir. R.P.C. Zegers, which he defended in August. All experiments were already finished in the course of 2011. The HS-PIV results during injection of fuel were published in Experiments in fluids. The work on toluene LIF was published in Applied Physics B: lasers and optics, combining the results with those of the sub-project of M. Yu, who used the same method for temperature characterization of fuel sprays in a high pressure cell.

Dissertations

1. Zegers, R.P.C. (2012, August 28). Unraveling advanced compression ignition combustion using optical diagnostics. TUE : Technische Universiteit Eindhoven (122 pag.) (Eindhoven: Technische Universiteit Eindhoven). Prom./coprom.: prof.dr. L.P.H. de Goey, dr.ir. C.C.M. Luijten & dr. N.J. Dam.

Scientific Publications

1. Zegers, R.P.C., Luijten, C.C.M., Dam, N.J. & Goey, L.P.H. de (2012). Pre- and post-injection flow characterization in a heavy-duty diesel engine using high-speed PIV. Experiments in Fluids, 53(3), 731-746.
2. Zegers, R., Aussems, J., Somers, L., Dam, N.J., Luijten, C.C.M., Goey, L.P.H. de (2012). Correlating Flame Location and Ignition Delay in Partially Premixed Combustion, SAE Technical Paper 2012-01-1579.

Projectleaders

LPH de Goey

Researchtheme

Complex dynamics of fluids

Participants

RPC Zegers, M Yu, NJ Dam, CCM Luijten

Cooperations

Radboud University Nijmegen
DAF, Shell global solutions, Wärtsilä, TNO

Funded

STW

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

Start of the project

2007

Information

RPC Zegers
040 247 2393
r.p.c.zegers@tue.nl
www.tue.nl/combustion

Flameballs, cells and cusps in ultra-lean hythane-air mixtures

Projectleaders
RJM Bastiaans

Researchtheme
Complex dynamics of fluids

Participants
RJM Bastiaans, LPH de Goey, Y Shoshin, F Hernandez Perez, J van Oijen, B Oostenrijk, A Manteghi, N Dam, A Sepman

Cooperations
STW

Funded
STW

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

Start of the project
2011

Information
Y Shoshin
040 247 5689
Y.S.Shoshin@tue.nl
www.tue.nl/combustion

Project Aim

Hydrogen-containing blends exhibit a very specific combustion behavior. Due to the high diffusivity of hydrogen, flames are strongly affected by so-called preferential diffusion effects The project is aimed on acquiring deep knowledge on the mentioned effects. To meet this goal a detailed experimental study using (ultra) lean two-dimensional laminar stationary flames of hydrogen-methane air mixtures is being carried out. The experiments are setup to model all key structural elements of cellular flames: 1. Flame cells; 2. Flame balls (in ultra-lean mixtures); 3. Flame cusps separating the cells. In addition, hydrogen-methane-air flames stabilization mechanisms are being studied. To this end, novel Flameball burner and multi-slot cooled 2-D Bunsen burner are designed and built. Extensive quantitative spatially resolved laser diagnostics for measuring concentrations of reacting species will be employed.

Progress

Raman scattering measurements for main species and temperature detailed distributions for normal gravity flame balls and for ultra-lean 2D flames of hydrogen-methane-air mixtures. 2. Numerical simulations of normal gravity flameballs have been performed and selected chemical/transport models tested by comparison with the experimental results. 3. The TLAF optical setup has been modified to perform measurement in the signal saturation regime, increasing thereby the method sensitivity and reducing the error. 4. Influence of preferential diffusion effects on behavior of lean inverted flames studied experimentally and by numerical simulations. Mechanism of the influence of mixture Lewis number of the flame stabilization/blow-off parameters suggested.

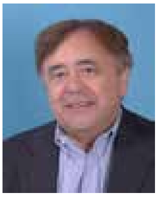
Dissertations

-

Scientific Publications

-

Process Technology



Prof.dr.ir. JJH Brouwers

Prof.dr. M Golombok

The programme of the group covers theoretical, numerical and experimental research on selected subjects in process technology. The subjects range from fundamentals to applications. The aims are to contribute to scientific issues relevant to the field, to develop tools for applying scientific results on practical cases and to design machinery and apparatus using these results.

Many research activities are carried out in co-operation with and with support from industry.

The subjects of research are:

1. Stochastic processes and turbulence

The stochastic process of turbulence is a key issue in process technology, since fluid flow in process apparatus is generally turbulent and predicting flow quantities is a central issue in their design. A theory has been developed for stochastic turbulence, which involves asymptotically exact solution methods and reveals the truncation errors. The theory has been validated by means of direct numerical simulation. Concerning numerical research, faster and more efficient numerical methods for DNS and LES models for particle-laden turbulent flow are being developed. Experimental research into inhomogeneous turbulence at intermediate and high Reynolds number is carried out by means of 3D-PTV in turbulent pipe flow.

2. Phase-transitional flow

Fluid flow in which a phase change occurs is of considerable importance in process technology. The research is focused on boiling, (dropwise) condensation and sublimation. The research is generic, aiming at results that are applicable in numerical methods and for the design of unit operations. As examples, the dependencies of drag and lift force coefficients on acceleration of bubbles and particles have been studied and the effect of the velocity field caused by condensation directly downstream of the inlet of a confined steam jet on self-similarity has been investigated. Current research focuses on inertia-dominated interaction of flow and bubbles or particles and on basic mechanisms of condensation and sublimation. The approach followed is analytical, experimental and numerical.

3. Development of new process technology

The insights gained in the first two topics are applied to new concepts of process technology, mainly in the area of rotational equipment, separation apparatus and heat and mass exchangers. These projects are carried out in close cooperation with industry and comprise the design, manufacturing and testing of new equipment. Centrifugal phase separation offers excellent opportunities for innovation. The group has a strong position in this field by the patented concept of rotational particle separation. A new development is the design where rotation is generated by swirl of the flow itself, which is particularly suited at high fluid pressures and receives much interest from the oil industry. A new in-house born idea is the wall-de-sublimator, which avoids the formation of aerosols by de-sublimating vapors on cooled surfaces of narrow-channeled heat exchangers. A relatively new means of ship propulsion is based on waterjets driven by pumps. The group studies the effects of non-uniform intake flow on performance and forces of the pump. A project on the development of a numerical method for unsteady flow in rotating machinery just started.

Statistical analysis of turbulent two-phase pipe flow by means of experiments

Project Aim

The aim of this research is to determine the statistical properties of inhomogeneous turbulence at intermediate and high Reynolds numbers, the effect of particles with inertia on these properties and the effects of flow orientation with respect to gravity and state of development of the flow.

Progress

In 2012, a paper and the thesis of Jorge Goes have been written. The analysis of particle laden flow is focused on the effect of turbulence on drag and lift in two regions of pipe flow. Different particle concentrations were measured in upflow and downflow of nearly neutrally buoyant solid particles.

Dissertations

1. J.L. Goes Oliveira, 3D-PTV of particle-laden turbulent pipe flow, PhD Thesis Eindhoven University of Technology.

Scientific Publications

-

Projectleaders

CWM van der Geld, JGM Kuerten

Researchtheme

Complex dynamics of fluids

Participants

JL Goes Oliveira, CWM van der Geld, JGM Kuerten

Cooperations

-

Funded

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

Start of the project

2003

Information

CWM van der Geld
040 247 2923
c.w.m.v.d.geld@tue.nl
www.wtb.tue.nl/woc/ptc

Large-eddy simulation of particle-laden flows

Projectleaders
JGM Kuerten

Researchtheme
Complex dynamics of fluids

Participants
W Michalek, JGM Kuerten

Cooperations
Prof. dr. A. Soldati, Dr. C. Marchioli, University of Udine, Italy, Prof. dr. B.J. Geurts, UT, Dr. J Pozorski, Polish Academy of Sciences, Gdansk.

Funded
STW, TU/e, DEISA

University	15 %
FOM	-
STW	85 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2003

Information
JGM Kuerten
040 247 2362
j.g.m.kuerten@tue.nl
www.wtb.tue.nl/woc/ptc

Project Aim

The aim of this project is the study of dispersion of non-passive particles in turbulent non-isothermal channel flow by means of DNS and LES. Especially models for subgrid contributions in case LES is used for the fluid flow are developed and tested, both for particle velocity and particle temperature.

Progress

Dispersion of non-passive particles in turbulent non-isothermal channel flow is studied by means of DNS and LES. A model for the subgrid contribution in the particle equation of motion has been developed and shows a substantial improvement in the statistical results of LES. For larger Reynolds numbers a combination of a stochastic model and the deterministic model based on approximate deconvolution mentioned above has been proposed and tested. The stochastic model is based on a priori results from DNS.

Dissertations

-

Scientific Publications

1. B.J. Geurts, J.G.M. Kuerten, Ideal stochastic forcing for the motion of particles in large-eddy simulation extracted from direct numerical simulation of turbulent channel flow, Phys. Fluids, 24, 081702, (2012).

BiOxyFuel: Torrefied biomass combustion under oxy-fuel conditions in coal-fired power plants

Project Aim

In this project interaction between different kinds of particles and between particles and flow will be studied in which the properties of the particles, such as size, shape, temperature and chemical composition change in time because of combustion and flow of the surrounding gas. Particles will be treated as point particles, but detailed numerical simulations will be carried out to obtain correlations for the forces on a particle.

Progress

An existing DNS code for Lagrangian simulations of point particles has been extended with equations for temperature and species concentration. Two-way coupling between gas and particle temperature has been incorporated.
In 2012 simulations of droplet-laden turbulent channel flow with evaporation and condensation have been performed for several cases. A compressible DNS code has been developed with particles and two-way coupling in which the particles represent biomass particles and undergo pyrolysis. The effect of varying particle mass load on the pyrolysis time has been studied.

Dissertations

-

Scientific Publications

-

Projectleaders

JGM Kuerten

Researchtheme

Complex dynamics of fluids

Participants

E Russo, JGM Kuerten, CWM van der Geld

Cooperations

JA van Oijen, Y Haseli (TU/e)
EM Gucho, G Brem, BJ Geurts (UT)

Funded

STW

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

Start of the project

2010

Information

JGM Kuerten
040 247 2362
j.g.m.kuerten@tue.nl
www.wtb.tue.nl/woc/ptc

Effects of cross-section variation and bubble-bubble interaction on bubble detachment in convective flow

Projectleaders
CWM van der Geld, JGM Kuerten

Researchtheme
Complex dynamics of fluids

Participants
C Baltis, J Desmarais, CWM van der Geld, JGM Kuerten

Cooperations
DAF, Spirotech B.V.

Funded
STW

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

Start of the project
2010

Information
CWM van der Geld
040 247 2923
c.w.m.v.d.geld@tue.nl
www.wtb.tue.nl/woc/ptc

Project Aim

The effect of flow on boiling bubble detachment from a heated plane wall is investigated for the effects mentioned in the title. Experiments serve to validate a model based on the diffuse interface method that will be further developed.

Progress

In 2012 a start has been made with the development of a multi-scale method for phase-transitional flow in which the small scales are modeled by the diffuse interface model. To this end open boundary conditions for this model have been developed based on extensions of the characteristic method and the method of perfectly matched layers. In 2012 a new measuring technique of instantaneous temperature fields in liquid, based on the use of phosphoric tracers, has been further developed and a paper has been written about it.
A new test section with multiple bubble generators at artificial sites has been commissioned. The electric conditioning has been further developed with modern electric components. The analyzing technique of axisymmetric bubbles has been published in 2012.

Dissertations

-

Scientific Publications

1. Geld, C.W.M. van der, Colin, C., Segers, Q.I.E., Pereira da Rosa, V.H., & Yoshikawa, H.N., 2012, Forces on a boiling bubble in a developing boundary layer, in microgravity with g-jitter and in terrestrial conditions. Physics of Fluids, 24 (8), 082104-1/29.

Bio-STIPS

Project Aim

The aim of this research is to develop a model for the calculation of the thickness of deposition that results after evaporation of a solvent from a droplet and of the distribution of (bio)molecules on/in the substrate.

Progress

Models for individual processes of evaporation, spreading and sorption of a microscopic drop on a porous or non-porous substrate have been further developed. The methods have been combined and validation with experimental results and results based on numerical simulation of the full Navier-Stokes equation has been performed. The model has been extended for convection and diffusion of the dissolved phase to allow for vertical concentration dependence and with a model for binding of solute molecules to the substrate and to the pore walls of the porous substrate.

Dissertations

1. Daniel Siregar, Numerical Simulation of Evaporation amd Absorption of Inkjet Printed Droplets, PhD Thesis, Eindhoven University of Technology.

Scientific Publications

1. J.G.M. Kuerten, D. Siregar, Drying of inkjet-printed droplets, in Inkjet-based Micromanufacturing; Editors: J.G. Korvink, P.J. Smith, D.-Y. Shin, Wiley-VCH, 97-110 (2012).

Projectleaders

JGM Kuerten

Researchtheme

Complex dynamics of fluids

Participants

DP Siregar, CWM van der Geld, JGM Kuerten

Cooperations

WUR, Philips Research. Océ

Funded

STW

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

Start of the project

2008

Information

JGM Kuerten
040 247 2362
j.g.m.kuerten@tue.nl
www.wtb.tue.nl/woc/ptc

Energy Technology

Prof.dr.ir. D Smeulders

Prof.dr.ir. AA van Steenhoven

Prof.dr. A Dietzel

Prof.dr. H Zondag

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

Control of transitional flow Titel

Project Aim

Bypass transition of a boundary layer takes place at high mainstream turbulence levels. It is governed by the intrusion of non-linear disturbances into the viscous sublayer. This study aims at understanding the nature of the transition process and the control of the transition process.

Progress

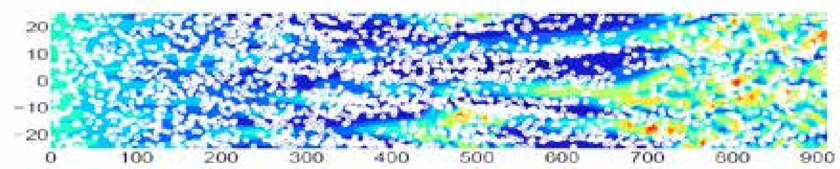
Flows laden with hard, spherical particles have been considered as control of transitional channel flow. Numerical analysis of a channel flow has been performed using both modal and non-modal analysis for heavy and light particles to investigate the initial stages to transition using a two-fluid model. Another aspect we investigated is the effect of heavy particles during the total transition in channel flow until turbulence is reached. This is done using a pseudo-spectral code (developed by M. Chevalier at KTH) with two-way coupled Lagrangian particles. The results confirm the transient growth from the non-modal analysis and they also show that particles delay turbulence, when the particle mass fraction is large enough. The same numerical code is also used to investigate particle clustering in a transitional boundary layer, except that the particles are one-way coupled. An instantaneous flow field is shown in the figure below. This is a result from a LES-simulation. To improve the accuracy, a PRACE project started to do the same analysis with Direct Numerical Simulations and a large domain. For the inclusion of light particles, where particle volume is more important, a coupled Euler-Lagrangian code (developed by WP Breugem at TU Delft) is used. We found that particles migrate laterally in a channel flow towards an equilibrium position. This position shifts towards the wall, when the interparticle spacing is smaller: when particle-particle interactions become important. Next to the numerical efforts, experiments in a water channel are performed. A boundary layer develops along a flat plate and we investigate the onset and development of this boundary layer both with and without particles. Particular interest is given to the positioning, whether particles have a preferential position. These results will be combined with those from numerical studies.

Dissertations

-

Scientific Publications

1. Klinkenberg, J., Lange, H.C. de, Brandt, L. Sardina, G.. Transition delay in particle-laden channel flow. EFMC9 conference, September 2012, Rome.
2. Klinkenberg, J., Breugem, W.P., Lange, H.C. de, Brandt, L . Particle equilibrium in 3D-channel flow for one and two particles. APS, division of Fluid Dynamics conference, November 2012, San Diego.



Instantaneous streamwise velocity field in bypass transition of a one-way coupled particle-suspended flow at wall-parallel plane y=1. White dots represent the particle positions (top view)

Projectleaders

HC de Lange, AA van Steenhoven

Researchtheme

Complex dynamics of fluids

Participants

J Klinkenberg, PR Bloemen

Cooperations

L Brandt, D Henningson and P Schlatter, KTH Stockholm, Sweden. WP Breugem, TU Delft

Funded

TU/e, KTH

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

Start of the project

2000

Information

HC de Lange
040 247 2129
h.c.d.lange@tue.nl
www.energy.tue.nl

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

Projectleaders
MFM Speetjens, HJH Clercx (AP-TU/e), AA van Steenhoven

Researchtheme
Complex structures of fluids

Participants
EA Demissie

Cooperations
O Baskan (PhD candidate of companion project at Dept. Applied Phys., TU/e), G. Metcalfe, CSIRO-MMT, elbourne, Australia, F. Posthuma-Scholtes, Primix BV, Mijdrecht, B. Ohlmeier, DSM Research, Geleen
W. Maas, Mecal NV, Veldhoven
A. Reusken, Dept. Mathematics, RWTH, Aachen, Germany.

Funded
STW-11054, (two companion PhD-Projects at TU/e; one at Dept. Mech. Eng,, one at Dept. Applied. Phys.)

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

Start of the project
2011

Information
MFM Speetjens
040 247 5428
m.f.m.speetjens@tue.nl
www.energy.tue.nl

Project Aim

Heat transfer admits representation in terms of the “motion of a “fluid.” This fundamental change in thermal modelling enables thermal analysis in terms of the thermal trajectories (thermal counterpart to fluid trajectories) by well-established – and very successful – methods from mixing studies. This Lagrangian mixing analysis of heat transfer offers promising new thermofluids-engineering capabilities beyond those of conventional Eulerian approaches based on e.g. temperature fields. Aim of the study is further development of this concept for practical utilisation by way of representative industrial heat exchangers based on the static-mixing principle.

Progress

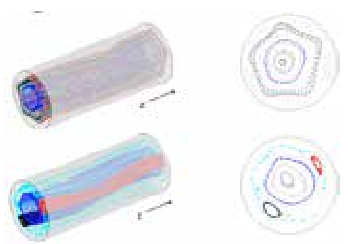
The computational toolbox for simulation of 3D Lagrangian coherent structures (LCSs) in flow fields has been extended by a volume-preserving integration algorithm. This proved essential to reliably determine LCSs. This extended toolbox has been tested on a number of analytical case studies and is currently being employed for simulation and analysis of 3D LCSs and their role in the transport properties of the Rotated Arc Mixer (RAM), a representative industrial heat-exchanger/mixer. Subjects of investigation are the role of the flow transition between consecutive mixer segments and fluid inertia on these LCS.

Dissertations

-

Scientific Publications

1. Speetjens, M.F.M. (2012). A generalised Lagrangian formalism for thermal analysis of laminar convective heat transfer. International Journal of Thermal Sciences, 61, 79-93.
2. Gorodetskyi, O., Speetjens, M.F.M. & Anderson, P.D. (2012). An efficient approach for eigenmode analysis of transient distributive mixing by the mapping method. Physics of Fluids, 24(5), 053602-1/16.
3. Metcalfe, G., Speetjens, M.F.M., Lester, D.R. & Clercx, H.J.H. (2012). Beyond passive : chaotic transport in stirred fluids. Advances in Applied Mechanics, 45, 109-188.
4. Znaien, J.G., Speetjens, M.F.M., Trieling, R.R. & Clercx, H.J.H. (2012). On the observability of periodic lines in 3D lid-driven cylindrical cavity flows. Physical Review E, 85(6), 066320-1/14.
5. Speetjens, M.F.M. (2012). A Lagrangian formalism for thermal analysis of laminar convective heat transfer. Proceedings of the 6th Termal Sciences Conference (Eurotherm 2012), 4-9 September 2012, Poitiers, France, (Journal of Physics: Conference Series). IOP.
6. Giessen, E. van der, Aref, H., Clercx, H.J.H. & Speetjens, M.F.M. (Eds.). (2012). Advances in applied mechanics. San Diego: Academic Press, 264 pp.



Bifurcation in 3D Lagrangian flow structure induced by fluid inertia (Re): (a) one familiy of concentric streamtubes for Re=10; (b) multiple families of streamtubes for Re=100. Shown are 3D streamlines (left) and the corresponding cross-sections with the inlet (right). Colours indicate individualstreamlines.

PROJECT AIM

Condensation of water is important for cloud formation in meteorological and climate models. Condensation of carbondioxide is important in industrial applications such as natural gas cleaning and CO2 sequestration. This study aims to experimentally investigate homogeneous nucleation of water and carbondioxide in an expansion wave tube.

PROGRESS

A horizontal expansion wave tube was installed which can be used for the optical detection of microscopically small condensate droplets. A 532 nm laser line-of-sight attenuation (LOSA) measurement is combined with 90 degrees constant angle Mie scattering (CAMS) to measure the concentration and growth of a cloud of condensate droplets over time. The condensation process is triggered by a rapid decrease of pressure and temperature in the setup where typical temperatures of 240 K are reached. This process is controlled by the pressure-time profile which can be selected to obtain a monodisperse cloud of droplets of identical size. It was shown that water nucleation in air and nitrogen is not significantly depending on carrier gas, but that the condensation rates are orders of magnitude above predictions by classical nucleation theory, which confirms findings from other publications on different gas-vapor mixtures.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Fransen, M., Sachteleben, E.,Hruby, J., Smeulders, D. (2012). Pulse-expansion wave tube for measuring nucleation and droplet growth. Proceedings of the 20th Int. Shock Interaction Symp., Stockholm 20-24 August 2012, pp. 27-30.
2. Fransen, M.A.L.J., Hruby, J., Smeulders, D.M.J. (2012). Nucleation and droplet growth measured by a pulse-expansion wave tube. European Aerosol Conference Handbook, Granada, 2-7 September 2012, p116.

PROJECTLEADERS

DJM Smeulders

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

M Fransen, E. Sachteleben, PR Bloemen, GJ Hoek, H van Griensven

COOPERATIONS

MEH van Dongen, TU/e, H Hruby, Prague

FUNDED

TU/e, Twister BV

University	95 %
FOM	-
STW	-
NWO Other	-
Industry	5 %
TNO	-
GTI	-
EU	-
Scholarships	-

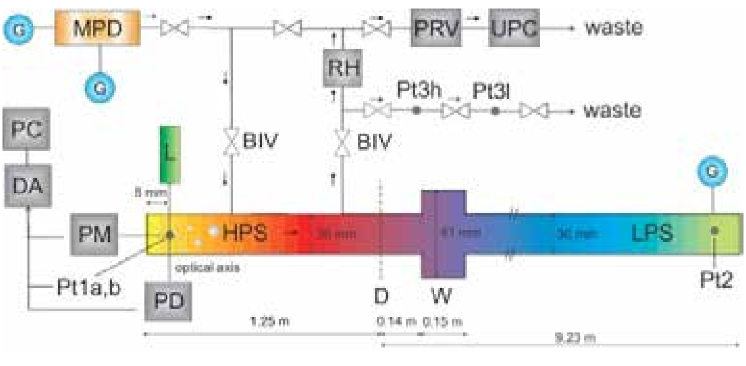
START OF THE PROJECT

2011

INFORMATION

M Fransen
040 247 2816
m.a.l.j.fransen@tue.nl

D Smeulders
040 247 3167
d.m.j.smeulders@tue.nl.



Schematic picture of the expansion wave tube. Condensate is formed in the high-pressure section (HPS). The laser (L) signal is attenuated/scattered and measured by photodetector PD and photomultiplier PM. Pressure decrease is initiated by the rupture of the diaphragm that separates the HPS from the low-pressure section LPS, and profiled by the local widening section W. The gas mixture is preconditioned in the mixture preparation device MPD. Additional valves and pressure sensors are also shown.

Fracture evaluation using shock-induced borehole waves

Projectleaders
DJM Smeulders

Researchtheme
Complex dynamics of fluids

Participants
H Fan, J Etienne, HKJ Heller

Cooperations
TU Delft

Funded
TU Delft, China Research Council

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

Start of the project
2008

Information
H Fan
h.fan@tudelft.nl

D Smeulders
040 247 3167
d.m.j.smeulders@tue.nl

Project Aim

The dispersive properties of surface acoustic waves propagating along poroelastic media and fractures are studied experimentally and theoretically. Fractured formations strongly affect the wave propagation. These effects are studied in a shock tube set-up, where surface waves are generated by means of shock impact.

Progress

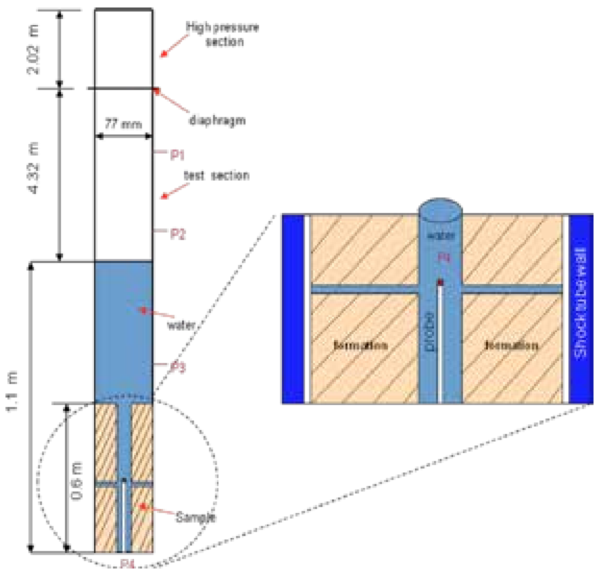
Theoretical and experimental investigations in boreholes surrounded by poroelastic formations give information of fractures around the borehole. These effects will be studied in this project by means of a shock tube facility. A logging probe will be installed in the borehole to measure the pressure profiles. Fluid wave regimes inside the fracture are taken into account to compute the attenuation and reflection at the fracture region of the Stoneley wave in the borehole. Full wave theory predicts the same results as simplified dynamic Darcy flow, for small fracture widths. Our shock tube setup generates borehole Stoneley waves that are used for fracture characterization. Experiments on PVC samples with one single horizontal fracture show that varying fracture widths significantly alter the recorded Stoneley wave pressure signal at fixed depth. The technique is easily extensible to fractured porous samples for hydrocarbon reservoir applications.

Dissertations

-

Scientific Publications

1. Fan, H., D.M.J. Smeulders (2012): Shock-induced borehole waves and fracture effects. Transport in Porous Media. 93, 263–270.
2. Fan, H., D.M.J. Smeulders (2012): Fracture evaluation using shock-induced borehole waves. 28th International Symposium on Shock Waves. 805-810.



Schematic of the experimental shock tube facility. The fractured test cylinder is placed in the bottom section of the tube and wave impact is recorded by the pressure probe

PROJECT AIM

Key issues in cutting-edge technologies (e.g. micro-electronics, lithographic systems) are massive heat removal and thermal homogenisation. Boiling heat transfer affords solutions to both issues and will play a central role in next-generation thermal-management schemes. However, to this end better control of the boiling process is essential. The study takes a first step towards this aim by the model-based development of control strategies for regu-lation of boiling under dynamic operating conditions in a representative 3D boiling system.

PROGRESS

The numerical-theoretical studies on dynamics and control of the pool-boiling system reported earlier have been finalized. Furthermore, first exploratory experiments on application of pool boiling for thermal management of battery packs in electric vehicles (EVs) have been performed. This demonstrated that pool boiling has great potential for thermal homogenization and rapid cooling of battery packs. Furthermore, a first proof of principle of regulation of the system via the pressure was given. This revealed that, remarkably, the boiling process allows significantly faster control (an essential advantage for EVapplications)compared to conventional thermal-management systems based on e.g. air or liquid cooling. The project has been concluded successfully with a PhD-defense in November 2012. Realization of a follow-up project is in progress.

DISSERTATIONS

1. Gils, R.W. van (2012). Feedback stabilisation of pool-boiling systems : for application in thermal management schemes. Eindhoven: Technische Universiteit Eindhoven. ((Co-) promot.: Speetjens, M.F.M., Nijmeijer, H. & Zwart, H.J.).

SCIENTIFIC PUBLICATIONS

1. Gils, R.W. van, Speetjens, M.F.M., Zwart, H.J. & Nijmeijer, H. (2012). Feedback stabilisation of a two-dimensional pool-boiling system by modal control. International Journal of Thermal Sciences, 61, 38-49.

PROJECTLEADERS

MFM Speetjens, H Nijmeijer

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

RW van Gils

COOPERATIONS

H. Zwart, Applied Mathematics, Dept. Electrical Engineering, Mathematics and Computer Science, University of Twente

P.H.L. Notten, Energy Materials and Devices, Dept. Electrical Engineering, TU/e

FUNDED

TU/e-W until May 2010; HTAS Range-Extender Innovations as of May 2010

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

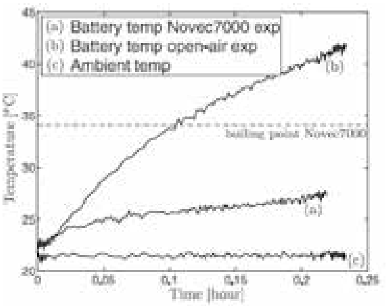
START OF THE PROJECT

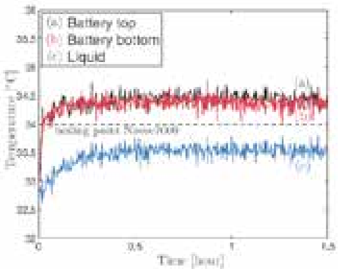
2008

INFORMATION

MFM Speetjens
040 247 5428
m.f.m.speetjens@tue.nl
www.energy.tue.nl

Proof-of-principle experiments on thermal management of battery packs in EVs by pool boiling using NOVEC-7000: (a) laboratory set-up; (b) temperature evolution for conventional air/liquid cooling; (c) temperature evolution for boiling heat transfer.





Integrated micro-fluidic cooling in laminated flexible micro-systems

Projectleaders
AJH Frijns, AA van Steenhoven

Researchtheme
Complex dynamics of fluids

Participants
G Gürsel

Cooperations
Holst Centre, IMEC, Philips

Funded
STW

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

Start of the project
2001

Information
A Frijns
040 247 4825
a.j.h.frijns@tue.nl
www.energy.tue.nl

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 in a laminated flexible micro-system.

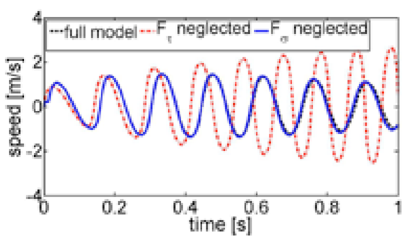
Progress
Numerical method is developed to understand the working principles of Pulsating Heat Pipes. Results of this study reveal that as the diameter is decreased the oscillatory motion comes to an end due to the increased effect of shear stress. However, with enough heat flux periodic oscillatory motion can be achieved even at very small diameters. Further studies will be conducted to investigate the effect of frequency and dynamic contact angle.

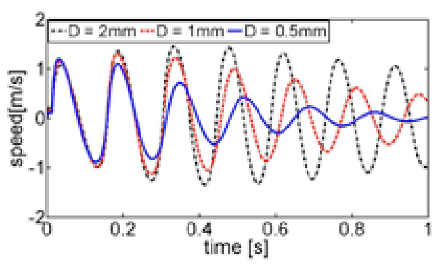
Dissertations
-

Scientific Publications

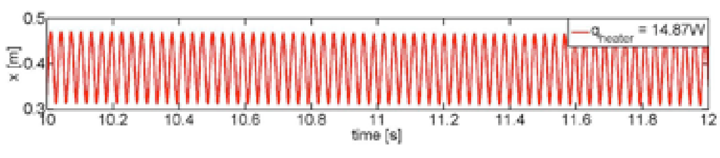
1. Gürsel, G., Frijns, A.J.H., Homburg, F.G.A. & Steenhoven, A. A. van (2012). Analysis of the onset of the oscillation motion in a pulsating heat pipe. Proceedings of the 3rd European Conference on Microfluidics, December 3-5 2012, Heidelberg, Germany.
2. Kalteh, M., Abbassi, A., Saffar-Avval, M., Frijns, A.J.H., Darhuber, A.A. & Harting, J.D.R. (2012). Experimental and numerical investigation of nanofluid forced convection inside a wide microchannel heat sink. Applied Thermal Engineering, 36(april), 260-268.

Left, the effect of shear stress (Fτ) and capillary (Fσ) forces on oscillation. Right, effect of diameter on oscillation





Displacement of the interface at high heat flux



Project Aim

The heat transfer in (laminar) micro-flows depends essentially on the topology of the Lagrangian fluid paths. Aim of the study is to investigate the fundamental connection between heat transfer and flow topology and to explore its potential with regard to control and optimisation of heat transfer in micro-flows.

Progress

Experimental studies on the 3D flow structure of a micro-flow driven by way of AC electro-osmosis (ACEO) have been continued. Goal was further experimental characterization of the 3D velocity field and flow structure and its comparison with numerical simulations. To this end 3D flow measurements using 3D micro-Particle-Tracking Velocimetry (3DμPTV) have been performed. This exposed electrode-wise symmetric pairs of 3D vortical structures and corresponding quasi-2D primary circulations that are in good qualitative agreement with numerical observations. More detailed (quantitative) investigations are in progress.

Dissertations

-

Scientific Publications

1. Liu, Z., Speetjens, M.F.M., Frijns, A.J.H. & Steenhoven, A.A. van (2012). Heat-transfer enhancement in AC electro-osmotic micro-flows, Proc. 6th Thermal Sciences Conference (Eurotherm, Poitiers, France, 2012), Journal of Physics : Conference Series, 395, pp. 012094.
2. Liu, Z., Speetjens, M.F.M., Frijns, A.J.H. & Steenhoven, A.A. van (2012). Experimental and numerical observations on vortical structures in 3D AC electro-osmotic flows. Proceedings of the 3rd European Conference on Microfluidics (Microfluidics 2012), 3-5 December 2012, Heidelberg, Germany, (pp. FLU12-80-1/12).

Projectleaders
MFM Speetjens, AJH Frijns, AA van Steenhoven

Researchtheme
Complex structures of fluids

Participants
Z Liu, PR Bloemen

Cooperations
C Cierpka, Universität der Bundeswehr, München, Germany

Funded
TU/e-W

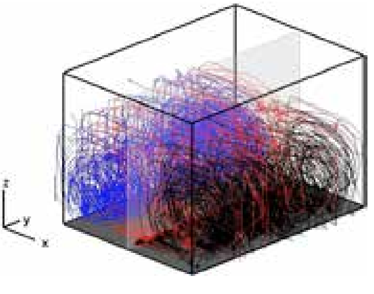
University	100 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2007

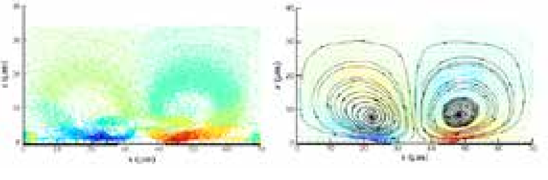
Information

M Speetjens
040 247 5428
m.f.m.speetjens@tue.nl
www.energy.tue.nl

Vortical structure of a 3D ACEO micro-flow measured by 3DμPTV:3D trajectories visualizing electrode-wise symmetric pairs of 3D vortices (black vs. blue; red indicates trajectories crossing the symmetry plane).



Quasi-2D primary circulation measured by 3DμPTV: (a) raw velocity data); (b) field interpolated on a regular grid including streamlines (colours indicate magnitude).

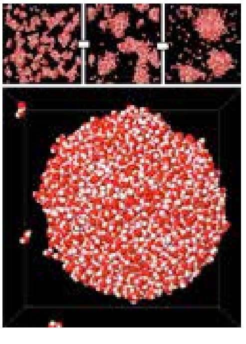


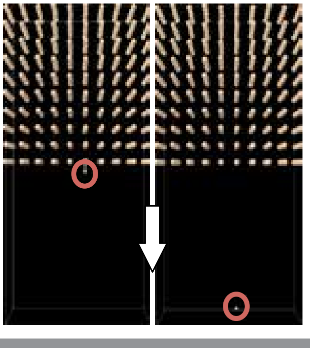
Microchannel cooling

Projectleaders
AJH Frijns, AA van Steenhoven
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
JH Kim, SV Gaastra-Nedea
Cooperations
J Reese, Y. Zhang, University of Stratchclyde, UK, M West, INFICON, Liechtenstein
Funded
GASMEMS (Marie-Curie, FP7)

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

Start of the project
2009
Information
A Frijns
040 247 4825
a.j.h.frijns@tue.nl
www.energy.tue.nl





Project Aim

There is a tendency that mechanical and electrical component become smaller and smaller. Since most components produce heat when operating, local, enhanced microchannel cooling becomes essential in order to ensure its performance and to ensure the life span of such a micro-component. Macroscopic models for heat transfer are not sufficient to describe the cooling mechanisms on this scale anymore. 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

Interaction between water and Silicon/Silica are very often present in many applications from the semiconductor industry. To accurately simulate these interactions on larger scale, tabulated models for the interactions between these molecules have been developed. Firstly, a new model for water was developed by tabulated potential using ReaxFF including hydrogen bonding energy. Water model was optimized in order to match the experimental results of diffusion coefficient and density. Secondly, a new implicit potential wall model has been developed by tabulating the ReaxFF potential between bulk wall molecules and one water atom. Silicon and Silica were modeled by using this method. Contact angle simulations were performed in order to optimize the potentials by configuring the energy well depth.

Dissertations

-

Scientific Publications

1. Kim, J., Frijns, A.J.H., Gaastra - Nedea, S.V. & Steenhoven, A.A. van (2012). Pressure calculations in nanochannel gas flows. 1st European Conference on Gas Micro Flows (GasMems 2012), (362). Bristol: IOP Science.
2. Kim, J., Frijns, A.J.H., Gaastra - Nedea, S.V. & Steenhoven, A.A. van (2012). Effects of expansion flow in nanochannels. Proceedings of the 3rd European Conference on Microfluidics (Microfluidics 2012), 3-5 December 2012, Heidelberg, Germany, (pp. FLU12-182-1/10).
3. Kim, J., Frijns, A.J.H., Gaastra - Nedea, S.V. & Steenhoven, A.A. van (2012). The effects of geometry and Knudsen numbers on micro- and nanochannel flows. Proceedings of the Ninth International Conference on Nanochannels, Microchannels, and Minichannels (ICNMM 2011), June 19-22, 2011, Edmonton, Canada, (pp. 1-8). ASME.
4. Akker, E.A.T. van den, Frijns, A.J.H., Kunkelmann, C., Hilbers, P.A.J., Stephan, P. & Steenhoven, A.A. van (2012). Molecular dynamics simulation of the microregion. International Journal of Thermal Sciences, 59, 21-28.
5. Frijns, A.J.H., Valougeorgis, D., Colin, S. & Baldas, L. (Eds.). (2012). Proceedings 1st European Conference on Gas Micro Flows (GasMems 2012). Bristol: IOP Science.

MD simulation of new water model to calculate liquid density of a water droplet (above), a development of tabulated potential for silicon wall and water atom interaction (below).

Biochip design for algae monitoring

Project Aim

The identification of algae species is useful and important for monitoring water quality and conditions for health and environmental applications. This project aims to develop a chip-based approach to identifying and classifying algae species in water in real-time, using microfluidics with integrated optical and/or other sensors. We use a femtosecond laser to create microchannels and optical waveguides in fused silica, to create integrated optofluidic microdevices on a single substrate.

Progress

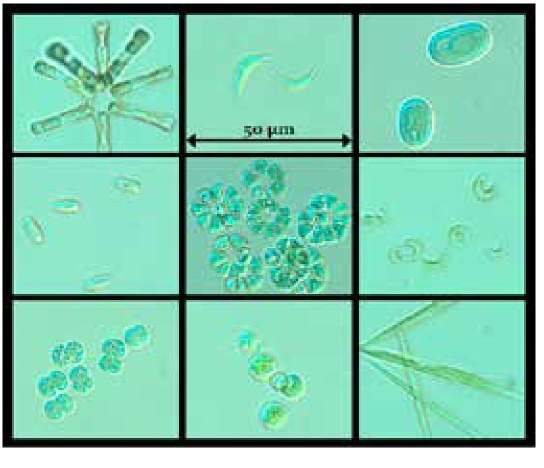
After demonstrating that our current system can successfully identify the species of individual algae in a mixture of a few species, we've been working in two directions. First, to better understand the relevant optical properties of the algae and the meaning of the signals we obtain from our sensing system, we are developing optical models of the algae and the optofluidic system. Secondly, we're simultaneously designing the next-generation system, and exploring how the unique fabrication facilities we have available can be exploited for a novel and yet simple, robust system for identifying algae in real-time. We've also written a few papers: one on the design of and results from the first prototype, one exploring the results obtained by using different pattern recognition techniques, and a literature review on the use of algae in lab-on-a-chip devices.

Dissertations

-

Scientific Publications

1. A. Schaap, T. Rohrlack, and Y. Bellouard, "Lab on a chip technologies for algae detection: a review," Journal of Biophotonics, 5(8–9), 661–672, 2012.
2. A. Schaap, T. Rohrlack, and Y. Bellouard, "Optical classification of algae species with a glass lab-on-a-chip," Lab on a Chip, 12(8), 1527–1532.
3. A. Schaap, T. Rohrlack, and Y. Bellouard, "Optofluidic microdevice for algae classification: a comparison of results from discriminant analysis and neural network pattern recognition," in Proceedings of SPIE, 8251, 2012.



Projectleaders

Y Bellouard, AH Dietzel

Researchtheme

Complex structures of fluids

Participants

A Schaap

Cooperations

Norwegian Water Research Institute

Funded

Eindhoven University of Technology, Dept. Mechanical Engineering, EC Project "Femtoprint" (FP7)

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

Start of the project

2010

Information

Y Bellouard
040 247 3715
y.bellouard@tue.nl
www.energy.tue.nl

Molecular dynamics study on sugar alcohol based phase change materials

Projectleaders
SV Nedea, CCM Rindt,
AA van Steenhoven, D Smeulders

Researchtheme
Complex dynamics of fluids

Participants
H Zhang

Cooperations
-

Funded

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

Start of the project
2012

Information
S Nedea
040 247 5410
silvia@win.tue.nl

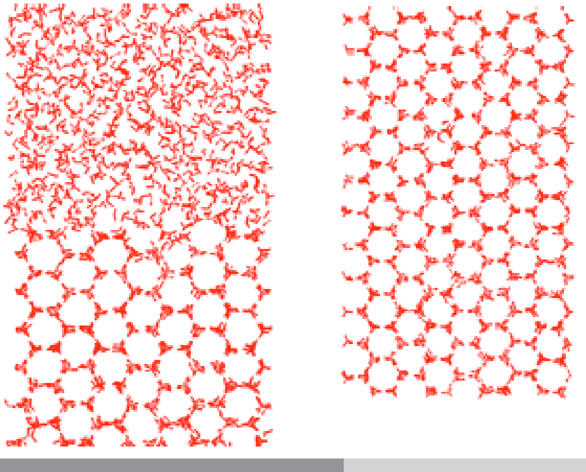
C Rindt
040 247 2978
C.C.M.Rindt@tue.nl
www.energy.tue.nl

Project Aim
This study focuses on the thermodynamics and kinetics of the nucleation and crystallization processes of molecular-alloy-based sugar alcohols (MASA), and derived carbon-MASA and encapsulated MASAs by molecular dynamics (MD) simulations. The nucleation mechanism of these materials is directly linked to their thermal performances in thermal energy storage applications. Several representative sugar alcohols (xylitol, erithritol, manitol, etc.) will be studied to explore their nucleation kinetics and associated heat and mass transfer processes. This will help to categorize MASAs based on their storage efficiency, heat power and recycling behavior. Order parameters will be extracted from the newly developed models, to scale up the calculations in both space and time, and eventually provide guidance to reactor (heat exchanger) design. The figure below shows a crystallization simulation of liquid water into hexagonal ice at 230K and 1.0 bar. The crystal/melt interface is located in the middle in the beginning of the simulation, and grows when interfacial liquid molecules crystallize. This simulation serves as a validation to future sugar alcohol studies.

Progress
Generalized AMBER force field has been selected to perform MD simulations. The coordinates of several representative sugar alcohols are generated from selected neutron diffraction data. Topologies are generated according to the force field. The TIP4P-2005 water model is used to validate the methodologies. Viscosity, heat conductivity calculations are performed based on non-equilibrium simulations. A test case simulation of crystallization is conducted with water, and the snapshots are shown in the figure above. Methodologies of studying nucleation and crystallization by MD simulations are systematically investigated, and will be implemented in near future.

Dissertations
-

Scientific Publications
1. Goga, N., Rzepiela, A., Melo, M.N., Vries, A.H. de, Hadar, A., Markvoort, A.J., Gaastra - Nedea, S.V. & Berendsen, H. (2012). Methods for multiscale modeling of membranes. In Iglic, A. (Ed.), Advances in planar lipid bilayers and liposomes, (pp. 139-170). Amsterdam: Elsevier.



Initial(a) and final(b) configuration of simulated crystallization of water at 230K, 1.0bar

Molecular simulations to study the compact heat storage materials

Project Aim

This study focuses on the dynamics of hydration and dehydration reactions of salt hydrates (MgSO4.7H2O, MgCl2.xH2O etc) from a molecular point of view. The project aims to identify the molecular and structural parameters which limit the kinetics and usability of salt hydrates as thermochemical heat storage materials. This study will help to classify such materials based on their storage efficiency, usability, kinetics, reusability etc. This information can be used to identify the best suitable material for thermochemical heat storage.

Progress

Molecular and crystalline structures of MgSO4 hydrates have been refined using Quantum Chemical (DFT) methods. Presence of an extensive network of hydrogen bonds in the structures seem to be influencing the kinetics of hydration and dehydration reactions. Thus, the meta-stability of sulfate based hydrates can be attributed to these strong hydrogen bonds. A reactive molecular dynamics force-field is developed using a newly developed application of Metropolis Monte-Carlo algorithm with simulated annealing. DFT data such as optimized geometries, equations of states, binding energy etc were used for parameterizing the force-field. The force-field appeared to reproduce the characteristics of the complicated potential energy surface of magnesium sulfate-water system. Simulation results show evidences for the decomposition of water molecules during the dehydration process. It also reproduces the famous Topley-Smith effect in the dehydration simulations of MgSO4. More simulations are being performed to investigate the details of molecular and structure changes during hydration and dehydration reactions.

Dissertations

-

Scientific Publications

1. Iype, E., Gaastra - Nedea, S.V., Rindt, C.C.M., Steenhoven, A.A. van, Zondag, H.A. & Jansen, A.P.J. (2012). DFT study on characterization of hydrogen bonds in the hydrates of MgSO4. Journal of Physical Chemistry C, 116(35), 18584-18590.
2. Iype, E., Arlemark, E., Gaastra - Nedea, S.V., Rindt, C.C.M. & Zondag, H.A. (2012). Molecular dynamics simulation of heat transfer through a water layer between two platinum slabs. 6th European Thermal Sciences Conference (Eurotherm 2012), Poitiers, France, (Journal of Physics : Conference Series, 395, pp. 012111). IOP Publishing.
3. Iype, E., Ozen, C., Gaastra - Nedea, S.V., Rindt, C.C.M. & Zondag, H.A. 2012). Quantum chemical analysis of the structures of MgSO4 hydrates. Proceedings of the 12th International conference on Energy Storage (Innostock 2012), 16-18 May 2012, Lleida, Spain.

Projectleaders

CCM Rindt, SV Nedea, AA van Steenhoven

Researchtheme

Complex dynamics of fluids

Participants

Eldhose Iype

Cooperations

Dr. Markus Huetter (Asso. Prof. Department of Mechanical Engineering, TU/e)

Funded

European Graduate School

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

Start of the project

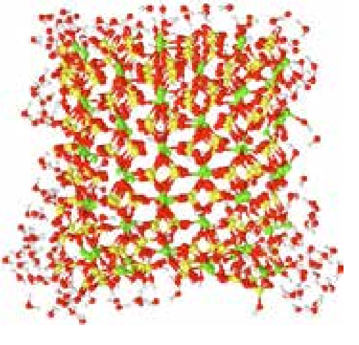
2009

Information

C Rindt
040 247 2978
C.C.M.Rindt@tue.nl

S Nedea
040 247 5410
silvia@win.tue.nl
www.energy.tue.nl

A snapshot of molecular dynamic simulation of MgSO4 and water system



Development of micro- and meso-scale models for thermo-chemical heat storage materials

Projectleaders
CCM Rindt, H.A Zondag, AA van Steenhoven

Researchtheme
Complex dynamics of fluids

Participants
Shuiquan Lan

Cooperations
ECN (Energy research Center of the Netherlands)

Funded
ADEM Innovation Lab Program

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

Start of the project
2011

Information
Camilo Rindt
040 247 2978
C.C.M.Rindt@tue.nl
www.energy.tue.nl

Project Aim

For the purpose of the development of solid sorption materials, micro- and meso-scale models will be developed for the hydration and dehydration processes taking place in powdery samples. These processes are a combination of heat and vapor transport in the grains constituting the powdery sample and in the voids between the grains of the powdery sample. A complication in the modeling is that due to the hydration and dehydration processes the macro- and micro- mechanical and transport properties will change.

Progress

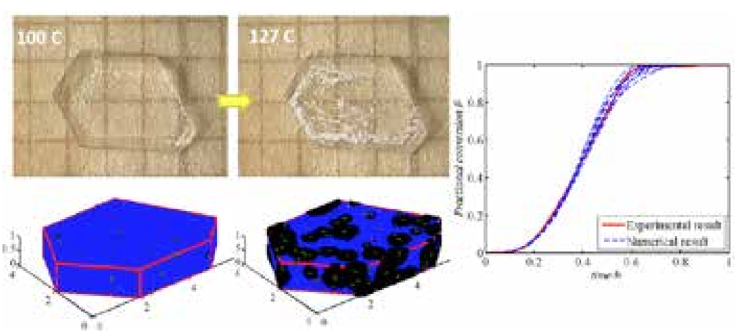
In order to develop a grain model for the hydration and dehydration processes, reaction kineitcs of solid-state reactions is studied. It is found in experiments that nucleation and nucli growth models could be the best candidate for our task. Thus, the Mampel model describing surface nucleation and nuclei growth processes is investigated both analytically and numerically. A stochastic approach is implemented in a Matlab code and validated by analytical solutions of grains with different geometries. Based on the observation from experiments, see Figure 1 (left), essential parameters including nucleation rate and growth rate are quantified and reaction kinetics (fractional conversion) is calculated. As shown in Figure 1 (right), a good agreement between experimental and numerical results is achieved. Moreover, several flow and heat simulations in OpenFOAM are practiced.

Dissertations

1. Sathyanarayanarao Subbarao, K.K. (2012). Particulate fouling of dry and liquid coated surfaces. Eindhoven: Technische Universiteit Eindhoven. ((Co-)promot.: Steenhoven, A.A. van & Rindt, C.C.M.).

Scientific Publications

1. Beek, T.J.J. van, Rindt, C.C.M. & Zondag, H.A. (2012). Performance analysis of an atmospheric packed bed thermo-chemical heat storage system. Proceedings of the 12th International conference on Energy Storage (Innostock 2012), 16-18 May 2012, Lleida, Spain.



Evolution of dehydration of $Li_2SO_4 \cdot H_2O$ crystal both from experiment and simulation (left) and comparison of the total fractional conversion (right)

Characterization of the water vapor sorption process in salt hydrates used as thermochemical materials for seasonal heat storage

Project Aim

A promising concept for seasonal heat storage in residential environment is based on the reversible water vapor sorption process into crystalline salt hydrates. In order to develop an adequate sorption material, identification and a control of the parameters influencing the heat and vapor transport in the material and the kinetics of reaction during the sorption process are required. It could be established during the first year of the project that two parameters influence the sorption process: the material properties of the salt hydrates and the operational conditions imposed by the storage system design (figure 1). Therefore, an experimental investigation was carried out to understand and control the kinetics of the process and the material stability of the salt hydrates under operating conditions of seasonal heat storage.

Progress

The two salt hydrates MgSO4.7H2O and MgCl2.6H2O, selected prior to this study for their high theoretical energy densities, showed promising performances under operating conditions of seasonal heat storage. MgSO4.7H2O can reach a storage density in packed bed around 1 GJ/m3 during the charging phase of the material. However, the slow kinetics of reactions of the material under the operating conditions showed a low heat release during the heat discharge. MgCl2.6H2O can store and release heat with fast kinetics of reaction at adequate operating temperatures with a storage density around 0.8 GJ/m3. However, the material presents some issues for a long term chemical stability. Presently, a modification of the material properties of these two salt hydrates and an adjustment of the operating conditions are carried out to improve their long term storage capacity.

Dissertations

-

Scientific Publications

1. Ferchaud, C., Zondag, H.A., Boer, R. de & Rindt, C.C.M. (2012). Characterization of the sorption process in thermochemical materials for seasonal solar heat storage application. Proceedings of the 12th International conference on Energy Storage (Innostock 2012), 16-18 May 2012, Lleida, Spain
2. Ferchaud CJ , Zondag HA , Veldhuis JBJ and de Boer R (2012). Study of the reversible water vapour sorption process of MgSO4 center dot 7H(2)O and MgCl2 center dot 6H(2)O under the conditions of seasonal solar heat storage 6th European Thermal Sciences Conference (Eurotherm 2012), Poitiers, France. Journal of Physics: Conference Series 395 (2012) 012069.
3. Ferchaud CJ , Zondag HA ,Rubino A ,de Boer R , Proceedings 450 of the 6th Heat Powered Cycle conference, HPC 2012, 10-12 September 2012, Alkmaar, NL

Projectleaders
HA Zondag, CCM Rindt

Researchtheme
Complex dynamics of fluids

Participants
CJ (Claire) Ferchaud

Cooperations
ECN (Energy research Centre of the Netherland)

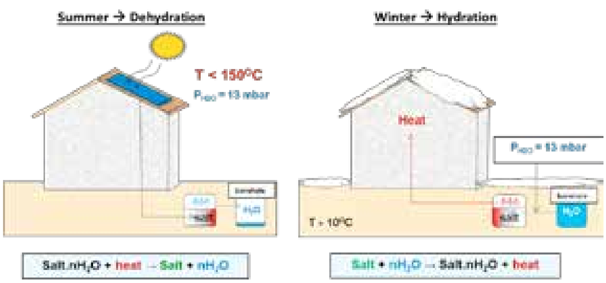
Funded
ADEM Innovation Lab Program

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

Start of the project
2010

Information
H Zondag
0224 564941
zondag@ecn.nl

040 247 2719
h.a.zondag@tue.nl
www.energy.tue.nl



Gas sensor membrane

Projectleaders
AJH Frijns, R Mandamparambil, AH Dietzel

Researchtheme
Complex structures of fluids

Participants
S van Pelt

Cooperations
Holst Centre

Funded
CATRENE / PASTEUR

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

Start of the project
2009

Information
S van Pelt
040 247 2186
s.v.pelt@tue.nl
www.energy.tue.nl

Project Aim

The PASTEUR project aims to build a disposable tag for food monitoring. Our work focusses on a membrane that will be used to enhance the functionality of the micro-scale gas sensors. The membrane will block solid particles and droplets and remove them from the sensor surface while still allowing the target gas to be transported to the sensor. Additionally it will enhance both the sensitivity and selectivity of the sensor using a perm-selective membrane in combination with a pumping system.

Progress

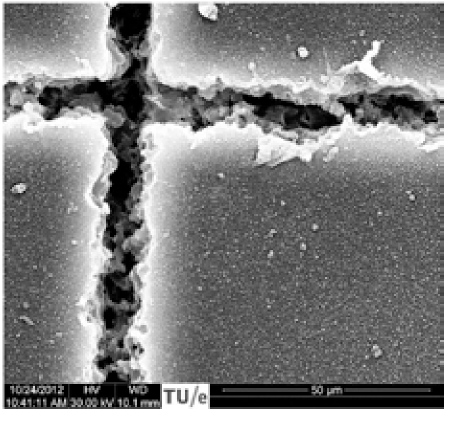
The membrane was patterned using excimer laser ablation. The ablation redeposits create a roughness on nano- and micro-scale that causes the membrane to become super-hydrophobic. Permeation experiments were carried out to characterize the created membranes. Also a new system was designed and simulated to use a perm-selective membrane to locally increase the concentration of the target gas. It is composed of several cascaded membranes and pumps. After each stage, the concentration of the target gas is increased depending on the perm-selectivity of the membrane material.

Dissertations

-

Scientific Publications

1. Pelt, S. van, Eggermont, J., Frijns, A.J.H. & Dietzel, A.H. (2012). Patterning of super-hydrophobic structures on permeable sensor membranes.Proceedings of the 3rd European Conference on Microfluidics (Microfluidics 2012), 3-5 December 2012, Heidelberg, Germany, (pp. FLU12-121-1/9).



Droplets on patterned membrane and SEM image of the pattern.

Humidity harvesting using water vapor selective membranes

Project Aim

Design and optimize a wind driven humidity harvesting device with the use of water-vapor selective membranes. For this purpose a thermodynamic model has to be built by which the optimal design can be determined as well as the linking of this design to the already existing components. A lab scale model should serve to validate the thermodynamic model and design choices which should eventually be up scaled to a demo- and a full scale system.

Progress

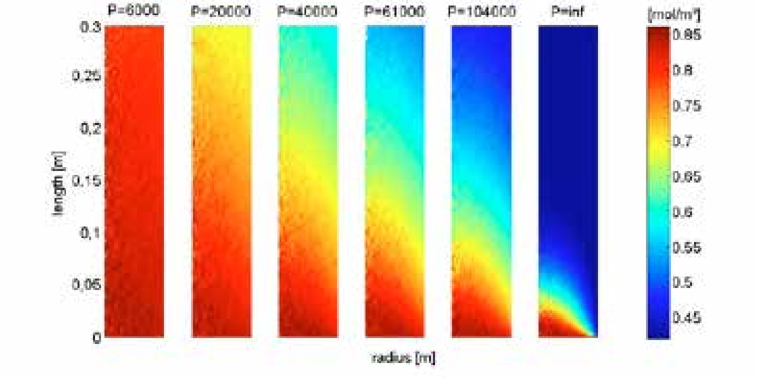
A simulation model for the movement of a diluted gas (water vapor) in a hollow fiber membrane was further developed. The routine based on the statistical representation of numerous molecules by simulation particles (Statistical Particle Displacement Model) allows for the prediction of the water vapor concentration distribution within, and the permeation out of a fiber (see figure). The result was compared to commercial CFD software and submitted to the CMES journal. Furthermore the water vapor transport towards the condenser on the permeate side for various input parameters was analyzed. One of the options more closely considered was working with different permeate-side pressures while maintaining the driving force across the membrane via a recirculation stream. To validate these considerations an experimental setup has been built, and different selective coatings for membrane modules are tried.

Dissertations

-

Scientific Publications

1. Bergmair, D; Metz, S J; Lange, H C de; Steenhoven, A.A. van (2012). Modeling of a water vapor selective membrane unit to increase the energy efficiency of humidity harvesting. 6th European Thermal Sciences Conference (Eurotherm 2012), Poitiers, France. Journal of Physics: Conference Series 395 (2012) 012161.



Water vapor concentration in hollow fiber membranes with various permeabilities (P in Barrer)

Projectleaders

HC de Lange, AA van Steenhoven

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

D Bergmair, H Ouwerkerk

Cooperations

Wetsus, Center of Excellence for sustainable water technology

Funded

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

Start of the project

2011

Information

R de Lange
040 2472129
h.c.d.lange@tue.nl
www.energy.tue.nl

Heat transfer in the human body

Projectleaders
AJH Frijns, AA van Steenhoven

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
BRM Kingma, C Jacquot, WD van Marken Lichtenbelt

Cooperations
University of Maastricht, University Hospital Maastricht, dept. Building Science TU/e

Funded
Agentschap NL

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

Start of the project
1999

Information
A Frijns
040 247 4825
a.j.h.frijns@tue.nl
www.energy.tue.nl

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 model will be used for medical applications and for the prediction of thermal comfort in the built environment.

Progress

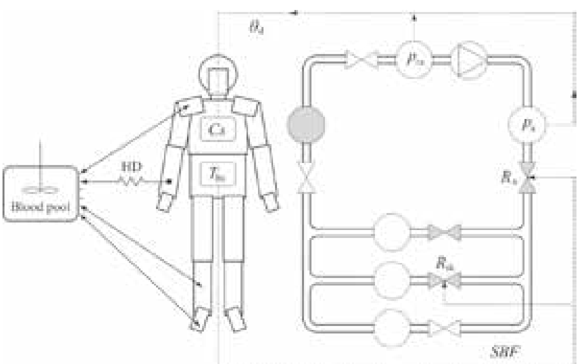
Our thermo-physiological model ThermoSEM is further improved by the introduction of a neurological based thermoregulation model. The new model outcomes are compared with experiments on volunteers. Good agreement is shown for blood flow, and for skin and core temperatures for young adults as well as for elderly. This thermo-physiological model was also used to predict the thermal responses to (changes in) the indoor climate. It was extended such that the thermal sensation can be predicted as well. Simulations and measurements showed a good agreement. Furthermore, the model is extended with a cardio-vascular module such that blood pressure can be predicted as well. It is successfully applied to model blood pressure changes during haemodialysis.

Dissertations

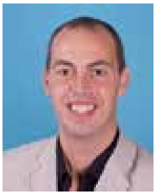
1. Kingma, B.R.M. (2012). Human thermoregulation : a synergy between physiology and mathematical modelling. Maastricht: Universitaire Pers Maastricht.((Co-)promot.: Saris, W.H.M., Steenhoven, A.A. van, Marken Lichtenbelt, W. van, Frijns, A.J.H.).

Scientific Publications

1. Droog, R.P.J., Kingma, B.R.M., Marken Lichtenbelt, W. van, Kooman, J.P., Sande, F.M. van der, Levin, N.W., Steenhoven, A.A. van & Frijns, A.J.H. (2012). Mathematical modelling of thermal and circulatory effects during hemodialysis. Artificial Organs, 36(9), 797-811.
2. Kingma, B.R.M., Frijns, A.J.H. & Marken Lichtenbelt, W. van (2012). The thermoneutral zone: implications for metabolic studies. Frontiers in Bioscience, E4, 1975-1985.
3. Kingma, B.R.M., Jacquot, C., Aa, A. van der, Steg, L., Frijns, A.J.H., Haas, F. de & Marken Lichtenbelt, W. van (2012). Energy efficient living - INTEWON: From measuring to modelling to managing. Proceedings of 7th Windsor Conference: The changing context of comfort in an unpredictable world Cumberland Lodge, Windsor, London.



Model for hypotension during hemodialyses



Prof.dr.ir. EH van Brummelen

The Multiscale Engineering Fluid Dynamics section of the Mechanical Engineering Department at TU Eindhoven has been established in 2009 within the framework of the 3TU Centre of Excellence for Multiscale Phenomena. The MEFD section focuses on the development, analysis and application of mathematical-physical models and advanced numerical techniques for multiscale flow problems in engineering applications, with particular emphasis on interface and free-boundary problems, flow problems in the transitional molecular/continuum regime and auxiliary field interactions, such as fluid-structure interaction. The research in the section has en underpinning and methodological character, while maintaining a strong connection to applications in the high-tech industry and in other sections at TU/e.

Goal-adaptive moment-closure approximations of the Boltzmann equation

Project Aim

Develop, analyze and implement a finite-element methodology in which the hierarchical rank of the moment-closure system and the computational mesh are adapted to generate optimal approximations to functionals of solutions of the Boltzmann equation (BE). This aim engenders 3 main objectives:

1. formulation of a suitable hierarchy of moment-closure systems, which facilitates implementation in a finite-element method, while retaining the fundamental properties of the underlying BE
2. development and implementation of a finite-element formulation for the moment-closure systems
3. development of a-posteriori error estimates and implementation of an adaptive refinement strategy.

Progress

Moment-closure systems based on approximations of the entropy minimizing (maximizing) distribution using an even-order Taylor-series approximation to the exponential were investigated. The even-order of the Taylor series approximation ensures that the distribution remains positive. The moment-closure formulation leads to a well-posed hierarchy of hyperbolic systems of partial-differential equations. The results convey that in this manner, it is possible to construct moment-closure systems that retain the desirable properties of Levermore's moment-closure systems, but for which the evaluation of moments of exponentials of arbitrary polynomials is replaced by the evaluation of high-order moments of Gaussians. Such moments of Gaussians can be evaluated in closed form. In addition, a preliminary numerical approximation using Discontinuous Galerkin finite elements based on the work of Barth has been extended to the developed moment-closure systems.

Dissertations

-

Scientific Publications

-

Projectleaders

EH van Brummelen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

MRA Abdel Malik

Cooperations

-

Funded

TU/e

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

Start of the project

2012

Information

EH van Brummelen
040 2475470
e.h.v.brummelen@tue.nl
www.tue.nl/vanbrummelen

MRA Abdel Malik
06 26419485
M.Abdel.Malik@tue.nl

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.

Rheology of blood clot formation

Project Aim

Blood clots form upon vascular injury in order to prevent blood loss and are involved in the process of wound healing. The structure of the blood clot plays a role in many pathologies and is influenced by the flow conditions under which the clot develops. However, the relation between structural properties influenced by the flow and the macroscopic mechanical properties of the clot is poorly understood. In this project constitutive equations are developed based on the structural properties of the different constituents of the clot to study its mechanical properties under various conditions.

Progress

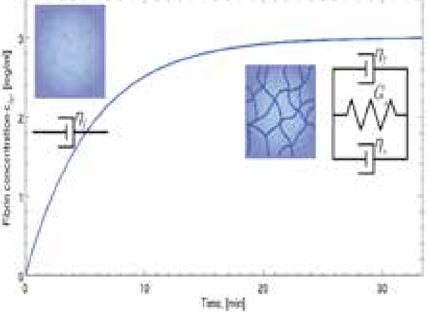
One of the main structural components of the blood clot is fibrin, a protein that forms a fibrous structure within the blood clot. A constitutive model is developed that describes the formation of the fibrin network in time. The network formation is modeled as a transition from a viscous fluid to a viscoelastic solid, where the transition is governed by the fibrin kinetics. The model is extended by taking into account the non-linear viscoelastic behavior of the network. The strain-stiffening behavior observed in large deformations is incorporated in the solid phase of the model. As validation, rheometry experiments are performed where a fibrin network is formed within the rheometer. Quantitative agreement is found between the model and experimental results.

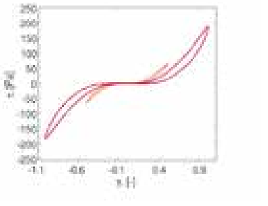
Dissertations

-

Scientific Publications

-





The formation of the fibrin network is modelled as a transition from a viscous fluid to a viscoelastic solid (left). The non-linear behaviour of the networks is observed when the strain (γ) is plotted versus the stresss (τ), (right).

Projectleaders

FN van de Vosse, GWM Peters

Researchtheme

Complex structures of fluids

Participants

THS van Kempen

Cooperations

TU/e Mechanical Engineering

TU/e Applied Physics

Funded

TU/e High Potential Research Program: Blood in Motion

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

Start of the project

2011

Information

THS van Kempen

t.h.s.v.kempen@tue.nl

Continuum modelling of blood clot formation and growth

Projectleaders
FN van de Vosse

Researchtheme
Complex dynamics of fluids

Participants
F Storti

Cooperations
TU/e Mechanical Engineering
TU/e Applied Physics

Funded
TU/e High Potential Research Program: Blood in Motion

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

Start of the project
2010

Information
F Storti
f.storti@tue.nl

Project Aim

Hemostasis is the complex process necessary to prevent blood loss. It involves the interplay between biochemical and physical processes, which normally keep the blood in a fluidic state and repair the walls of veins and arteries in case of injury. When this happens a blood clot forms around the injury. The phenomenon of blood clotting mainly consists of two mechanisms:

1. dynamics of platelet and chemical species;
2. clot growth and remodelling.

The aim of the project is to create a mathematical model that describes the blood clot formation and growth. Particular attention is given to the interaction between the blood flow and the porous clot.

Progress

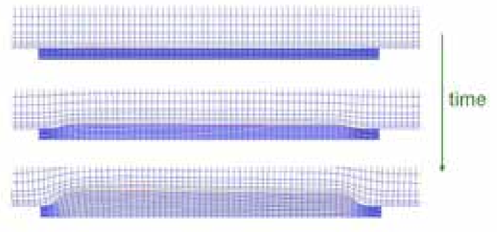
The initial formation of the clot is modelled through a system of convection-diffusion-reaction equations. Unactivated platelets, activated platelets, chemical activators and chemical inhibitors are modelled as concentrations. All these factors represent the onset of the coagulation process. Once the clot is formed, it is represented by means of an elastic solid, which interacts with the flow around it through basic FSI. The clot growth is represented by mesh update (ALE method) and once in a while remeshing is necessary. To represent the porosity of the clot a Brinkman term is included in the Navier-Stokes equations for the fluid and the elastic solid is modified into a porous elastic solid.

Dissertations

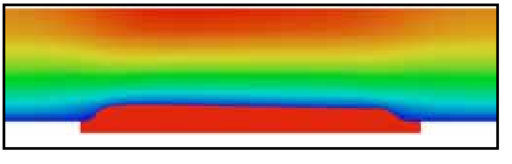
-

Scientific Publications

1. 6th European Postgraduate Fluid Dynamics Conference, 10-12th July 2012, Imperial College London, London: "A coupled overlapping domani method for continuum modelling of blood clot growth", F. Storti, A.C. Verkaik, A.C.B. Bogaerds, M.A. Hulsen and F.N. van de Vosse.



Schematic representation of the modelling of blood clot growth. Mesh update (left). FSI (below): the clot is modelled as a poro-elastic solid (red) and the blood flow by means of the Navier-Stokes equations (blue).



PROJECT AIM

Because of the high volume contents of red blood cells (RBCs) in blood, mechanics of a single RBC plays a large role in plasma mixing and lateral transport of its components. Therefore, a characterization of the dynamical parameters of RBCs under different flow conditions is needed. Our strategy involves estimation of mechanical properties of the RBC using an inverse analysis which combines both numerical and experimental tools. A RBC is deformed under elongational flow. Advantage of this experimental method is that there is no contact between a solid and the cell membrane, which would complicate the analysis, especially during dynamic deformations. To create a setup with elongational flow, a cross-slot microfluidics device is built (left figure). Rigid channels in SU-8 photoresist on glass are sealed with a PDMS foil. The foil also serves as a deflecting membrane for the valves, which enable position control of the cell. Piezo-electric elements are used in closed loop control to actuate the valves. To change the stress on the RBC dynamically, a pulsatile microfluidics pump is designed, built, and tested.

PROGRESS

Active repositioning of the cell is necessary to perform repetitive measurements. However, a linear feedback loop seems to be inadequate. For the design of a suitable feedback system with feedforward control, a numerical tool is developed. This involves 2D FEM simulations of the cross-slot (Stokes flow), in which lumped parameter models that represent the channel hydraulics, are added to the boundary conditions of the in- and outflow channels. By matching the experimental open-loop system identification measurements with the simulations, the parameters for the lumped elements are fitted. Hence, this hybrid model is used as a platform to design a non-linear controller.

PROJECTLEADERS

FN van de Vosse, ACB Bogaerds, PD Anderson

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

RCH van der Burgt

COOPERATIONS

TU/e Mechanical Engineering
TU/e Applied Physics

FUNDED

TU/e High Potential Research Program: Blood in Motion

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

START OF THE PROJECT

2009

INFORMATION

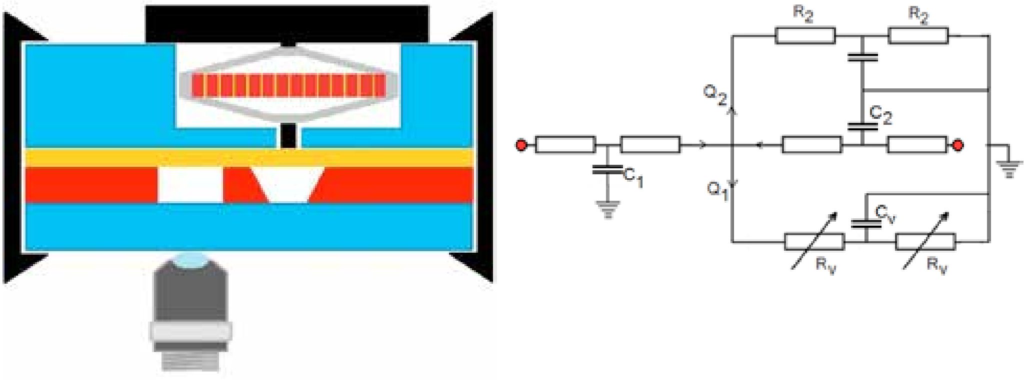
R van der Burgt
r.c.h.v.d.burgt@tue.nl

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Left:Schematic view of the cross-slot device. SU-8 photoresist channels (red) on a glass slide (lower blue) are sealed by PDMS (orange). The piezo-electric actuators are attached to a polycarbonate plate (upper blue). An aluminium frame (black) is clamping the other components. Right: Schematic representation of the microfluidics chip of the cross-slot setup: the channels are modeled as RC lumped parameter elements. The computed flows are used as boundary conditions for a 2D FEM simulation of the cross-slot.

Projectleaders
FN van de Vosse, MA Hulsen
ACB Bogaerds

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
AC Verkaik

Cooperations
TU/e Mechanical Engineering

Funded
TU/e

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

Start of the project
2008

Information
AC Verkaik
A.C.Verkaik@tue.nl

Project Aim

Distal to artificial heart valves transitional (transition to turbulence) flow with small scale local velocity fluctuations can be found. To compute transitional flow spectral elements can be used, however we also want to compute accurately the fluid stress near the deforming structure. Therefore, this study will focus on the implementation of a coupling method between spectral and finite elements to compute fluid-structure interaction for transitional flow through artificial heart valves.

Progress

In previous periods we proposed a fully Coupled Overlapping Domain (COD) method to couple the fixed grid fluid domain with an Arbitrary Lagrangian Eulerian (ALE) moving grid fluid domain. This allows for an optimal conformal coupling between the fluid elements and the structural elements. The convergence of the spectral elements was proved. Last year we focused on testing the fluid-fluid coupling of the COD method for several benchmark problems and some first test problems with fluid-structure interaction were made.

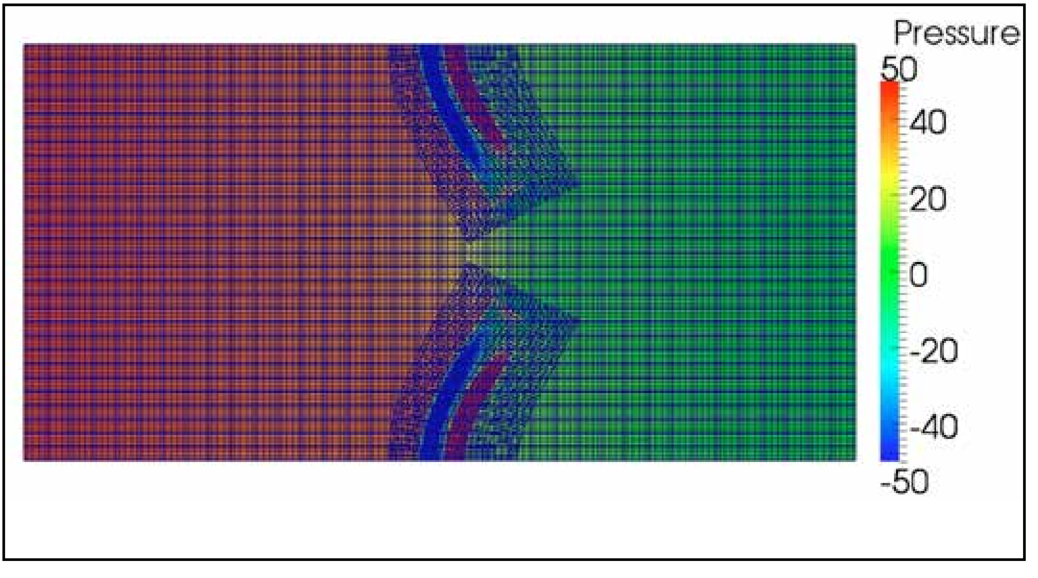
Dissertations

-

Scientific Publications

1. A.C. Verkaik, A.C.B. Bogaerds, F. Storti and F.N. van de Vosse, Method for the computation of transitional flow through artificial heart valves using a coupled overlapping domain method. ASME Summer Bioengineering Conference, Puerto Rico 2012.

The pressure of flow throug two elastic beams.



Prof.dr.ir. B Koren

Prof.dr.ir. F Toschi

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

- Hydro-acoustic instabilities in sheared flows.
- Boundary condition for mean flow profiles with vanishing boundary layer thickness.
- The critical layer in shear flows.

Progress

Instability analysis of an incompressible flow with a linear-the-constant velocity profile. An enhanced Ingard-Myers type boundary condition for a mean flow with vanishing boundary layer thickness. An analytical formula and a contourplot covering parameter values for the critical thickness in an incompressible linear setup, where the flow becomes absolutely unstable. Extensions to smooth profiles. Critical layer singularities in sheared flow: stability, effects, situations when they are negligible. The trailing vorticity field behind a mass point source in 2D incompressible flow.

Dissertations

1. Acoustic liner - mean flow interaction. Defence on 10th September 2012.

Scientific Publications

1. E.J. Brambley, M.Darau, S.W. Rienstra The critical layer in linear shear boundary layers over acoustic linings, Journal of Fluid Mechanics, 710, pp 545-568, doi:10.1017/jfm.2012.376.
2. S.W. Rienstra, M. Darau & E.J. Brambley The trailing vorticity field behind a line source in 2D incompressible linear shear flow, Accepted for publication in Journal of Fluid Mechanics.

Projectleaders

S Rienstra, B Mattheij, S Balint

Researchtheme

Complex dynamics of fluids

Participants

M Darau

Cooperations

West University of Timisoara, Romania, University of Cambridge, DAMTP

Funded

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

Start of the project

2008

Information

S Rienstra
040 247 4603
s.w.rienstra@tue.nl

Simulating unsteady conduit flows with smoothed particle hydrodynamics

Projectleaders
RMM Mattheij, AS Tijsseling

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
Qingzhi Hou

Cooperations
University of Nottingham

Funded
The Chinese Scholarship Council

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

Start of the project
2008

Information
Qingzhi Hou
040 247 5546
q.hou@tue.nl

Project Aim

Smoothed Particle Hydrodynamics (SPH) numerical techniques are used to model the important problem of liquid slugs moving at high speeds in pipelines. The impact of such slugs at pipe bends, pumps and valves may cause great material damage. Slug flow, waterhammer and flow separation are the phenomena dealt with. Experimental data obtained for the controlled filling and emptying of a large-scale pipeline are used for validation.

Progress

The PhD thesis has been completed and the defence took place on June 25, 2012.

Dissertations

1. Q. Hou. Simulating Unsteady Conduit Flows with Smoothed Particle Hydrodynamics. PhD Thesis, Eindhoven University of Technology, Eindhoven, The Netherlands.

Scientific Publications

1. Q. Hou, A.C.H Kruisbrink, A.S. Tijsseling and A. Keramat. Simulating transient pipe flow with corrective smoothed particle method. BHR Group, 11th International Conference on Pressure Surges, Lisbon, Portugal, October 2012, pp. 171-188.
2. A.S. Tijsseling, Q. Hou, B. Svingen and A. Bergant. Acoustic resonance in a reservoir-double pipe-orifice system. ASME 2012 Pressure Vessels & Piping Conference, Toronto, Canada, July 2012, Paper PVP2012-78085.
3. J. Laanearu, I. Annus, T. Koppel, A. Bergant, S. Vučkovič, Q. Hou, A.S. Tijsseling, A. Anderson and J.M.C. van 't Westende. Emptying of large-scale pipeline by pressurized air. ASCE Journal of Hydraulic Engineering, 138 (2012), 1090-1100.
4. Keramat A., Tijsseling A.S., Hou Q., Ahmadi A. Fluid-structure interaction with pipe-wall viscoelasticity during water hammer. Journal of Fluids and Structures, 28 (2012), 434-455.

Sound propagation in a duct with sheared flow and non-locally reacting liners

Project Aim

The goal of the project is to further develop and make available a class of semi-analytical solutions (based on modes) for the propagation and attenuation of sound in flow ducts, aiming in particular to the reduction of noise from the auxiliary power unit (APU, a turbine engine) of aircraft. Here, the walls of the duct are covered with acoustically damping material, i.c. non-locally reacting liners (e.g. metallic foam). Furthermore, the mean flow exhibits strong shear and temperature gradients. Keywords: duct acoustics, aeroacoustics.

Progress

The development of a new code based on a modal representation of the acoustic field has been continued. The code handles a segmented duct with non-locally reacting impedance walls, non-uniform mean flow and non-uniform temperature, where each segment has different impedance properties. A method for computing the acoustic modes in case of a non-locally reacting liner based on complex contour integration has been investigated and implemented. This method guarantees that all axial wavenumbers (eigenvalues) within a certain region of the complex plane are found. The combined effect of multiple segments is computed by using the mode-matching approach, which is based on setting up a system of equations for the modal amplitudes at each interface between two segments. The matrix entries are usually computed by numerically evaluating an inner product. A new method (based on an 'adjoint' Pridmore-Brown equation) has been developed and implemented, for which the inner product integrals can be evaluated in closed form, which is computationally advantageous. A working visit of 6 weeks has been made to Airbus, Toulouse.

Dissertations

-

Scientific Publications

-

Projectleaders

RMM Mattheij, P Sijtsma, SW Rienstra

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

P Sijtsma (supervisor NLR), SW Rienstra (supervisor), RMM Mattheij (promotor), M Oppeneer (PhD-student)

Cooperations

Airbus

Funded

National Aerospace Laboratory NLR

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

Start of the project

2009

Information

P Sijtsma
0527 248661
sijtsma@nlr.nl

Development of a computational tool for the simulation of wind-farm aerodynamics

Projectleaders
B Koren

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
B Sanderse

Cooperations
Energy research Centre of the Netherlands (ECN)

Funded

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

Start of the project
2008

Information
B Sanderse
020 592 4161
b.sanderse@cwi.nl

Project Aim

The Dutch government plans that a significant portion of the Dutch future energy need is to be produced by wind farms at the North Sea. A wind farm is a large set of wind turbines, often positioned in some matrix form. Various research questions still exist with respect to wind farms; economical, ecological and technological. A major technological question is how to position and design the separate wind turbines, such that the energy production of the wind farm as a whole is maximal. The goal of this project is to make a step towards answering this question.

Progress

A new boundary treatment for the spatial discretization of the incompressible Navier-Stokes equations was developed. Further, a new actuator method approach for the modeling of wind turbines was proposed. The method uses immersed interfaces. The entire computational method has been implemented in a new parallelized Navier-Stokes solver, ECNS (Energy-Conserving Navier-Stokes Solver).

Dissertations

-

Scientific Publications

1. B. Sanderse and B. Koren, Accuracy analysis of explicit Runge-Kutta methods applied to the incompressible Navier-Stokes equations, Journal of Computational Physics, 231, 3041-3063 (2012).
2. B. Sanderse and B. Koren, New explicit Runge-Kutta methods for the Incompressible Navier-Stokes equations, Proceedings Seventh International Conference on Computational Fluid Dynamics, Big Island, Hawaii, 2012, ICCFD7-1403, http://www.iccfd.org/iccfd7/proceedings.html.
3. B. Sanderse and B. Koren, Linearly implicit energy-conserving Runge-Kutta methods for the incompressible Navier-Stokes equations, Proceeding ECCOMAS 2012 -European Congress on Computational Methods in Applied Sciences and Engineering, Vienna 2012, e-Book Full Papers, 2294-2306.

Investigation of edge localized modes by further development and application of computational tools

Project Aim

Edge Localized Modes (ELMs) are disruptive magnetohydrodynamic (MHD) instabilities observed in torus-shaped fusion devices in which an extremely hot plasma is confined magnetically (tokamaks) for the eventual goal of energy production. The project aim is to acquire a deeper understanding of the nonlinear development of ELMs. This is required to predict their impact on next-generation tokamaks, like ITER, and to find ways to control or trigger ELMs in an early stage of their development.

Progress

The effect of toroidal rotation on reversed shear Alfvén eigenmodes and flow shear was investigated. The step to nonlinear MHD was made by extending an existing reduced MHD code to the full viscoresistive MHD equations. This extension allows a study of the nonlinear evolution of MHD equilibria, waves and instabilities.

Dissertations

-

Scientific Publications

1. J. W. Haverkort, H. J. de Blank, and B. Koren, The Brunt-Väisälä frequency of rotating tokamak plasmas, J. Comput. Phys., 231, 981-1001 (2012).
2. J. W. Haverkort, The effect of toroidal plasma rotation on low-frequency reversed shear Alfvén eigenmodes in tokamaks, Plasma Phys. Control. Fusion, 54,:025005 (2012).
3. J. W. Haverkort and H.J. de Blank, Flow shear stabilization of rotating plasmas due to the Coriolis effect, Phys. Review E., 86,:016411 (2012).

Projectleaders

B Koren, HJ de Blank

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

JW Haverkort

Cooperations

FOM-DIFFER, CWI

Funded

FOM (FOM Program 120, “Active Control of Magnetohydrodynamic Modes in Burning Plasmas”)

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

Start of the project

2009

Information

JW Haverkort
020 592 4161
J.W.Haverkort@cwi.nl
www.cwi.nl/~haverkort

Control and mitigation of edge localized modes by further development and application of computational tools

Projectleaders
B Koren, HJ de Blank
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
B van Es
Cooperations
FOM-DIFFER, CWI
Funded
FOM (FOM Program 120, "Active Control of Magnetic Hydrodynamic Modes in Burning Plasmas")

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

Start of the project
2011
Information
B van Es
020 592 4166
b.van.es@cwi.nl

Project Aim

Edge Localized Modes (ELMs) are disruptive magnetohydrodynamic (MHD) instabilities observed in torus-shaped fusion devices in which an extremely hot plasma is confined magnetically (tokamaks) for the eventual goal of energy production. The project aim is to find ways to control and mitigate ELMs in an early stage of their development.

Progress

New finite difference and finite volume methods for extreme anisotropic diffusion were developed. The methods were tested on various discriminating benchmark problems. Results were presented at three international scientific conferences.

Dissertations

-

Scientific Publications

1. B. van Es, B. Koren and H. de Blank, Discretization methods for extremely anisotropic diffusion, Proceedings Seventh International Conference on Computational Fluid Dynamics, Big Island, Hawaii, 2012, ICCFD7-1401, http://www.iccfd.org/iccfd7/proceedings.html.
2. B. van Es, B. Koren and H. de Blank, Numerical modelling of strongly anisotropic dissipative effects in MHD, Proceedings 39th European Physical Society Conference and 16th International Congress on Plasma Physics, Stockholm, 2012, http://ocs.ciemat.es/epsicpp2012pap/html/.
3. B. van Es, B. Koren and H. de Blank, Special finite-difference methods for extremely anisotropic diffusion, Proceedings ECCOMAS 2012 – European Congress on Computational Methods in Applied Sciences and Engineering, Vienna, 2012, e-Book Full Papers, 3871-3888.

PROJECT AIM

Development of efficient models and numerical methods for simulating fluid flow and heat transfer in arbitrarily shaped pipes. The motivation comes from the need for predicting and describing fluid transport through complex geometries, such as the ones present in corrugated pipes. The research done in this project combines both, numerical and analytical techniques. The research covers the cases of isothermal laminar flow, non-isothermal laminar flow (including forced and natural convection) and isothermal turbulent flow.

PROGRESS

In the case of isothermal laminar flow we developed a very efficient analytical formula for computing the friction factor in slowly varying pipes. For more general geometries, we present an efficient numerical model which uses a periodicity decomposition in order to reduce the numerical domain to just one period. We use the numerical model for systematically evaluating the accuracy of the analytical formula. Based on the presented models, we also address the problem of wall-shape design. In the case of laminar forced convection, we solved the problem of constant wall heat flux with a periodicity decomposition technique. The case of natural convection was first handled from a practical point of view. In particular we proposed a numerical model for simulating a thermosyphon loop for a cryogenic storage tank featuring corrugated pipes. Based on the model, we showed that the wall-shape of the corrugated pipe can be designed to achieve a better performance. We developed a simplified (homogenized) model for simulating natural convection in a vertical corrugated pipe. The model was obtained by applying a boundary layer expansion and a multiple scale expansion. Using formal homogenization we obtained effective boundary conditions which allow to simplify the numerical domain, while keeping the physical effects of the wall-shape. The homogenized model is able to capture the long scale behavior and it can be used for accurate predictions of averaged quantities such as the flow rate and overall heat transfer. For the cases studied, the homogenized model was between 5 and 175 times faster than direct numerical solution methods.For the case of isothermal turbulent flow, we presented a comparison between the 2 equation k-ε model and the algebraic LVEL model. We compared the predictions of both models with available experimental data of turbulent flow in straight pipes. The models were also compared with respect to speed, robustness and accuracy.

DISSERTATIONS

1. P.I.Rosen Esquivel,“Efficient Simulation of Flow and Heat Transfer in Arbitrarily Shaped Pipes”, Technical University of Eindhoven, PhD Thesis 2012.

SCIENTIFIC PUBLICATIONS

1. P.I. Rosen Esquivel, J.H.M ten Thije Boonkkamp, J.A.M. Dam. “An asymptotic formula for the friction facto of laminar flow in pipes of varying cross section”. Mathematics in Engineering Science and Aerospace 3, 1, 2012.

PROJECTLEADERS

RMM Mattheij, J Dam, JHM ten Thije Boonkkamp

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

PI Rosen Esquivel

COOPERATIONS

-

FUNDED

Ballast Nedam

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

START OF THE PROJECT

2008

INFORMATION

PI Rosen Esquivel
040 247 3162
p.i.rosenesquivel@tue.nl

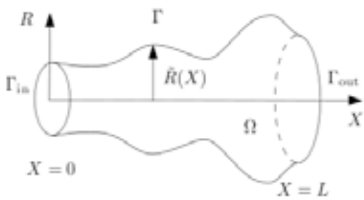


FIGURE 1. Axisymmetric pipe with center line along the X-axis. Γ stands for the wall of the pipe, Γ_{in} for the cross section at $X = 0$ and Γ_{out} the cross section at $X = L$.

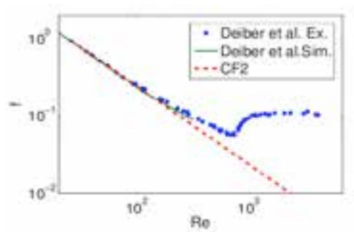


FIGURE 4. Experimental results (blue dots), 2D numerical solution (solid green line) for the friction factor by Deiber et al. [14, p. 642], and approximation obtained with correction factor $CF2$ (41) (dashed line).

Applied Analysis

Prof.dr.ir. CJ van Duijn

Prof.dr. JJM Slot

The Eindhoven Applied Analysis group focuses on modeling, analysis of nonlinear differential equations and related computational methods. This diverse expertise is applied to a broad spectrum of problems arising in the engineering sciences, physics and industry. The philosophy is to contribute to the solution of relevant problems in these applied sciences as well as to participate in the development of the underlying mathematical framework. At the moment the main areas of applications are fluid mechanics, rheology, material science (including polymers) and porous media. For example:

Porous media

Porous media are (micro-) structures that appear in many disciplines of science and engineering, like ground water hydrology, soil mechanics, petroleum engineering, bioremediation, agricultural science, tissue engineering, or paper production. Typical for such problems is that different phenomena take place on different scales. One of the research topics is upscaling microstructures to macromodels. Examples are problems from hydrology, like groundwater flow, in particular seawater intrusion in coastal waters, contamination of aquifers, or subsurface storage of materials.

Aero acoustics

One of the many measures taken to reduce the noise of aircraft engines is the application of acoustic lining in the inlet and bypass duct. In order to optimize the damping properties we need to model the sound propagation through the duct. By utilizing the inherent slow variation of a typical flow duct we found an analytic asymptotic solution of the problem that appeared to compare very favorably with proven numerical solutions. This solution was the starting point of a series of similar solutions for related cases, while it has been used to produce a superior matching procedure to connect CFD-type source data to the acoustic field, which is now being used throughout Europe to support CAA implementations.

Rheology

Rheology is the branch of science focusing on the flow and deformation behavior of complex materials. Complex materials often contain long molecules and/or particles that give them particular flow and deformation behavior in comparison with simple fluids like water or simple solids like pure metals. Examples can be found in industry, the environment, living systems and around the house: paints, polymer processing, production of tires, ink, glues, pharmaceutical -, agricultural - and cosmetic products, in oil production, production of photographic materials, displays and magnetic tapes, food products such as mayonnaise, cheese, margarine, domestic products like toothpaste and liquid detergents, mud, clay, blood and saliva. As in all branches of science also in rheology, in addition to experiment, mathematical modeling and numerical simulation play a very important role. From its inception in the beginning of the last century, when it involved almost exclusively continuum mechanics and constitutive modeling, rheology heavily relies on disciplines belonging to classical applied mathematics, such as differential equations, functional analysis, perturbation theory etc. However, with the increasing focus on the relationship between microscopic structure/processes and macroscopic properties of these complex materials nowadays, probability theory and in particular the theory of stochastic processes has become an essential discipline too. Currently, two focal areas of interest are the constitutive modeling of concentrated solutions of main chain liquid crystalline polymers and that of melts of entangled arbitrarily branched polymers.

Dynamic capillarity in porous media

Project Aim

This work addresses mathematical and numerical analysis questions related to non-standard porous media flow models, and investigate the effect of different capillary pressure assumptions. In particular, we seek for non-standard entropy solutions to two-phase porous media flow problems, as limit cases when the capillary effects vanish.

Progress

We obtained the existence of weak solutions for the nonlinear and degenerate mathematical equation modelling two-phase flow porous media, involving dynamic effects in the capillary pressure. Furthermore, we introduced an extra unknown: capillary pressure, and transformed the equation into different systems. Then we proved the equivalence of different forms of the model equation. New numerical schemes were introduced and tested with different numerical settings. A-posteriori error estimates are obtained for the complete two-phase flow model, but in the equilibrium/standard case.

Dissertations

1. Fan, Y. (2012). Dynamic Capillarity in Porous Media - Mathematical Analysis. Eindhoven: Technische Universiteit Eindhoven. (Supervisor: C.J. van Duijn and I.S. Pop).

Scientific Publications

-

Projectleaders

CJ van Duijn

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Y Fan, CJ van Duijn, IS Pop

Cooperations

Dr. C. Cances (Paris), Dr. M. Vohralik (Paris), Dr. C. Choquet (Marseille), Prof. dr.ir. S.M. Hassanizadeh (Utrecht), Prof. dr.ir. R. Helmig (Stuttgart), Prof. dr. C. Rohde (Stuttgart), Prof. dr. A. Mikelic (Lyon), Prof. dr. ir. L.A. Peletier(Leiden)

Funded

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

Start of the project

2008

Information

IS Pop
040 247 5516
i.pop@tue.nl

Constitutive modeling of concentrated solutions of main-chain liquid crystalline polymers

Projectleaders
JJM Slot
Researchtheme
Complex dynamics of fluids
Participants
O Matveichuk
Cooperations
Prof. dr. J. Molenaar (WUR),
Prof. dr. S. Picken (TUD),
Teijin Aramid R&D
Funded
Teijin-Aramid BV

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

Start of the project
2008
Information
JJM Slot
040 247 4381
j.j.m.slot@tue.nl

Project Aim

The primary objective of this project is to develop a molecularly based constitutive model for the rheological behavior of concentrated solutions of main-chain liquid crystalline polymers (LCP) that may show nematic order. The model will be restricted to monodomain (single director) morphologies and the main focus will be on the role that chain flexibility plays in this behavior.

Progress

The code for the simulations of the rod-spring-bead model for the description of concentrated solutions of LCP was developed. The model incorporates hairpins and allows large deviations from highly-ordered state. The model is also capable of treating possible entanglements between polymer chains with hairpins. The code is validated by comparing the results of simulations with the predictions of the earlier developed model for highly-ordered LCP solutions. The results of these simulations were presented at the Annual European Society of Rheology (AERC2012). The results of simulations are in agreement with the available experimental data. The second half of 2012 was primarily devoted to writing the thesis that summirizes the results achieved during the time of this project.

Dissertations

-

Scientific Publications

1. AERC2012 conference procedings. O.Matveichuk, J.J.M.Slot. Constitutive modeling of highly ordered solutions of main-chain liquid crystalline polymers containing hairpins.

Constitutive modeling of arbitrary branched polymer melts

Project Aim

The primary objective of this project is to develop a molecularly based constitutive model for the rheological behavior of polymer melts consisting of arbitrary branched polymer molecules. An industrially relevant and prime example of such a system is provided by a melt of low-density polyethylene (ldPE). As such a system shows such an extreme variation in molecular composition, a description of this composition can only be given in statistical terms. Hence, the idea is to describe such a system by a finite set (ensemble) of representative molecular structures (topologies). Such an ensemble can be obtained via a combination of kinetic modeling and Monte Carlo simulation. This work on kinetic modeling and Monte Carlo simulation is done at the University of Amsterdam in a twin PhD project (not part of the JMBC).

Progress

In 2012 we have focused on the idea of using a statistical representation of ldPE molecules, where the concept of seniority plays the key role. By seniority we mean a segment “depth” from the topological exterior of a molecule. This quantity is simply the number of segments that connects a given segment to the retracting chain end responsible for its relaxation. From our point of view, it is the best measure of topological structures within the ensemble of arbitrary branched polymers. From numerical experiments on theoretical ldPE samples we have observed that segments of seniorities up to 7 compose around 97% of the system mass. Thus, we can reduce the calculation of the linear stress-relaxation response of a complex melt by taking into account only relaxation of such segments. In other words, from every complex branch in a molecule we only explicitly treat the relaxation of a part of it and let the rest be implicitly relax by constraint release. As we want to develop a new computational approach based on the earlier work of Evelyne van Ruymbeke, we have started validation of her model for the ensembles of well described molecules: monodisperse stars, blends of stars, blends of stars and linears, asymmetric stars, symmetric h-polymers, asymmetric h-polymers.

Dissertations

-

Scientific Publications

-

Projectleaders

JJM Slot

Researchtheme

Complex dynamics of fluids

Participants

V Shchetnikava

Cooperations

Prof. dr. ir. E. van Ruymbeke, UCL, Belgium, Prof. dr. P.D. Iedema, UvA

Funded

Dutch Polymer Institute (DPI)

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

Start of the project

2009

Information

JJM Slot
040 247 4381
j.j.m.slot@tue.nl

Second generation of integrated batteries

Projectleaders
P Notten, MA Peletier, IS Pop

Researchtheme
Complex dynamics of fluids

Participants
K Kumar, TL van Noorden, P Notten, MA Peletier, IS Pop

Cooperations
Prof. R. Helmig (Stuttgart)
Prof. W. Jäger (Heidelberg)
Prof. A. Mikelić (Lyon)
Prof. F.A. Radu (Bergen)
Dr. M. Neuss-Radu (Erlangen)

Funded
STW

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

Start of the project
2008

Information
K Kumar
kkumar@ices.utexas.edu

S Pop
040 247 5516
i.pop@tue.nl

Project Aim

The project is related to the development of all-solid state rechargeable batteries having a high storage capacity. Such devices have a complex 3D geometry for the electrodes to enhance the surface area. The challenges are in the development of the appropriate technologies for the formation of these electrodes. In particular we focus on chemical vapor deposition processes (CVD), with the aim of getting a deeper understanding of the reactions taking place in a complex geometry.

Progress

Depending on the size of the reaction domain, the changes in the pore structure that are due to the deposition process may or may not be neglected. In mathematical terms, the models are defined in a fixed, respectively variable geometry, when the deposition layer generates a free boundary at the pore scale. We have developed mathematical models for both situations and carried out numerical simulations for both the fixed geometry and variable geometry showing a good agreement with the experimental results obtained for the deposition of Titanium dioxide inside trenches of different diameters, This work has implied determining the physical and chemical parameters.
For the multi-scale computations, numerical methods inspired from domain decomposition ideas have been proposed and the convergence of the scheme has been proved. Computing the full solution in a domain with oscillating boundary requires a lot of computational effort, as one has to achieve an accuracy that agrees with the scale of oscillations. To approximate these solutions, one defines equations in a simpler domain, where flat boundaries but modified boundary conditions approximate the rough one. The two situations mentioned before were considered: the fixed geometry case, and the time dependent geometry at the microscale (free boundaries). We have derived an approximating (effective) model where a flat boundary is replacing the oscillatory boundary, but defining an effective boundary condition. In the fixed geometry case, we provide rigorous mathematical proofs for the upscaling procedure. The second case, when we take into account the geometry changes at the microscale, is more involved, and we use formal asymptotic methods to derive these boundary conditions. Further, to understand the flow in a domain with variable geometry, we have considered a thin strip with reactions taking place at the lateral boundaries of the strip under dominant transport conditions. We have derived upscaled equations for the solute concentration, which are similar to the Taylor dispersion and we have performed numerical simulations to compare the upscaled equations with other simpler upscaled equations. We have further studied the rigorous homogenization process for the reactive flows for a periodic array of cells and proved the validity of upscaled equations. These reactive flows model the crystal precipitation and dissolution processes in a porous medium. Our results are in agreement with the macroscale equations proposed in the literature. In addition, numerical methods, for instance, mixed finite element method, to compute the solution have been proposed and the proofs for the convergence of these schemes have been obtained..

Dissertations

1. Upscaling of Reactive Flows, Sep 2012, CASA, TU Eindhoven.

Scientific Publications

-

Multiphase Rectors Group

Prof.dr.ir. JAM Kuipers

Prof.dr.ir. M van Sint Annaland

The research group SMR participates amongst others in the OSPT and the JMBC for fluid mechanics 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. The generation of new knowledge and the development of new reactor models with improved predictive capability for this industrially important class of chemical reactors constitutes an important goal of our research activities. 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 three areas: Multiphase Reactors, Advanced Experimental Techniques and Novel Reactors, 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 the near future 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 are being developed and models which treat the dispersed phase (particles, bubbles or droplets) in a discrete manner accounting for possible encounters between the dispersed elements.

The second important area of our research deals with the development 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 of the 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. Of course this research activity is intimately connected to the first research topic. Our third important area of research deals with the development of novel (multiphase) reactors with emphasis on integration and intensification of relevant process steps. As an example we can mention here the Rapid Reaction Cycling Reverse Flow (RRCRF) which integrates (in a thermal sense) endothermic and exothermic heterogeneously catalyzed chemical reactions where the endothermic reaction causes rapid (reversible) catalyst deactivation. These types of chemical reaction systems often arise in practice for instance in the production of lower alkenes form the corresponding alkanes via heterogeneously catalyzed dehydrogenation. The knowledge and tools developed within the other two areas of attention provide a sound basis to place this research activity on a firm footing.

Characterization of the fluid dynamics and discrete particle modelling of a novel spouted bed apparatus

Project Aim

To develop a spouted bed reactor for material which are difficult to fluidised and investigate the influence of operating parameters on bed dynamics under dry and wet conditions by considering heat and mass trasfer effects.

Progress

In this work, the hydrodynamics of a spout fluidized bed with draft plates were studies to identify the flow characteristics by constructing a flow regime map by means of image analysis and a fast Fourier transform (FFT) of the measured pressure signal. In addition, we determined the effect of the geometrical parameters (entrainment height and static bed height) and physical properties of particles on the dynamics of the bed by combined particle image velocimetry (PIV) and digital image analysis (DIA), to determine the particle velocity and volume fraction. In addition, simulations were performed by considering a discrete particle model (DPM) with a sub grid scale (SGS) turbulence model and the obtained results were compared with previously obtained experimental data.

Dissertations

-

Scientific Publications

-

Projectleaders

JAM Kuipers

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

NG Deen, VS Sutkar

Cooperations

Prof. S. Heinrich., Dr. S. Antonyuk
Hamburg University of Technology

Funded

STW & DFG

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

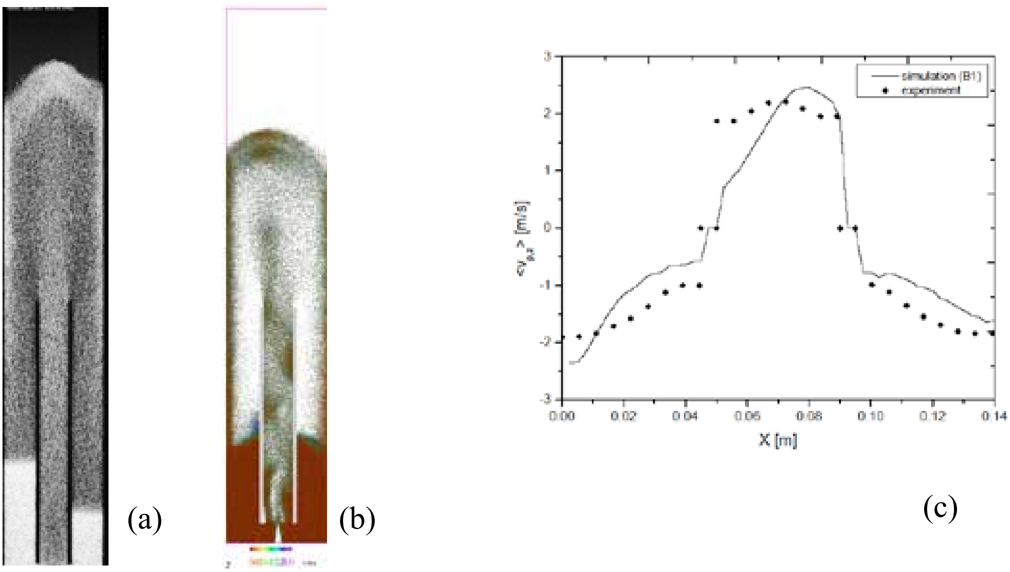
Start of the project

2010

Information

JAM Kuipers
040 247 4158
J.A.M.Kuipers@TUe.nl
www.chem.tue.nl/smr

Snapshots of spouting-with-aeration regime in a spout fluidized bed with an entrainment height (h) = 0.03 m and static bed aspect ratio( ) =1 for glass particles (a) experimental results (b) simulation results and (c) comparison of time-averaged particle velocity profile in lateral direction at z = 30 cm.



Predictive modeling of polyolefin reactors

Projectleaders
JAM Kuipers

Researchtheme
Complex dynamics of fluids

Participants
MM Banaei, Z Li, M van Sint Annaland, NG Deen

Cooperations
-

Funded
DPI (Dutch Polymer Institute)

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

Start of the project
2012

Information
M Banaei
040 247 3673
m.banaei@tue.nl

Project Aim

The aims of the project are:

1. Extension of numerical models for prediction of hydrodynamics, heat transfer and also mass transfer in polymerization reactors.

2. Developing the PIV/DIA measurements for pressurized gas fluidized beds and quantitative investigation of the heat effects of liquid injection.

Progress

Since the start of the project, a literature survey was made about modeling and experimental techniques of fluidized beds.

Dissertations

-

Scientific Publications

-

Project Aim

The projects aims to prepare a computational model based on an Euler-Lagrange approach to simulate a bubble column with a wire-mesh inside it. The effect of the wires will be to cut bubbles into smaller pieces and thereby enhance the mass transfer in the column. The liquid phase flow patterns may shift towards plug flow kind of behavior leading to reduced back-mixing. The presence of catalyst coated wires will also be modeled by specifying reaction zone along wires.

Progress

Liquid hydrodynamics has been modeled and verified first without presence of bubbles. After that bubbles were introduced. Bubble cutting through wires was achieved by a self developed bubble cutting algorithm. Test cases to verify the algorithm were successful. Thereafter the effect of various parameters such as mesh pitch, gas superficial velocity etc., were studied. Currently the mass transfer is being included in the model and it will be verified with a variety of test cases.

Dissertations

-

Scientific Publications

-

Projectleaders

NG Deen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

D Jain, JAM Kuipers

Cooperations

-

Funded

European Research Council

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

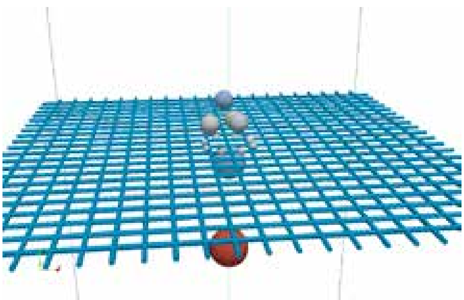
Start of the project

2011

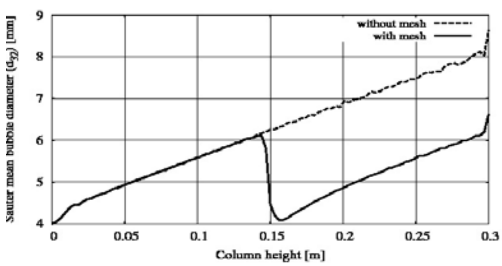
Information

NG Deen
040 247 3681
040 247 4931
N.G.Deen@TUe.nl
www.tue.nl/staff/N.G.Deen

Cutting of single large bubble into smaller bubbles by wire mesh.



Sauter mean diameter as a function of column height with and without mesh. Mesh is placed at column height 0.15 m.



Cutting bubbles, micro-scale interaction mass and heat transfer

Projectleaders
NG Deen
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
QIE Segers, JAM Kuipers
Cooperations
-
Funded
EU (ERC Starting Investigator Grant 259521)

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

Start of the project
2010
Information
NG Deen
040 247 3681
N.G.Deen@tue.nl
www.chem.tue.nl/smr

Project Aim

A proper test system is selected based on simulation and measurement with dyes in bubbly flows with and without wires. Measurement of heat and mass transfer rate as function of wire mesh layout and bubble mesh distance in a flat bubble column.

Progress

A fully-implicit Immersed Boundary Method (IBM) has been applied to flows past a wire mesh section. From these simulations a more accurate prediction of the hydrodynamic drag has been formulated in the shape of a correlation. This correlation is directly used in coarser simulations not solving for the flow in micro-scale namely the Discrete Bubble Method (DBM). The work continues is predicting heat transfer for the same type of flows. An experiment is simultaneously developed to verify the simulation results.

Dissertations

-

Scientific Publications

1. Segers, Q.I.E., Deen, N.G. & Kuipers, J.A.M. (2012). Bubbly flow through a static wire mesh. Proceedings of the 22nd International Symposium on Chemical Reaction and Engineering (ISCRE 2012), 2-5 September 2012, Maastricht, The Netherlands.

Fundaments of chemical looping for biomass processing

Project Aim

In the ECN MILENA Process, biomass is gasified by an indirect route comprising of a system of two coupled reactors. The performance of both interlinked reactors (bubbling fluidized bed reactor and riser reactor) is investigated in detail in relation to their respective operating conditions, especially focusing on the heat and oxygen transport in the system, and the effect of the residence time of gas and particles. Advanced experimental techniques PIV/DIA is used to study the hydrodynamics and to quantify the rate of heat and oxygen transport. An extended phenomenological model is developed and used for process optimization and scale up effects.

Progress

A novel technique (ePIV/DIA) has been developed by coupling a high speed camera and a Nd:Yag laser with high temperature endoscopes, allowing PIV/DIA to study the hydrodynamics of gas-solid fluidized beds at high temperatures. A first validation of technique has been done at room temperature in a cold flow set up. A lab set up has been designed and constructed for the implementation of the endoscopic-laser PIV/DIA under production relevant conditions.

Dissertations

-

Scientific Publications

-

Projectleaders

M van Sint Annaland, F Gallucci, P Colonna

Researchtheme

Complex dynamics of fluids

Participants

I Campos Velarde

Cooperations

-

Funded

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

Start of the project

2011

Information

I Campos Velarde
040 247 3685
i.camposvelarde@tue.nl

PROJECTLEADERS
M van Sint Annaland, F Gallucci

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
L Marra

COOPERATIONS
SINTEF, HYBRID, TECNALIA

FUNDED
ReforCELL, FP7/2007-2013: Fuel Cells and Hydrogen Joint Technology Initiative

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

START OF THE PROJECT
2012

INFORMATION
M van Sint Annaland
040 247 2241
M.v.SintAnnaland@TUe.nl

F Gallucci
040 247 3675
F.Gallucci@tue.nl
www.chem.tue.nl/smr

PROJECT AIM

The aim of ReforCELL is to develop a novel, cheaper and more efficient multi-fuel membrane reformer for pure hydrogen production in order to intensify the process of hydrogen production through the integration of reforming and purification in one single unit. The research activity is focused on the lab scale design, construction and testing of novel reactors (membrane micro-channel reactor and membrane assisted micro-fluidized bed). The objectives are:

- Selection of ATR-CMR components: catalysts, membranes and supports, and sealing.
- Integration of these elements in lab scale reactors specifically designed for ATR.
- Validation of the lab scale reactors performances and identification of the best design for a prototype pilot.

The design of the reactor will be supported by a modeling task to identify the most suitable reactor configuration, with information on catalysts and membranes. Modeling will also set guidelines for required properties of the catalysts and membranes.

PROGRESS

Fabrication of several stainless steel microreactors.

Synthesis and characterization (BET, ICP, TEM) of Rh/ZrO2 catalyst.

Reactions of ATR of methane will be performed in the next months. The integration of the membrane will be take into account as soon as the permeation tests will be done.

Kinetics analysis, together with stability study of Ni/Al2O3 and Rh/ZrO2 catalysts has been performed (SRM, TOX And ATR reactions) and compared with Numagughi model.

Development of a 1D pseudohomogeneous model for fixed-bed and coated-wall microreactor and validation of the model with the experimental data obtained making the reaction in the microreator.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

SS microreactor module without membrane integration, made for ATR tests (TU/e)

Cutting bubbles. The coalescence and break-up of bubbles on micro scale

Project Aim

Bubbles that rise in a bubble column have the tendency to coalesce. This reduces the interfacial area with respect to the volume of the gas. To reduce the loss of interfacial area, a wired mesh is introduced in the column. This mesh will introduce the break-up of bubbles. In this research, the effect of the coalescence and break-up of the model due to the wired mesh is studied using Direct Numerical Simulations. The results of the simulations will be validated using clean experiments. The experiments will be performed in well defined environments for increasingly complex wire configurations.

Progress

The Volume of Fluid method has been extended to enable the simulation of the formation of bubbles at an inlet. Furthermore, the surface tension model of the Volume of Fluid method has been improved using a height function. Furthermore, the Front Tracking method was combined with the Immersed Boundary method developed by Kriebitzsch et al. (2012). The resulting code was used to simulate dense bubble slurry flows. Moreover, an experimental technique was developed to study the interactions between two bubbles. This technique has been used to study the coalescence of bubbles in a viscous medium.

Dissertations

-

Scientific Publications

-

Projectleaders

NG Deen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

MW Baltussen, JAM Kuipers

Cooperations

-

Funded

European Research Council

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

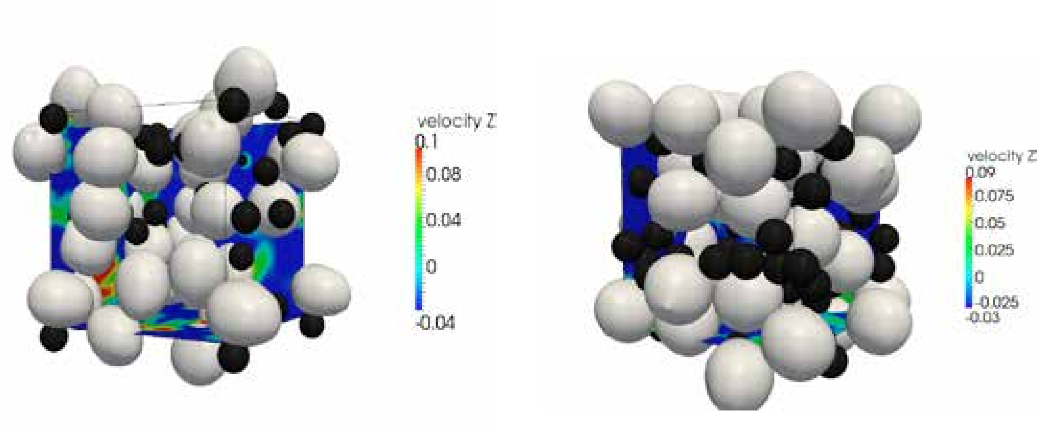
Start of the project

2011

Information

JAM Kuipers
040 247 4158
J.A.M.Kuipers@TUe.nl
www.chem.tue.nl/smr

Snapshots of a simulation with a void fraction of 20% and particle fraction 2.5% (left) and a void fraction of 30% and particle fraction 7.5% (right).



PROJECTLEADERS
M van Sint Annaland

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
HM Slagter

COOPERATIONS
-

FUNDED
Dutch Polymer Institute

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

START OF THE PROJECT
2010

INFORMATION
HM Slagter
040 247 3685
h.m.slagter@tue.nl

PROJECT AIM

The main objective of this PhD research is to fundamentally understand and quantitatively describe the complex interaction between hydrodynamic properties of the fluidized bed (bubble size distributions, solids velocity patterns, etc.) and sorption and transport phenomena in/around polymer particles. A combined computational and experimental approach is followed. In-house developed CFD models will be adapted to account for sorption and swelling effects of the particles and their influence on the collision parameters and used to investigate their influence on the hydrodynamic behavior of the fluidized bed. For the validation of the numerical models, a pseudo 2D fluidized bed is constructed to enable application of detailed non-invasive optical measuring techniques like PIV and DIA to obtain hydrodynamic information on the bubble and emulsion phases simultaneously under sorption conditions.

PROGRESS

The influence and importance of the collisional parameters (normal and tangential restitution and particle friction), temperature and swelling are investigated in detail with a Discrete Particle Model. With several measurement techniques the behavior of LLDPE particle under influence of sorption and temperature are researched. Moreover, a pseudo-2D bed is constructed to investigate the effects of sorption on the hydrodynamic characteristics.

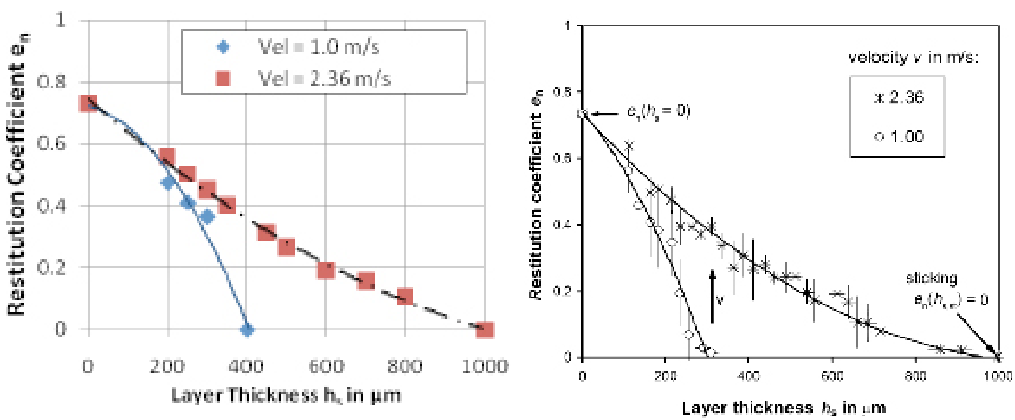
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Simulation results (left); Experimental results (right) Ref. Antonyuk et al. 2009; Influence of impact velocity on restitution coefficient of Al2O3 granules impacting on water layers with varying thickness



Membrane-assisted micro-fluidized beds: An experimental and numerical study on the hydrodynamics and mass transfer

Project Aim

The objective of this research is to design a micro-fluidized bed membrane reactor for ultra-pure H2 production based on studies in concerted action by detailed simulations using advanced fundamental models and advanced experimental techniques.

Progress

1) Simulation studies on the effect of gas permeation on the hydrodynamic characteristics of membrane-assisted micro-fluidized beds, especially the effect of gas extraction on the formation of densified zones has been investigated and quantified in detail. Results show qualitatively good agreement with experimental findings.

2) Experimental studies on gas back-mixing and gas mixing with influence of gas permeation via flat membranes in a micro-fluidized bed have been carried out, as well as mass transfer in bubbling fluidized beds with a novel IR technique.

Dissertations

-

Scientific Publications

1. J.F.de Jong, T.Y.N.Dang, M.van Sint Annland, J.A.M.Kuipers, Comparison of a Discrete Particle Model and a Two-Fluid Model to Experiment of a fluidized bed with Flat Membranes- Powder Technology230, p. 93-105, 2012.
2. Tan L. and van Sint Annaland, M., 2012. Simulation study on the hydrodynamic characteristics of membrane-assisted micro-fluidized beds. 9th international Conference on CFD in Minerals and Process Industries CSIRO, Melbourne, Australia. Online.

Projectleaders

M van Sint Annaland, F Gallucci

Researchtheme

Complex structures of fluids

Participants

M van Sint Annaland, F Gallucci, N Dang, L Tan

Cooperations

-

Funded

STW

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

Start of the project

2009

Information

M van Sint Annaland
040 247 2241
M.v.SintAnnaland@TUe.nl
www.chem.tue.nl/smr

Direct numerical simulation of particulate flow with heat transfer

Projectleaders
JAM Kuipers

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
H Tavassoli, EAJF Peters

Cooperations
-

Funded
European Research Council

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

Start of the project
2010

Information
JAM Kuipers
040 247 4158
J.A.M.Kuipers@tue.nl
www.chem.tue.nl/smr

Project Aim

The objective of this project is to investigate numerically the heat transfer characteristics inside packed and fluidized beds. Non-isothermal flows through a random array of (non-)spherical particles are simulated using direct numerical simulation. According to the detailed flow and temperature fields, an average heat transfer coefficient is estimated in terms of packing fraction, Reynolds number and particle shape.

Progress

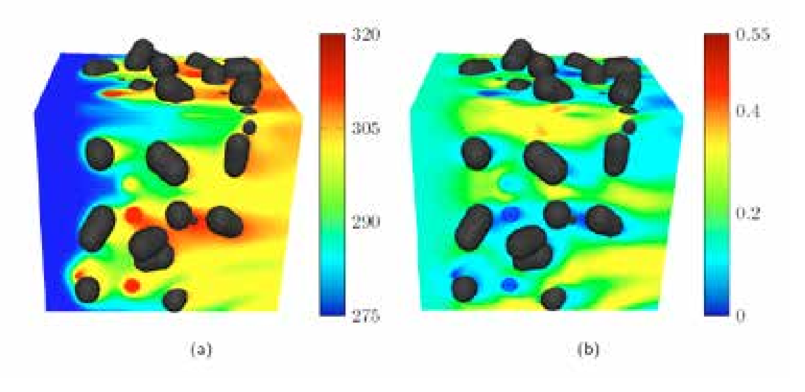
Direct numerical simulations are conducted to characterize the fluid-particle heat transfer in dense arrays of non-spherical particles. In this study, we employed the Immersed Boundary method to simulate non-isothermal flow through a complex geometry (i.e. a random array of non-spherical particles). The non-spherical particle used in present study is a sphero-cylinder with the diameter D and length L. Three different aspect ratios (L/D) of 2, 3 and 4 are investigated to determine the effect of the aspect ratio on the fluid-particle heat transfer. The results are compared to the well-known correlation (i.e. Gunn) for heat-transfer of spherical particles by introducing an effective diameter for the non-spherical particles.

Dissertations

-

Scientific Publications

-



Computed fluid [a] temperature (K) and [b] velocity (m/s) distributions in a random array of sphero-cylindrical particles. (Re = 13.572, L = D = 2 and packing fraction = 0.1)

Bubbles on the cutting edge: Experimental investigation on micro-structured bubble columns

Project Aim

The aim of the project is to construct a laboratory scale micro-structured bubble column reactor with a wire mesh to demonstrate proof of principle. The impact of wire mesh on bubble cutting, hydrodynamics characteristics will be studied in-depth experimentally using advanced measurement techniques such as Laser Doppler Anemometry and X-ray tomography. X-ray tomography experiments will be done in co-operation with HZDR, Dresden, Germany. The reaction enhanced mass transfer will also be studied for the case of CO_2 in NaOH to determine interfacial area and mass transfer coefficient.

Progress

Bubble column reactor design with a wire mesh insert is in progress and construction will proceed in the following period. Preliminary experiments have been done with Laser Doppler Anemometer for the case of a bubble column without wire mesh and it will be extended in future. The technique for measuring the mass transfer characteristics in the bubble column reactor is also being developed.

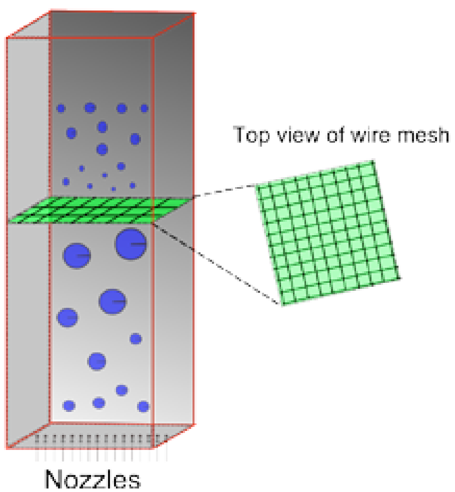
Dissertations

-

Scientific Publications

-

Schematics of bubble cutting in a Micro-Structured bubble column (MSBC)



Projectleaders

NG Deen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

K Thiruvalluvan Sujatha,
JAM Kuipers

Cooperations

HZDR, Dresden, Germany

Funded

European Research Council

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

Start of the project

2012

Information

NG Deen
040 247 3681
040 247 4931
N.G.Deen@TUe.nl
www.tue.nl/staff/N.G.Deen

Predictive modeling of polyolefin reactors

Projectleaders
JAM Kuipers

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
Z Li, M Banaei, NG Deen, M van Sint Annaland

Cooperations
-

Funded
Dutch Polymer Institute (DPI)

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

Start of the project
2012

Information
JAM Kuipers
040 247 4158
J.A.M. Kuipers@tue.nl
www.chem.tue.nl/smr

Project Aim

It is well known that the fluid dynamic behavior of the solids phase in a fluidized bed reactor has a profound influence on the heat management and consequently the performance of the reactor (i.e. the productivity) and the quality of the product. The fluid dynamics strongly depends on the particle properties, i.e. size distribution, density, restitution coefficient and stickiness. The particle properties in turn depend on the reaction kinetics, the sorption characteristics and liquid injection. This project is aimed to extend the discrete particle model and multi-fluid model with heat and mass balances to obtain an accurate description of polymerization processes on a lab-scale system and bench scale system under actual process conditions, i.e. involving reaction, significant heat production and high pressures.

Progress

The discrete particle model (DPM) is adapted to include liquid injection, and heat and species balances to accommodate chemical reactions. At first we will assume a simple heat source mimicking the exothermic process. In a later stage, this will be extended to a more realistic kinetic model in close collaboration with the industrial partners.

Dissertations

-

Scientific Publications

-

Polydispersed granular flows through inclined channels

Project Aim

The aims of the project are :

- To study the flow behavior of polydisperse granular particles on non-rotating and rotating chute.
- Prediction of influences of polydispersity and non-uniformity of the particles, on flow characteristics
- To compare the discrete particle model (DPM) simulation results with experimental measurement.

Progress

The rotating chute flow setup has been built to investigate flow behaviour monodisperse and bidispersed granular flow through inclined rotating chute. The experiemnts has been performed for monodisperse granular flow for different angles of inclination and rotation rates of the chute. The bed and surface particle velocity in the chute is measured using electronic ultrasonic height sensors and Particle image velocimetry (PIV). Particle Tracking Velocimetry is now used to get more detailed surface flow information.

Dissertations

-

Scientific Publications

1. Shirsath, S.S., Padding, J.T., Clercx, H.J.H. & Kuipers, J.A.M. (2012). Modelling of granular flows through inclined rotating chutes using a discrete particle model. Presentation and published conference proceeding of the Ninth International Conference on CFD in the Minerals and Process Industries, 10-12 December 2012, Melbourne, Australia.

Projectleaders

JAM Kuipers

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

SS Shirsath, JT Padding, HJH Clercx

Cooperations

NG Deen

Funded

STW and Tata Steel

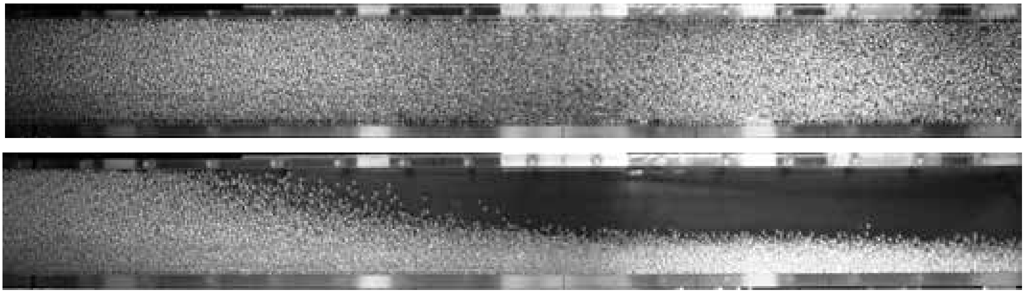
University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2010

Information

JAM Kuipers
040 247 4158
J.A.M.Kuipers@TUe.nl
www.chem.tue.nl/smr



Snapshots of granular material flowing down an inclined chute (top view, flowing from left to right of the picture) at an inclination angle of 30 degrees for rotation rates of 0rpm and 16rpm.

An efficient multi-particle collision approach to large scale dissipative granular and multiphase flow

Projectleaders
JAM Kuipers

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
LJH Seelen, JT Padding

Cooperations
-

Funded

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

Start of the project
2012

Information
LJH Seelen
040 247 3673
l.j.h.seelen@tue.nl

Project Aim

The goal of the project is to obtain a Discrete Particle Method suitable for simulations of large scale granular flows. This method can give more insight into the formation of large scale heterogeneities that form in granular flows. A multi-particle collision dynamics (MPCD) approach will be used to coarse-grain the detail binary collisions that are usually modeled with DPM. This method, together with a GPU based implementation, will allow for the simulation of millions of particles.

Progress

A two 2D version of the original MPCD method has been created and has been used to get acquainted with the method. This Stochastic Rotation Dynamics (SRD) model has been used to reproduce hydrodynamics in both simple flow configurations and more complex flow configurations. This model has been extended to include a biased collision scheme, to simulate non-ideal equations of state. This 2D version of the MPCD method will be the basis for the extension to 3D and will be tuned to simulate an equation of state of a hard-sphere gas.

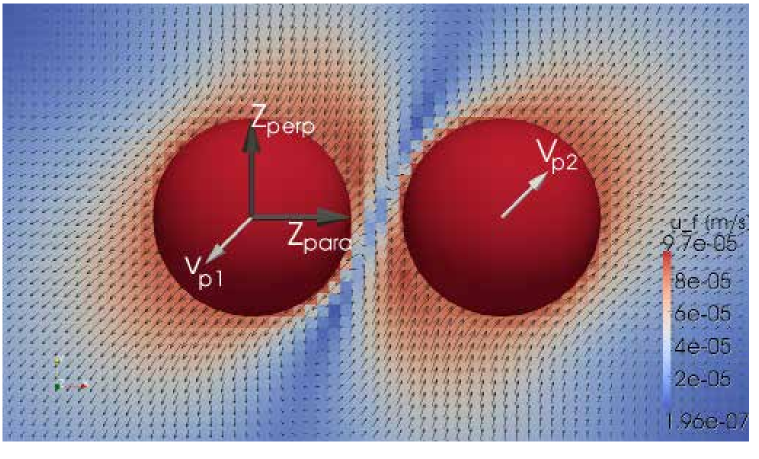
Dissertations

-

Scientific Publications

-

Hydrodynamic interaction of 2 particles



New driving forces for dry fractionation

Project Aim

The project aim is to combine separation methods to enhance the separation (of crude food materials) in terms of energy efficiency. Therefore, it is important that there is no water needed as dehydration of the product is energy intensive. The main focus of the project will lie on the use of tribo-electrification as the base for the separation method. Our partners at WUR will experimentally investigate the tribo-electric charging of pneumatically conveyed powder, while we will do that via a numerical route using CFD-DEM. The combined insights will be used to develop a separator.

Progress

It is shown that electrostatic interaction between the particles will become important for the particles trajectory (and thus their charging behavior) when the particles get charged (by the amount experimentally determined). The same holds for the charge induced at the (conducting) walls which can be modeled by image charges. A cut-off distance is derived in order to keep this computational expensive force within limits. For this cut-off it is derived that the influence of particles beyond this distance will always have a smaller value than some threshold. Furthermore, a literature study on tribo-electrification is performed. This shows that not much is really understood of this phenomenon making it hard to implement a valid model. However, first attempts are made, showing promising results.

Dissertations

-

Scientific Publications

-

Projectleaders

JAM Kuipers

Researchtheme

Complex structures of fluids

Participants

MJT Padding (TU/e), J Wang (WUR), M Schutyser (WUR)

Cooperations

-

Funded

STW

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

Start of the project

2011

Information

M Korevaar,
040 247 3674
m.w.korevaar@tue.nl

Numerical and experimental study of cylindrical fluidized beds

Projectleaders
JAM Kuipers
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
Vikrant, NG Deen, JT Padding
Cooperations
HZDR, Germany
Funded
European Research Council

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

Start of the project
2010
Information
JAM Kuipers
040 247 4158
J.A.M.Kuipers@TUe.nl
www.chem.tue.nl/smr

Project Aim

Aim of this project is to develop a Two fluid model (TFM) for fluidized beds in the cylindrical coordinate with advance numerical and computational approach. This approach will enhance the system in terms for computational complexity and lead to fast and robust computer simulations of fluidized beds even for larger dimensions geometry. Experiments are performed in collaboration with HDZR, Dresden Germany, using X-ray Tomography technique to study flow dynamic in a cylindrical fluidized beds. This experimentation results will be used to validate results from developed TFM. Further extending model for heat transfer and placement of internals inside the gas-solid fluidized beds.

Progress

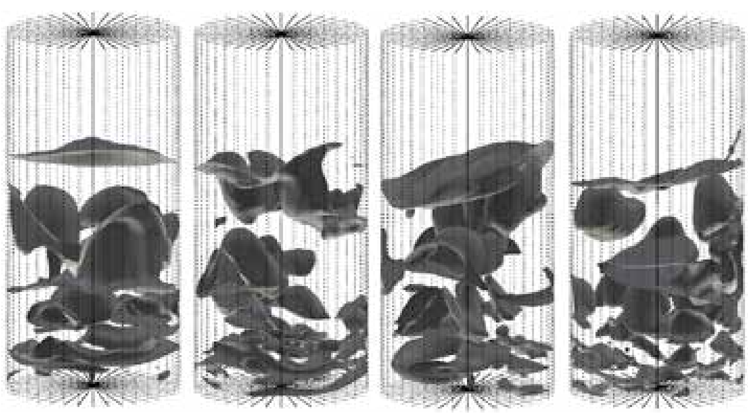
Two-fluid model (TFM) using KTGF theory for fluidized bed in cylinderical coordiantes is developed with advance numerical and computational approach. TFM is used to study bubble formation at a central orifice in a gas-solid fluidized bed. X-ray tomography (XRT) experiments were conducted at HZDR, Germany. Exprements resulst shows good agreement with litrature correlations. Simulations are performed using TFM for XRT experimental setting and comparion is made. Detailed bubbles characterstics in the fluidized beds are under investigations. Simulations are also performed for large scale fluidized bed to comapre experimental results of Laverman et al. 2012. Higher pressure fluidization using TFM simulations is under progress.

Dissertations

-

Scientific Publications

-



Bubbles iso-surface for LLDP particles predicted from Two-fluid model simulations.

A combined experimental and computation study of the dense granular flow in the spray dryer

Project Aim

The main objective of this research is to develop a simulation tool that can provide the particle size, velocity and flux distribution for a highly turbulent gas flow section of a large-scale spray dryer. These results ought to be used as boundary conditions for coarse-grained simulations. For this purpose, we will use an Eulerian-langrangian approach, while considering the various phenomena of collisions, coalescence and agglomeration between droplet-droplet, droplet-particle and particle-particle combinations in a highly turbulence gas flow at the top section (near the nozzle) of a spray dryer.

Progress

We implemented the stochastic modified direct simulation Monte Carlo modelling approch in code. For the validation of that model, we simulated the same cases in a deterministic (Discrete Particle) simulation and compared the collision frequency with the one predicted by DSMC. The results are in good agreement. After the implementation of the particle collision model, we turned to implementation of a droplet-droplet collision model. We simulated a single spray nozzle using a droplet-droplet collision model and compared our outcome with experimental results provided by Tetra Pak. For turbulent gas jet flow, we implemented a sub grid scale model (SGS) in the flow solver. Simulations of a turbulent jet reveal that the velocity profile is in good agreement with the existing literature data on turbulent jets.

Dissertations

-

Scientific Publications

1. S.K. Pawar, J.T. Padding, N.G. Deen, J.A.M. Kuipers, A. Jongsma and F. Innings, “Eulerian-Lagrangian modelling with stochastic approach for droplet-droplet collisions” Ninth International Conference on CFD in the Minerals and Process Industries CSIRO, Melbourne, Australia 10-12 December 2012 , Conference proceeding.

Projectleaders

JAM Kuipers

Researchtheme

Complex dynamics of fluids

Participants

SK Pawar, JT Padding, NG Deen

Cooperations

-

Funded

Tetra Pak

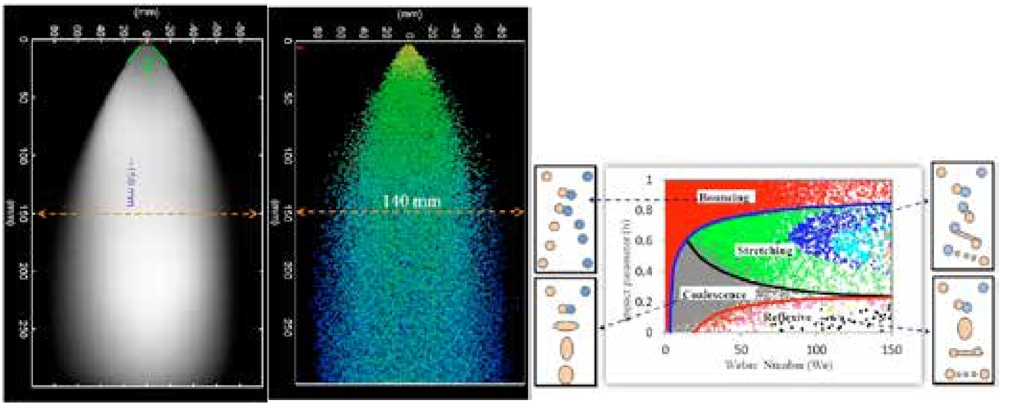
University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2010

Information

JAM Kuipers
040 247 4158
J.A.M.Kuipers@TUe.nl
www.chem.tue.nl/smr



a) snap shot of the experimental results of single spray nozzle. b) snap shot of the simulation results of single spray nozzle. c) Validation of the droplet-droplet collision model with literature data.

Multi-scale modeling of mass and heat transfer in dense gas-solid flows: Direct Numerical Simulations

Projectleaders
JAM Kuipers

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
EAJF Peters, SHL Kriebitzsch, MA van der Hoef

Cooperations
-

Funded

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

Start of the project
2011

Information
JAM Kuipers
040 247 4158
J.A.M.Kuipers@TUe.nl
www.chem.tue.nl/smr

Project Aim

This project is aimed at providing a comprehensive understanding of large-scale dense gas-solid flows based on first principles, which means the exchange of mass, momentum and heat at the surface of the individual solid particles.

Progress

Immersed Boundary Method (IBM) is applied to perform direct numerical simulations (DNS) of gas-solid flows. Our code was firstly verified by modeling the stokes flow around a single sphere, which has a theoretical solution of the drag force. However, the IBM results are found being grid-independency. Therefore, a methodology has been proposed to obtain grid-independent results of IBM simulations. This methodology is by far demonstrated by applying it for the flows in random arrays at Reynolds number 50 and 100.

Dissertations

-

Scientific Publications

-

Heat transfer in dense particulate flow, an experimental study to particle fluid closure relations

Project Aim

The primary objective of this study is to develop new experimental techniques to study particle-fluid heat transfer. The second goal is to use these techniques to complement and validate the knowledge gained with the multi-scale modelling approach.

Progress

In the past few months a thorough study of the literature has been done and a problem definition has been made. A review of possible experimental techniques has been given and concrete plans on the experimental setups and techniques have been made. The dimensions of the setup have been calculated and the possible constraints determined. The first few experiments are in the pipeline and will be ready to be studied starting middle of February 2013.

Dissertations

-

Scientific Publications

-

Projectleaders

JAM Kuipers

Researchtheme

Complex dynamics of fluids

Participants

KA Buist, NG Deen

Cooperations

-

Funded

European Research Committee

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

Start of the project

2012

Information

KA Buist
040 247 5740
K.A.Buist@tue.nl
www.tue.nl

Projectleaders
JAM Kuipers
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
EAJF Peters
Cooperations
-
Funded

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

Start of the project
2010
Information
A Patil
040 247 5582
A.V.Patil@tue.nl

Project Aim

The aim of the project is to extend the multi-scale modeling of gas-fluidized beds with mass and heat transfer, where previously only momentum transfer between the gas and solid phase was considered.

Progress

A heat transfer model for fluidized bed was implemented with heat transfer coupling between gas and particles in fluidized beds. The developed heat transport model is verified by comparisons with analytical equation before being put to use for fluidized bed study. In relation to verification, the model is verified by matching with a simple 1D coupled heat differential equation for two phase discretization and analytical equation obtained by its integration. Using the developed model bubble injection was performed in 2D bed with different injection temperature. This work contains a study of the formation and rise of hot gas bubbles in beds. This includes variations with changing particle sizes and injection temperatures. The mass flux of bubble is fixed to observe the changes in the formed bubble due to temperature. These simulation runs are also being extended for 3D systems having 3D bubbles. A part from this heat transfer between particles due to direct contact is being developed and implemented.

Dissertations

-

Scientific Publications

-

Prof.dr. WJ Briels

The Computational BioPhysics group (CBP) at the University of Twente is interested in the rheological and thermodynamical properties of complex soft matter. Typical multiphase systems being studied include dispersions of hard particles, e.g. spherical colloids or rod-like fd virusses, dispersed in Newtonian and non-Newtonian liquids. Close to equilibrium, the rheological properties are determined by the structural properties of the dispersed phase. Since these structures are usually stabilized by free energies in the order of several kT, they can easily be perturbed by applying flow gradients, which thus give rise to flow-induced modifications of the rheological properties. Well known phenomena resulting from this interplay between structure and flow are shear thinning, shear banding and temporal oscillations of optical and rheological properties in liquid crystalline polymer solutions. Self-assembly plays an important role in a number of systems being studied, ranging from surfactant-based worm-like micelles and lipid bilayers to various proteins that form neatly ordered structures, e.g. fibers and cages, or merely aggregate into disordered protein plaques. We are also interested in the rheology of linear and branched polymersm, and the role played herein by entanglements.

The tools that we use belong to the field of particle based computer simulations. Since a full description of the observed phenomena requires a multi-scale approach, our simulation methods range from Molecular Dynamics (MD) and Monte Carlo (MD) to Multi Particle Collision Dynamics (MPCD) and Brownian Dynamics (BD). Detailed atomistic simulations are used to calculate the free energies that constitute the main interactions in subsequent simulations at a mesoscopic level. Our main strength is in developing new methods for (highly) coarse-grained simulations. We have, for instance, developed the twentanglement algorithm to investigate entangled melts of linear and branched polymers, introduced event-driven BD algorithms to simulate colloidal suspensions, developed Responsive Particle Dynamics (RaPiD) to study the flow properties of several non-linear fluids, and extended the patchy-particle approach to non-spherical particles to simulate self-assembly of protein clusters.

A single-molecule view on protein aggregation (SMPA)

Project Aim

The goal of the SMPA consortium, a collaboration of 8 Dutch research groups, is to unravel the physical mechanisms that underlie protein aggregation in the brains of patients suffering Parkinson's disease. To gain insight into the nucleation and growth process, the Computational BioPhysics group will develop a novel highly coarse-grained modeling technique specifically aimed at the secondary and tertiary structure of proteins. This method will be used to simulate and explore the formation and structure of alpha-synuclein aggregates.

Progress

We are developing a highly coarse-grained model in which proteins are represented as short chains of soft particles with patchy interaction sites distributed over their surfaces. To simulate the motions of these particles, we have implemented a Brownian Dynamics algorithm for translational and rotational dynamics. This code has been tested by comparing the simulated translational and rotational diffusion of asymmetric particles against their theoretical behavior. In a second test, we simulated the self-assembly of clathrin, a protein with three long curved legs, into polyhedral cages (see figure).

Dissertations

-

Scientific Publications

-

Projectleaders

WJ Briels, WK den Otter

Researchtheme

Complex structures of fluids

Participants

IM Ilie

Cooperations

-

Funded

FOM

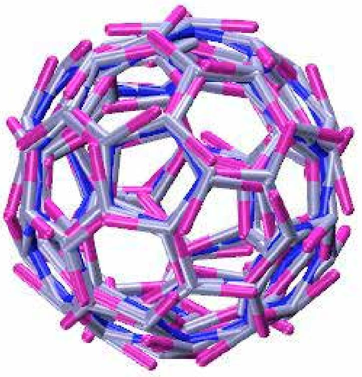
University	-
FOM	100 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2011

Information

WJ Briels
053 489 2947
w.j.briels@utwente.nl
http://cbp.tnw.utwente.nl



Structure formation in colloidal suspensions in flow and near walls

Projectleaders
WJ Briels
Researchtheme
Complex dynamics of fluids
Participants
IS Santos de Oliveira, WK den Otter
Cooperations
JT Padding (TU/e), J Vermant (Leuven, B), JKG Dhont (Julich, D)
Funded
EU - Nanodirect

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

Start of the project
2008
Information
WJ Briels
053 489 2947
w.j.briels@utwente.nl
http://cbp.tnw.utwente.nl

Project Aim

Particle based simulations are used to study structure formation of colloids in various types of solvents and flows. The solvents to be simulated range from simple Newtonian to strongly shear-thinning visco-elastic fluids. Flows envisaged include stationary and oscillatory shear, and elongational flows. Colloids will range from spheres to rods and plates. Besides flow, the influence of walls will be studied as well.

Progress

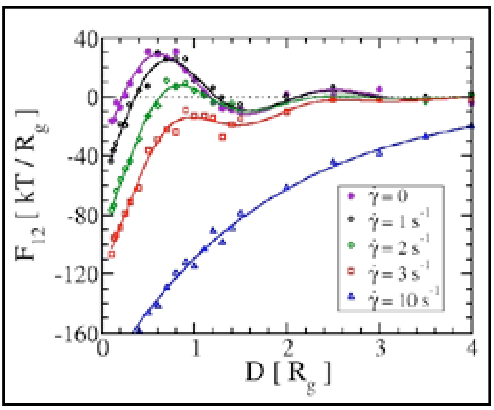
We carried out computer simulations using the Responsive Particle Dynamics (RaPiD) method to investigate bidispersions of colloids in shear-thinning wormlike micellar solutions. The colloids with different sizes distribute homogeneously in the quiescent fluid. Under shear they align in the flow direction. Besides alignment, we also observed that the colloids segregate according to their sizes, forming preferentially monodispersed strings of colloids, in agreement with experimental observations. We investigated the physical origins of alignment and segregation by systematically varying the parameters of the simulated fluids, by analyzing the flow-induced effective colloidal interactions and the density distribution of polymeric particles around the colloids. Wall effects on the distribution of the colloids were also investigated. We observed colloidal migration towards the confining walls in sheared systems.

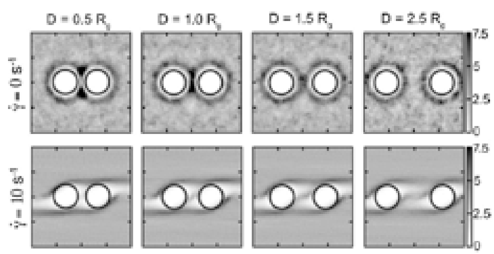
Dissertations

1. I.S. Santos de Oliveira, “Simulations of flow induced ordering in viscoelastic fluids”, PhD Thesis, University of Twente, 2012.

Scientific Publications

1. I.S. Santos de Oliveira, W.K. den Otter and W.J. Briels. The origin of flow-induced alignment of spherical colloids in shear-thinning viscoelastic fluids, J. Chem. Phys. 137, 204908 (2012).





Effective forces between two colloids at various shear rates and separation distances (left). Density distributions around two colloids (right); note the shear-induced depletion between the colloids.

Coarse grained simulations for the study of the rheology and dynamic response in star polymer melts

Project Aim

The aim of this project is to study the complicated rheology of star polymer melts. This is facilitated by using coarse grained simulations where particles are approximated as point particles. The eliminated degrees of freedom are then used to define an appropriate inter-particle interaction potential. In addition to studying the rheology, shear protocols will be developed to study the dynamic response of the star polymer systems..

Progress

Low functionality, or arm, star polymers have been the subject of initial simulation. Rheological data sets provided by experimentalists have been modeled with the coarse-grained algorithm approach. The principal investigation has focused upon the characterization of the star polymer melt through the reproduction of both the storage and loss modulus as well as demonstrating excluded volume effects. Currently shear protocols are being developed to study the shear stress response in the same star polymer melts. The development of an obvious stress overshoot will be of interest in this study. In addition the nonlinear viscoelastic response of the same systems will be also be considered through the application of LAOS. In summary current simulations have reproduced experimental behaviors.

Dissertations

-

Scientific Publications

-

Projectleaders

WJ Briels

Researchtheme

Complex dynamics of fluids

Participants

B Fitzgerald, WK den Otter

Cooperations

Prof. D. Vlassopoulos (Crete)

Funded

ESMI – European Soft Matter Infrastructure

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

Start of the project

2012

Information

WJ Briels,
053 489 2947
w.j.briels@utwente.nl

PROJECTLEADERS
WJ Briels
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
L Liu, WK den Otter
COOPERATIONS
JT Padding (TU/e)
FUNDED
EU- DYNACOP

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

START OF THE PROJECT
2009
INFORMATION
WJ Briels
053 489 2947
w.j.briels@utwente.nl
http://cbp.tnw.utwente.nl

PROJECT AIM

It has been found that the polymer melts with variety of chain architectures, like linear, staror H-shaped etc., possess different dynamic behaviors. Thus to have a good understanding of the properties of polymers concerning with various possible topologies would be of great use to optimize the processing and synthesis techniques from both industrial and scientific perspectives. In this project, we have studied the dynamics and rheological properties of branched polymers under coarse-grain method, which will be experimentally and theoretically analyzed.

PROGRESS

Coarse-grained simulations of entangled polymer melts with different topologies are carried out by extended TWENTANGLEMENT techniques. Based on this approach, we studied the properties of star polyethylene melt B(B3)3 , that consists of one branch point and to which three arms are attached, each consisting three blobs, as shown the sketch in Fig.1. From this work, the structural diffusion of entangled star can be analyzed by the typical blob mean square displacement, presented in Fig.2. Furthermore chain stress relaxation modulus G(t) and star mode relaxations have also been calculated and compared with corresponding linear chains.

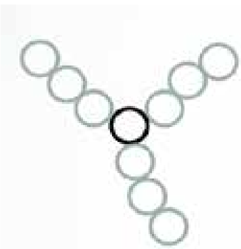
DISSERTATIONS

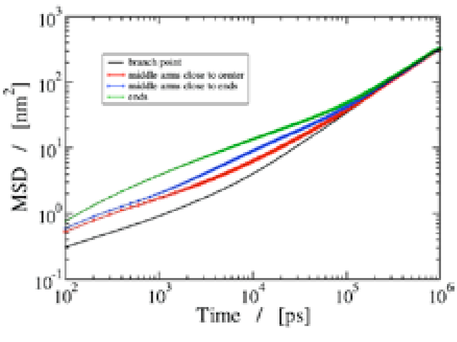
-

SCIENTIFIC PUBLICATIONS

-

Sketch of star $B(B_3)_3$



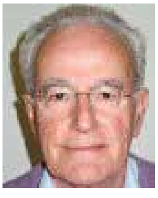


Mean Square Displacement of each blob in star $B(B_3)_3$

Physics of Fluids

Prof.dr. D Lohse

Prof.dr. A Prosperetti



Prof.dr.ir. L van Wijngaarden

Prof.dr. JF Dijksman

Prof.dr.ir. D van der Meer

Prof.dr. R Verzicco

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.

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 Aim

Rayleigh-Bénard convection is a system in which a fluid is heated from below and cooled from the top. This simple system has a large set of applications in astro –and geophysics. When the temperature difference between top and bottom is sufficiently large the system enters a fully turbulent state, where both the boundary layers and the bulk are highly turbulent. It is expected that the heat transfer properties in this regime can be extrapolated towards arbitrary large systems. Experiments have recently entered this so-called ultimate regime and we aim to achieve this in direct numerical simulations as well. This would provide a substantial increase in the knowledge of this ultimate regime, as in simulations all flow field information is available to study the turbulent characteristics, while information from experiments is more limited.

Progress

It is a major computational effort to reach the ultimate regime in direct numerical simulations. To give the reader an idea the highest Ra number simulation so far used about 5 million CPU hours were used in the highest Rayleigh number simulation so far and reaching the ultimate regime requires even requires larger simulations. In order to increase the performance of our simulations a lot work is done on improving the efficiency of the code. This work was awarded the Wim Nieuwpoort award 2012 for the most efficient use of SURF/SARA high performance computing facilities. We have optimized our cylindrical code and created a two-dimensional and a rectangular code. Both the two-dimensional and the rectangular code are faster than the cylindrical code and therefore it is easier to reach the ultimate regime for these cases. In figure 1 a flow is depicted that is not in the ultimate regime. However, the flow is partly turbulent. In the ultimate regime the large spatial and temporal fluctuations, which are now only seen in the corners, will probably occupy the complete horizontal extent of the boundary layer. This increases the heat transfer but unfortunately also increases the computational demands of the simulations.

Dissertations

-

Scientific Publications

1. R.J.A.M. Stevens, Q. Zhou, S. Grossmann, R. Verzicco, K.-Q Xia, D. Lohse, Thermal boundary layer profiles in turbulent Rayleigh-Bénard convection in a cylindrical sample, Phys. Rev. E 85, 027301 (2012).
2. E.P. van der Poel, R.J.A.M. Stevens, K. Sugiyama, D. Lohse, Flow states in two-dimensional Rayleigh-Bénard convection as a function of aspect-ratio and Rayleigh number,

Phys. Fluids 24, 085104 (2012).

3. G. Ahlers, E. Bodenschatz, D. Funfschilling, S. Grossmann, X. He, D. Lohse, R.J.A.M. Stevens, R. Verzicco, Logarithmic temperature profiles in turbulent Rayleigh-Bénard convection, Phys. Rev. Lett. 109, 114501 (2012).
4. R.J.A.M. Stevens, H.J.H. Clercx, D. Lohse, Breakdown of the large-scale wind in aspect ratio Γ= 1/2 rotating Rayleigh-Bénard flow, Phys. Rev. E 86, 056311 (2012).
5. R. Lakkaraju, R.J.A.M. Stevens, R. Verzicco, S. Grossmann, A. Prosperetti, C. Sun, D. Lohse, Spatial distribution of heat flux and fluctuations in turbulent

Projectleaders
D Lohse

Researchtheme
Complex dynamics of fluids

Participants
EP van der Poel, RJAM Stevens, R Lakkaraju, D Lohse

Cooperations
Prof. Dr. H.J.H. Clercx (Eindhoven, Netherlands), Prof. Dr. G. Ahlers (Santa Barbara, USA), Prof. Dr. R. Verzicco (Tor Vergata, Italy), Prof. dr. S. Grossmann, (Philipps-Universität Marburg)

Funded
FOM

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

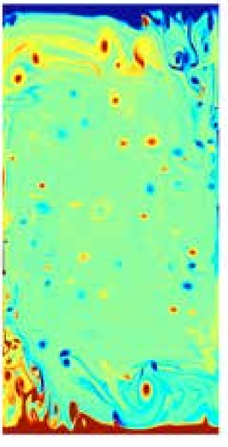
Start of the project
2008

Information

D Lohse
053 489 8076
d.lohse@utwente.nl
pof.tnw.utwente.nl

EP van der Poel
053 489 2487
e.p.vanderpoel@utwente.nl

Rayleigh-Bénard convection, Phys. Rev. E 86, 056315 (2012).
6. Grossmann, S. & Lohse, D., Logarithmic temperature profiles in the ultimate regime of thermal convection, Phys. Fluids 24, 125103 (2012).
7. R. Lakkaraju, R.J.A.M. Stevens, P. Oresta, R. Verzicco, D. Lohse, A. Properetti, Heat transport in boiling turbulent Rayleigh-Bénard convection. Submitted to PNAS.



Instantaneous temperature field of a two dimensional Rayleigh-Benard simulation at Ra=???

The role of vapor/air layer in droplet-surface interactions

Project Aim

(1) To study the air entrainment and splashing processes of impacting droplet on various kinds of surfaces: smooth solid surfaces, micro-structured solid surfaces, solid surfaces covered by a thin liquid film, liquid surfaces,

(2) To study the boiling and hydrodynamic processes of liquid droplets on superheated surfaces, in particular, the role of the vapor layer in affecting the spreading and boiling behaviors of droplets.

Progress

Highlights:

- The color interferometry method to measure the thickness of the air layer under impacting droplet.
- The maximal air bubble entrainment at liquid drop impact.
- The air entraiment process of liquid droplets impacting on liquid pool.
- The impact of droplets on superheated smooth and micro-structured surfaces.
- The splashing threshold of micro-droplets on superheated surfaces.

Dissertations

-

Scientific Publications

1. T. Tran, H. J. J. Staat, A. Prosperetti, C. Sun, and D. Lohse, Drop Impact on Superheated Surfaces, Physical Review Letters 108, 036101 (2012).
2. R. C. A van der Veen, T. Tran, D. Lohse, and C. Sun, Direct measurements of air layer profiles under impacting droplets using high-speed color interferometry, Physical Review E 85 026315 (2012).
3. W. Bouwhuis, R. C. A. van der Veen, T. Tran, D. L. Keij, K. G. Winkels, I. R. Peters, D. van der Meer, C. Sun, J. H. Snoeijer, D. Lohse, Maximal air bubble entrainment at liquid drop impact, Physical Review Letters 109, 264501 (2012).

Projectleaders

D Lohse, C Sun

Researchtheme

Complex dynamics of fluids

Participants

T Tran, D van der Meer, J Snoeijer, E-J Staat, RCA van der Veen, W Bouwhuis

Cooperations

-

Funded

FOM

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

Start of the project

2011

Information

C Sun
053 489 5604
c.sun@utwente.nl
http://pof.tnw.utwente.nl

Supersonic microjets

Projectleaders
D Lohse, C Sun

Researchtheme
Complex dynamics of fluids

Participants
CW Visser, Y Tagawa

Cooperations
TimesLab, Leiden University Medical Center

Funded
FOM

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

Start of the project
2011

Information
Chao Sun
c.sun@utwente.nl
pof.tnw.utwente.nl

Project Aim

(1) To study and optimize the generation of extremely fast laser-induced microjets;

(2) Study the impact of these jets and the impact of jet-generated droplets. In particular, the use for needle-free injection (i.e. shooting the jet through the skin to deliver medicine to humans) will be explored.

Progress

Highlights:

- The impact of fast jets on human skin showed that the laser-induced jetting device is feasible to inject medicine below the human skin.
- The impact of jet-generated microscale droplets up to 100 m/s was investigated. This showed the crucial influence of the boundary layer during droplet impact.
- The formation of the jet was numerically modeled.
- Within the project, Nikolai Oudalov (MSc student) and Martin Klein Schaarsberg (BSc student) successfully graduated. Marise Gielen is currently doing her master project.

Dissertations

-

Scientific Publications

1. Tagawa, Y., Oudalov, N., Visser, C.W., Peters, I., van der Meer, D., Sun, C., Prosperetti, A., and Lohse, D., 2012, “Highly focused supersonic microjet”, Physical Review X, Vol. 2, 031002.
2. Visser, C.W., Tagawa, Y., Sun, C., and Lohse, D., 2012, “Microdroplet impact at high velocity”, Soft Matter, Vol. 8, pp.10732-10737.
3. Tagawa, Y., Oudalov, N., Ghalbzouri, A. El, Sun, C., and Lohse, D., 2013, “Needle-free injection into skin and soft matter with highly focused microjets”, Lab on a Chip (in press), DOI: 10.1039/C2LC41204G (available online: http://pubs.rsc.org/en/content/articlelanding/2013/LC/C2LC41204G).
4. Peters, I. R., Tagawa, Y., Oudalov, N., van der Meer, D., Sun, C., Prosperetti, A., and Lohse, D., 2013, “Highly focused supersonic microjets: numerical simulations”, Journal of Fluid Mechanics, 719, 587.

Enhanced growth of interacting bubbles

Project Aim

The aim of the project is to improve the quantitative understanding of the physical mechanisms involved in gas exsolution and bubble formation under conditions mimicking those encountered in an oil field.

Progress

The growth of a single bubble in a supersaturated solution of CO2 in water has been extensively investigated. An unexpected behavior has been found: the onset of density driven convection around the bubble, caused by the depletion of gas in the medium surrounding the bubble. Two articles are now in preparation; one describing the experimental system designed for this project and the other reporting our findings in the single-bubble growth. A full quantitative understanding of the interaction of the bubble with the surrounding medium is being pursued with the help of numerical simulations in collaboration with Dr. Sugiyama from the University of Tokyo. The growth of several bubbles in close vicinity is now under study.

Dissertations

-

Scientific Publications

-

Projectleaders

D Lohse, A Prosperetti, D van der Meer, C Sun

Researchtheme

Complex dynamics of fluids

Participants

OR Enríquez

Cooperations

Dr. Kazuyasu Sugiyama

Funded

Shell/FOM

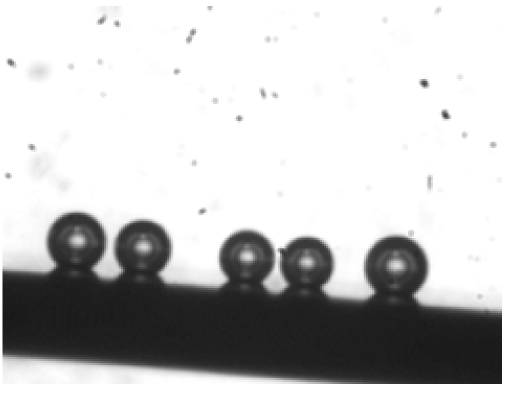
University	-
FOM	100 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2010

Information

D van der Meer
053 489 2387
d.vandermeer@utwente.nl



Carbon dioxide bubbles in water, growing from a line of 5 micro pits etched on a silicon wafer.

Projectleaders
D Lohse, JH Snoeijer,
HJW Zandvliet

Researchtheme
Complex dynamics of fluids

Participants
JRT Seddon, JH Weijs,
RP Berkelaar, E Dietrich, XH Zhang

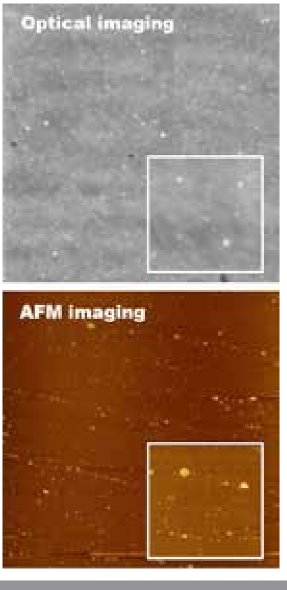
Cooperations
Physics of interfaces and Nanomaterials group, University of Twente, Prof.dr.ir. HJW Zandvliet

Funded
UT, FOM, M2i, TNO, NWO-nano/STW

University	25 %
FOM	25 %
STW	25 %
NWO Other	-
Industry	13 %
TNO	12 %
GTI	-
EU	-
Scholarships	-

Start of the project
2004

Information
D Lohse
053 489 8076
d.lohse@utwente.nl
pof.tnw.utwente.nl



Project Aim

Immersing hydrophobic substrates in water leads to the surprising formation of nanoscopic bubbles adhered to the substrate. These surface nanobubbles are spherical caps, with typical heights and diameters of 15nm and 50nm, respectively. Several fundamental questions exist, for example: (i) Why do surface nanobubbles not disappear through diffusion (they exist for at least 10 orders of magnitude longer than expected for diffusion), (ii) moreover, how do they form, and (iii) how are they affected by substrate topography?

To answer these questions, we are using a combination of experimental, numerical (including molecular dynamics), and theoretical techniques.

Progress

Experimental: A novel technique has been used to optically image nanobubbles. This technique makes it possible to image nanobubbles non-intrusively with a high temporal resolution. In addition, the effect of temperature on the shape and distribution of nanobubbles has been investigated, showing a peak in total nanobubble volume at 33° C. Numerical: A surprising feature of nanobubbles is their universal contact angle. MD simulations show that when a gas layer forms between nanobubble and substrate, this will result in a contact angle which is independent of the substrate. These layers are also observed experimentally and are called micropancakes, after their flat and round geometry. Theoretical: A new theory has been developed which explains the exceptional long life-time of nanobubbles by the fact that the contact-line is pinned and the gas dissolution through the liquid layer is slow.

Dissertations

-

Scientific Publications

1. Nonintrusive Optical Visualization of Surface Nanobubbles. S. Karpitschka, E. Dietrich, J.R.T. Seddon, H.J.W. Zandvliet, D. Lohse, and H. Riegler. Phys. Rev. Lett. 109, 066102 (2012).
2. Formation of Surface Nanobubbles and the Universality of Their Contact Angles: A Molecular Dynamics Approach. J.H. Weijs, J.H. Snoeijer, and D. Lohse. Phys. Rev. Lett. 108, 104501 (2012).
3. Temperature Dependence of Surface Nanobubbles. R.P. Berkelaar, J.R.T. Seddon, H.J.W. Zandvliet, and D. Lohse. Chem. Phys. Chem. 13, 2213 (2012).
4. A Deliberation on Nanobubbles at Surfaces and in Bulk. J.R.T Seddon, D. Lohse, W.A. Ducker, and V.S.J. Craig. Chem. Phys. Chem. 13, 2179 (2012).
5. Weijs, J.H., Seddon, J.R.T. & Lohse, D. Diffusive Shielding Stabilizes Bulk Nanobubble Clusters. ChemPhysChem 13, 2197 (2012).

Fluid dynamics in EUV Sources

Project Aim

The aim of the project is to provide fundamental understanding of fluid dynamics in EUV sources in order to increase the conversion efficiency of the next generation lithography machines. Topics of this work include droplet generation, coalescence dynamics, target shaping, plasma droplet interaction, interaction of gas flows with droplet trajectory, process stability and splashing. The project has an experimental focus, supported by theory and numerical modeling.

Progress

A basic droplet generation setup with imaging system has been build. The first results are now being analysed.

Dissertations

-

Scientific Publications

-

Projectleaders

D Lohse, JF Dijksman

Researchtheme

Complex dynamics of fluids

Participants

P Sleutel

Cooperations

Ramin Badie (ASML), Herman Wijshof (Oce, NanonextNL)

Funded

NanonextNL

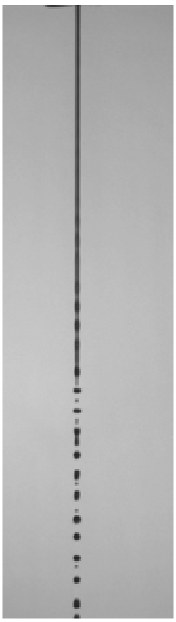
University	-
FOM	-
STW	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

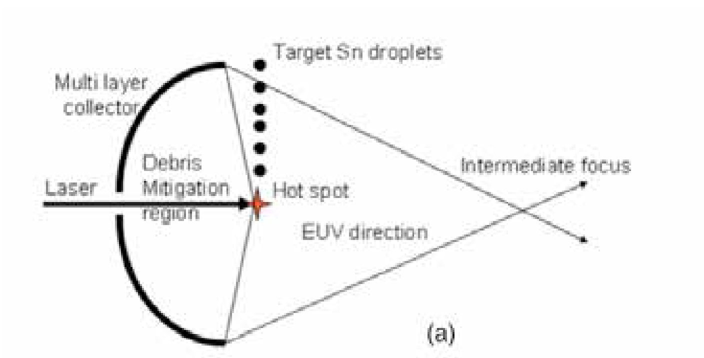
Start of the project

2012

Information

P Sleutel
053 489 4213
c.p.sleutel@utwente.nl
http://pof.tnw.utwente.nl





Air entrapment and drop formation in drop on demand inkjet printing

Projectleaders
D Lohse, M Versluis, JF Dijksman

Researchtheme
Complex dynamics of fluids

Participants
T Driessen, M van der Meulen, E Staat

Cooperations
Océ Technologies:
H Reinten, H Wijshoff, M van den Berg, A van der Bos
ACFD-consultancy:
R Jeurissen

Funded
Océ Technologies, STW, FOM, HiPrins

University	-
FOM	17 %
STW	33 %
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2009 - T Driessen
2011 - M van der Meulen
2012 – E Staat

Information
TW Driessen
TWDriessen@tnw.utwente.nl

MP van der Meulen
m.p.vandermeulen@tnw.utwente.nl

HJJ Staat
H.J.J.Staat@tnw.utwente.nl

D Lohse
053 489 8076
d.lohse@utwente.nl
http:// pof.tnw.utwente.nl

Project Aim

A bubble that is entrained in the ink channel of a piezo-driven inkjet print head can lead to malfunction. This project works on a method to understand the air entrapment at the nozzle. To complement the acoustic measurements, visual recordings of the droplet formation and air-entrapment are being done with high-speed cameras. In another part of the project the acoustics and the free surface dynamics of the ink that has left the nozzle are analyzed experimentally, analytically and numerically, in order to optimize the drop formation process.

Progress

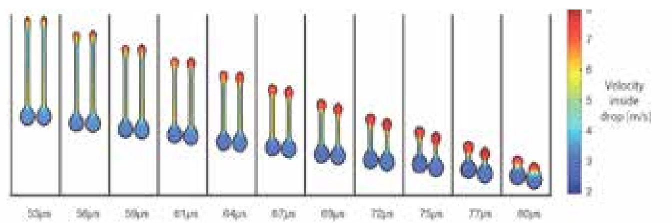
To find the relevant parameters for the droplet formation process, a second order accurate droplet formation model was developed, in which both droplet coalescence and separation can be simulated. Preliminary results from the comparison of detailed experiments with the model are shown in the figure below. In order to compare the experimental results with the numerical results, very high experimental accuracy in the imaging of the drop formation process is essential. For this cause a Laser induced fluorescence setup (iLIF) has been developed, which is capable of delivering a spatially incoherent light pulse of 6 nanoseconds. This method provides enough light to zoom in and exclude motion blur at the same time.

Dissertations

-

Scientific Publications

-



The result of the matching, $\sigma = 35 \pm 2$ mN/m, and a viscosity of $\nu = 9 \pm 3$ mm^2/s.

PROJECT AIM

Taylor-Couette (TC) flow is the flow between two coaxial, independently rotating cylinders. As it is a closed system, global transport balances can be established, which give more insight into the fundamental behavior of the flow, as they reflect the interplay of bulk and boundary layer. TC can be seen as an angular velocity transport from the inner to the outer cylinder. We want to further elucidate the analogy with Rayleigh Bénard, by both numerical simulations and experiments using the T3C setup, for independently rotating inner and outer cylinders. We want to reveal scaling laws for the torque and other system responses. Recent experiments have revealed an optimum transport at a certain counterrotation rate, which we want to reproduce numerically, as well as trying to reproduce this maximum experimentally at different geometries. Also we want to study the boundary layers, and local transport.

PROGRESS

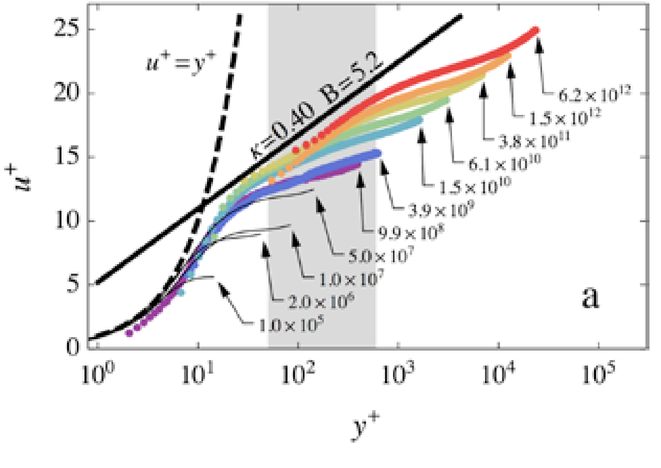
We measured the local flux using PIV and published an article detailing the wind Reynolds number as a function of Taylor number. Additionally we have added LDA measurements to our setup and related the optimal transport also to local features of the flow. Furthermore, experiments have been performed that measured the velocity boundary layer profiles in the Taylor-Couette geometry and a publication has been written, and submitted.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Gils, D. P. M. van, Huisman, S.G., Grossmann, S., Sun, C. & Lohse, D. Optimal Taylor–Couette turbulence. J. Fluid Mech. 706, 118 (2012).
2. Huisman, S.G., Gils, D.P.M. van, Grossmann, S., Sun, C. & Lohse, D. Ultimate Turbulent Taylor-Couette Flow. PRL 108, 024501 (2012). See also: Viewpoints in Physics 5, 4 (2012).
3. Huisman, S.G., Gils, D.P.M. van & Sun, C. Applying Laser Doppler Anemometry inside a Taylor-Couette geometry - Using a ray-tracer to correct for curvature effects.Eur. J. Mech. - B/Fluids 36, 115 (2012).



PROJECTLEADERS
D Lohse, C Sun

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
SG Huisman, R Ostilla Monico, R Verzicco, S Grossmann

COOPERATIONS
-

FUNDED
University of Twente, STW

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

START OF THE PROJECT
2008

INFORMATION

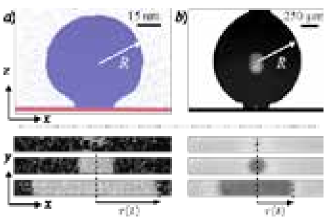
D Lohse
053 489 8076
d.lohse@utwente.nl
pof.tnw.utwente.nl

Inertial contact lines: how wetting affects large scale flows

Projectleaders
JH Snoeijer
Researchtheme
Complex dynamics of fluids
Participants
A Eddi, W Bouwhuis, JF Hernandez-Sanchez, K Winkels, J Weijs
Cooperations
-
Funded
NWO VIDI, Lam Research

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

Start of the project
2011
Information
JH Snoeijer
053 489 3085
j.h.snoeijer@utwente.nl
http://pof.tnw.utwente.nl



Project Aim

The "contact line", the separation between fluid domains on a solid surface, is highly susceptible to instabilities, rendering it difficult to manipulate in the presence of fast flows. The motion of the contact line might be so fast that the inertia (or kinetic energy) dominates over viscous friction. These "inertial contact lines" are barely explored experimentally or in theory, and we aim at providing new fundamental insight into what is happening in the fluid near the contact line at small scales as well as relating it to its consequences into the macroscopic flow.

Progress

We investigated the very first stages of spreading of a water droplet on a partial wetting substrate, using Molecular Dynamics simulations and experimental measurements. In the experiments, we found that shortly after contact spreading exhibits universal behavior, dominated by inertia. These universal dynamics are independent of the equilibrium contact angle. Only at later stages a deviation starts to occur depending on the wetting characteristic of the substrate. We then experimentally investigated the coalescence of viscous drops on a substrate. We identified an initial self-similar regime with a linear growth of the liquid bridge connecting the two drops. A lubrication analysis based on thin-film equations explains quantitatively the experimental observations. We also theoretically study 'pouring flows' bending from a solid surface theoretically. Applying viscous or potential corner flow solutions results in estimations for the forces on the free surface, that can be used to predict dynamical wetting transitions in the inertial regime. Finally, we studied bubble entrapment during drop impact. Surprisingly, there is an optimal impact speed that generates a maximum bubble size – this speed can be predicted from scaling arguments.

Dissertations

-

Scientific Publications

1. K.G. Winkels, J.H. Weijs, A. Eddi and J. H. Snoeijer, Universal spreading dynamics of liquid drops on partially wetting surfaces, Phys. Rev. E 85, 055301(R) (2012).
2. A. Marchand, T.S. Chan, J.H. Snoeijer and B. Andreotti, Air entrainment by contact lines of a solid plate plunged into a viscous fluid, Phys. Rev. Lett. 108, 204501 (2012).
3. J.F. Hernandez-Sanchez, L.A. Lubbers, A. Eddi and J.H. Snoeijer, Symmetric and asymmetric coalescence of drops on a substrate, Phys. Rev. Lett., 109, 184502 (2012).
4. W. Bouwhuis, R.C.A. van der Veen, T. Tran, D.L. Keij, K.G. Winkels, I.R. Peters, D. van der Meer, C. Sun, J.H. Snoeijer and D. Lohse, Maximal air bubble entrainment at liquid drop impact, Phys. Rev. Lett., 109, 264501 (2012).

Project Aim

The goal of the project is to characterize and quantify bubble clustering in turbulent flows. Novel experimental techniques such as 3D Particle Tracking Velocimetry (PTV) and Phase Sensitive Constant Temperature Anemometry (CTA) are employed for this study. The experimental results will provide useful information for comparison with numerical simulations: closures of front tracking DNS and point-particle simulations.

Progress

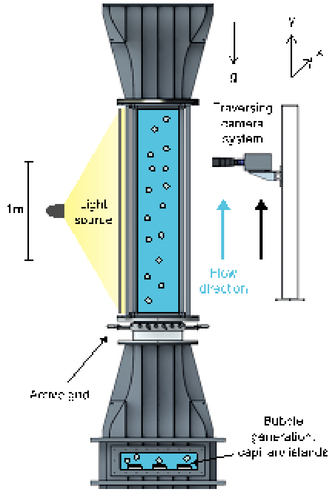
We have studied the Lagrangian acceleration statistics of light particles in nearly homogeneous and isotropic turbulence. Micro-bubbles with a diameter 340 μm, and also finite-sized bubbles with diameter 3mm were dispersed in the turbulent Twente Water Tunnel. The Particle Tracking Velocimetry (PTV) technique was used (both 3D and 2D) to obtain the Lagrangian trajectories of the bubbles at different Reλ. We study the Lagrangian velocity and acceleration statistics of these light particles and compare our results with numerical simulations. We also studied the clustering behavior of inertial particles (light, neutral and heavy) in homogeneous isotropic turbulence using a 3D Voronoi Analysis. We also conduct a 3D Lagrangian Voronoi analysis for the first time. We also applied the 3D Voronoi analysis to study freely rising deformable bubbles. Here, we quantified two different types of clustering morphologies - a regular lattice arrangement and irregular clustering.

Dissertations

-

Scientific Publications

1. V. N. Prakash, Y. Tagawa, E. Calzavarini, J. M. Mercado, F. Toschi, D. Lohse, and C. Sun, "How gravity and size affect the acceleration statistics of bubbles in turbulence", New J. Phys, 14, 105017 (2012).
2. J. M. Mercado, V. N. Prakash, Y. Tagawa, C. Sun, and D. Lohse, "Lagrangian statistics of light particles in Turbulence", Phys. Fluids, 24, 055106 (2012).
3. Y. Tagawa, J. M. Mercado, V. N. Prakash, E. Calzavarini, C. Sun, and D. Lohse, "Three-dimensional Lagrangian Voronoi analysis for clustering of particles and bubbles in turbulence", J. Fluid Mech, 693, 201-215 (2012).



Projectleaders

D Lohse

Researchtheme

Complex dynamics of fluids

Participants

VN Prakash, Y Tagawa, J Martínez Mercado, C Sun

Cooperations

AKZO-Nobel, Corus, DSM, Shell, Prof. J.A.M. Kuipers and M. van Sint Annaland TU/e, Prof. Federico Toschi TU/e

Funded

FOM-IPP Programme: Fundamentals in heterogeneous bubbly flow

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

Start of the project

2007

Information

D Lohse
053 489 8076
d.lohse@utwente.nl
http:// pof.tnw.utwente.nl

C Sun
053 489 5604
c.sun@utwente.nl
http:// pof.tnw.utwente.nl

The effect of air on sand near the jamming point

Projectleaders
D van der Meer, MA van der Hoef, JAM Kuipers, D Lohse

Researchtheme
Complex dynamics of fluids

Participants
TAM Homan

Cooperations
-

Funded
FOM

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

Start of the project
2009

Information
TAM Homan
053 489 4473
t.a.m.homan@utwente.nl

D van der Meer
053 489 2387
r.m.vandermeer@utwente.nl
http://pof.tnw.utwente.nl

Project Aim

Static granular matter is traditionally studied in terms of contact forces between the particles only. Recent experimental evidence shows that this framework is insufficient to describe loosely packed fine granular matter: The influence of the interstitial air needs to be taken into account. This influence becomes particularly strong where the contact forces between the grains become vanishingly small, i.e., close to the jamming point. The objective of this project is to study in detail how the ambient, interstitial air influences the structure of loosely packed, static granular matter close to the jamming point.

Progress

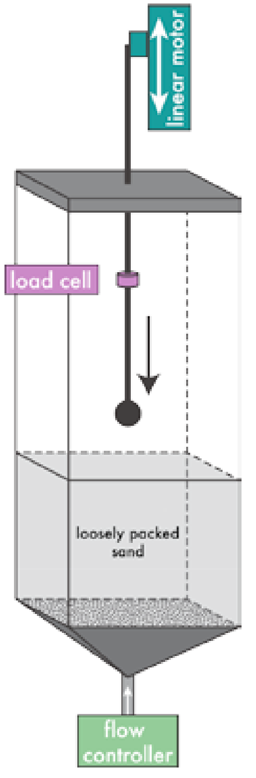
A new setup has been built that consists of a container filled with very fine, loose sand and a linear motor. The linear motor allows us to, very controllably, push an intruder into the sand bed. Several parameters are varied, such as the final depth, the moving velocity and the intruder shape. With a loadcell the drag force on the object is measured directly, while the intruder moves through the sand. One of the first surprising results is a measured drag reduction for higher velocities. Changing the ambient pressure in the experiment will give more insight into the influence of the interstitial air on the drag.

Dissertations

-

Scientific Publications

-



Project Aim

The impact of a liquid droplet on a layer of grains is amongst the most common events in nature. Nevertheless, surprisingly little is known about the physics that governs it. First, we want to know what causes sand and water to mix during impact? Second, when there is no mixing, what controls the amount of momentum that is transferred from the liquid to the sand? Third, how can we understand the different crater shapes that are generated? With experimental work we want to resolve this questions.

Progress

The project has started in November 2012. A start has made with single droplet impact experiments. We found that mixing of sand and water is the fastest when sand grains sizes are large. Next to that a high impact velocity gives fast mixing.

Dissertations

-

Scientific Publications

-

Projectleaders

D van der Meer

Researchtheme

Complex dynamics of fluids

Participants

R de Jong

Cooperations

-

Funded

-

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

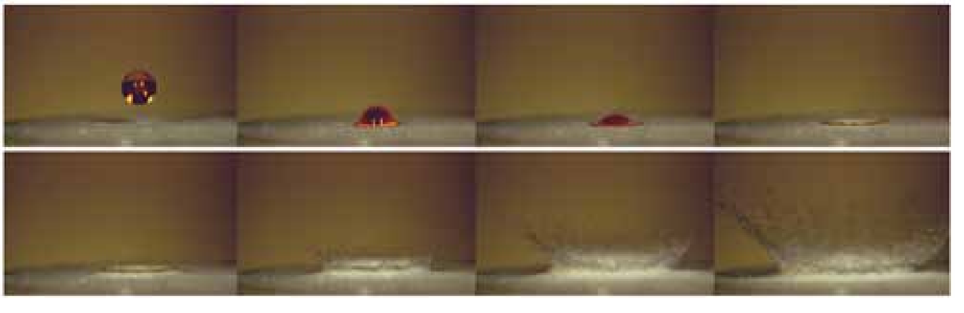
Start of the project

2012

Information

R de Jong
053 489 3479
r.dejong@utwente.nl

D Lohse
053 489 8076
d.lohse@utwente.nl
http:// pof.tnw.utwente.nl



Projectleaders
M Versluis

Researchtheme
Complex dynamics of fluids

Participants
B Verhaagen, C Boutsioukis, D Fernandez Rivas

Cooperations
R Macedo, L-M Jiang (Academic Center for Dentistry, Amsterdam, Netherlands), LWM van der Sluis (Paul Sabatier University, Toulouse, France), JP Robinson, AD Walmsley (Dental School, University of Birmingham, UK)

Funded
STW, Marie Curie (EU)

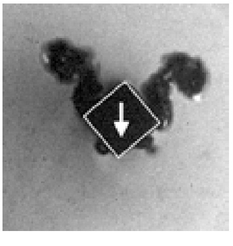
University	-
FOM	-
STW	50 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	50 %
Scholarships	-

Start of the project
2007

Information
M Versluis
053 489 6824
m.versluis@utwente.nl

B Verhaagen
053 489 3084
b.verhaagen@tnw.utwente.nl

C Boutsioukis
053 489 2470
c.boutsioukis@utwente.nl



Cloud of cavitation bubbles (black) visualized around an ultrasonically oscillating endodontic file (outlined in white)

Project Aim

Ultrasonic irrigation of the root canal is found to be much more efficient than conventional root canal irrigation using a syringe and needle, after which bacteria often remain, leading to persistent infection. Why ultrasonic irrigation is more effective is not known, however. Through high-speed visualizations and numerical simulations (CFD) we try to elucidate the cleaning mechanisms (streaming, cavitation, or other mechanisms) involved in root canal cleaning, with the final goal of improving root canal irrigation even more.

Progress

The amount of cavitation that occurs during ultrasonic activation has been measured for several endodontic files using sensitive dosimetry techniques. High-speed visualizations showed a cloud of cavitation bubbles, however they don't contribute to cleaning because they remain near the file. In another system, the cleaning potential of cavitation was demonstrated using controlled cavitation from artificial gas pockets to removing several contaminant layers. Erosion was also quantified. The transport of chemicals into side channels (diameter 2.5-100 μm) of the root canal has been studied experimentally and numerically.

Dissertations

1. L-M Jiang, "Insights into passive ultrasonic irrigation ", PhD thesis, University of Amsterdam, April 4, 2012.
2. B Verhaagen, "Root canal cleaning through cavitation and microstreaming", PhD thesis, University of Twente, September 28, 2012.
3. P Sleutel, "Transport phenomena in dental microchannels", master thesis, University of Twente, March 23, 2012.

Scientific Publications

1. Verhaagen, B., Boutsioukis, C., Heijnen, G.L., Sluis, L. W. M. van der & Versluis, M. Role of the confinement of a root canal on jet impingement during endodontic irrigation.Exp. in Fluids, 53, 1841 (2012).
2. Malki, M., Verhaagen, B., Jiang, L.-M., Nehme, W., Naaman, A., Versluis, M., Wesselink, P., & Sluis, L.W.M. van der. Irrigant flow beyond the insertion depth of an ultrasonically oscillating file in straight and curved root canals: visualization and cleaning efficacy. J. Endod. 38, 657 (2012).
3. Verhaagen, B., Lea, S.C., Bruin, G.J. de, Sluis, L.W.M. van der, Walmsley, A.D. & Versluis, M. Oscillation Characteristics of Endodontic Files: Numerical Model and Its Validation. IEEE T. Ultrason. Ferr. 59, 2448 (2012).
4. Fernandez Rivas, D., Verhaagen, B., Seddon, J.R.T., Zijlstra, A.G., Jiang, L.-M., Sluis, L.W.M. van der, Versluis, M., Lohse, D., & Gardeniers, H.J.G.E. Localized removal of layers of metal, polymer, or biomaterial by ultrasound cavitation bubbles. BIOMICROFLUIDICS 6, 034114 (2012).
5. Boutsioukis, C. & Kishen, A. Fluid dynamics of syringe-based irrigation to optimise anti-biofilm efficacy in root-canal disinfection. Roots 4, 22 (2012).
6. Jiang LM, Lak B, Eijsvogels LM, Wesselink P, van der Sluis LW. Comparison of the cleaning efficacy of different final irrigation techniques. J Endod. 38(6):838-41 (2012).
7. L.W.M. van der Sluis, M. Versluis, B. Verhaagen, L.-M. Jiang and R. Macedo. Disinfection of the root canal system by sonic, ultrasonic and laser activated irrigation. Chapter in book: Disinfection of Root Canal Systems.
8. L.W.M. van der Sluis, M. Versluis, C. Boutsioukis, B. Verhaagen, L.-M. Jiang and R. Macedo. Root canal irrigation. Chapter in book: The root canal biofilm.

Project Aim

The aim of this project is to investigate the flow patterns in evaporating drops, and to use this knowledge to control the formation of drying stains by evaporating colloidal suspension drops. To this end, both experimental (μ-PIV) and theoretical methods are used. In addition, we study droplet evaporation on superhydrophobic substrates, and the formation of (three-dimensional) colloidal microstructures by evaporation.

Progress

We have developed an analytical model to describe the Stokes flow patterns near the contact line of an evaporating drop. For larger contact angles, flow reversal towards the centre of the drop can occur. For smaller contact angles, the lubrication approximation can be used to describe the flow inside the drop. Furthermore, we have developed an experimental method to create spherical, ordered three-dimensional colloidal structures by evaporating drops from a special microstructured superhydrophobic substrate. We have performed a scaling analysis to show how the final packing fraction of these structures depends on the evaporation dynamics, particle size and number of particles in the drop.

Dissertations

1. Flow near the contact line of an evaporating droplet, Master's thesis by Oscar Bloemen.

Scientific Publications

1. Building microscopic soccer balls with evaporating colloidal fakir drops, A.G. Marin, H. Gelderblom, A. Sussarey-Arce, A. van Houselt, L. Lefferts, H. Gardeniers, D. Lohse and J.H. Snoeijer, Proc. Natl. Acad. Sci.109(41), pp.16455-16458 (2012).
2. Stokes flow near the contact line of an evaporating drop, H. Gelderblom, O. Bloemen and J.H. Snoeijer, J. Fluid Mech. 709, pp 69-84 (2012).
3. Fysica voor aan de koffietafel: orde en wanorde in koffiekringen, H. Gelderblom, A.G. Marin, D. Lohse en J. H. Snoeijer, Nederlands Tijdschrift voor Natuurkunde (Jan. 2012).

Projectleaders

JH Snoeijer, D Lohse

Researchtheme

Complex dynamics of fluids

Participants

H Gelderblom, ÁG Marín, JH Snoeijer, D Lohse

Cooperations

L Lefferts, UT-CPM, JGE Gardeniers, UT-MCS

Funded

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

Start of the project

2010

Information

D Lohse
053 489 8076
d.lohse@utwente.nl
http:// pof.tnw.utwente.nl

Inkjet Printing of Suspensions

Projectleaders
JF Dijksman, JH Snoeijer, D Lohse

Researchtheme
Complex dynamics of fluids

Participants
JF Dijksman, JH Snoeijer, D Lohse, E Sandoval Nava, F Boyer

Cooperations
-

Funded
Holst Center, TNO, Eindhoven
Dutch Polymer Institute

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

Start of the project
2012

Information
JH Snoeijer
053 489 3085
j.h.snoeijer@utwente.nl

JF Dijksman
06 2334 1331
j.f.dijksman@utwente.nl
http:// pof.tnw.utwente.nl

Project Aim

The main focus of this research is investigating inkjet printing of stabilized suspensions of PEDOT:PSS (1% solution in water) and silver nanoparticles (20 to 60 % in water), with the aim of employing inkjet technology for industrial applications, trying to identify the relevant parameters that can be adjusted in the inkjet formulation.

Progress

During this reporting period, consideration has been mostly given to the impact dynamics of complex fluids drops. Drop impacts on a solid surface constitute a yet classical but still poorly understood interfacial hydrodynamics paradigm. Investigations on how drops of suspensions impact on substrates of different nature (glass, polymer, structured, non-structured) will reveal how the non-Newtonian behaviour of these fluids changes (drastically in some cases) the impact dynamics.

Dissertations

-

Scientific Publications

-

Nucleation and boiling of a highly superheated liquid

Project Aim

We aim at describing the nucleation of a vapor bubble and subsequent boiling dynamics of a liquid that is highly superheated, i.e. a metastable liquid having a temperature above the saturation temperature.

Progress

We studied the model configuration of a sessile drop of a volatile liquid immersed in a non-volatile liquid. We identified the different configurations for nucleation: Inside the drop, at the wall, at the liquid-liquid interface and at the triple line. We also observed and understood the influence of the location of the nucleation on the subsequent boiling dynamics.

Dissertations

-

Scientific Publications

1. M.A.J van Limbeek, H. Lhuissier, C. Sun, A. Prosperetti and D. Lohse. "Explosive boiling?" Milton van Dyke Award of the DFD APS meeting.

Explosive boiling of a superheated water drop in sunflower oil

Projectleaders

D Lohse

Researchtheme

Complex dynamics of fluids

Participants

MAJ van Limbeek, H Lhuissier, S Wildeman, C Sun, A Prosperetti

Cooperations

-

Funded

ERC: Physics of liquid-vapor phase transition

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

Start of the project

2011

Information

D Lohse
053 489 8076
d.lohse@utwente.nl

C Sun
053 489 5604
c.sun@utwente.nl
http:// pof.tnw.utwente.nl

MICRO/NANO PARTICLE MANIPULATION USING ULTRASOUND

PROJECTLEADERS
M Versluis

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
T Segers

COOPERATIONS
Bracco, St. Antonius Ziekenhuis Nieuwegein

FUNDED
NanoNextNL

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

START OF THE PROJECT
2011

INFORMATION
T Segers
035 489 4213
t.j.segers@utwente.nl
pof.tnw.utwente.nl/

PROJECT AIM

The sensitivity in medical ultrasound imaging using ultrasound contrast agents (UCA) can be improved by narrowing down the bubble size distribution. This can be achieved in two ways; commercial UCA can be sorted or alternatively novel highly monodisperse UCA can be developed. We investigate both possibilities. We propose an acoustic sorting strategy in combination with optical techniques to obtain a particular size distribution in real time. We also develop an innovative process to coat monodisperse bubbles produced in flow focusing geometries to make them suitable for medical imaging. We also develop a method to count and size microbubbles in cardiopulmonary bypass machines during open heart surgery. The aim is to find a correlation between the amount and the size of the bubbles pumped back into the patient and the post-operative cognitive decline.

PROGRESS

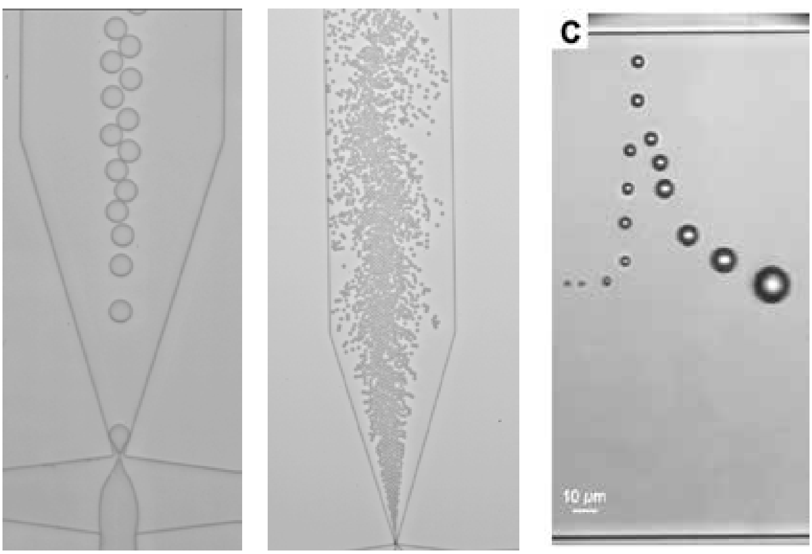
A lab-on-a-chip device capable of sorting microbubbles was developed. Bubbles are manipulated by primary radiation forces. The bubbles resonant to the applied ultrasound field are sorted from a suspension with a wide size distribution. The sorting technique was applied for ultrasound contrast agent enrichment; the microbubbles most sensitive to the ultrasound sorting frequency are separated from the polydisperse bubble suspension (Fig. C).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Prof.dr. F Mugele

MISSION

The goal of the PCF group is to understand and control the structure and the mechanical properties of liquids and interfaces on length scales ranging from molecular to submillimeter scales. The activities fall in three main categories: i) nanofluidics, ii) (electro)wetting & microfluidics, iii) soft matter mechanics. Our nanofluidics research focuses on understanding the range of validity of macroscopic continuum physics and in its breakdown upon approaching molecular scales, where physico-chemical aspects become increasingly important. In microfluidics, many properties of fluids, in particular drops, are controlled by interfacial effects. By patterning surfaces surfaces and in particular by making use the electrowetting effect we control the shape, the motion, and the generation of microdrops. These processes involve various challenging fundamental issues, such as contact angle hysteresis, the dynamics of contact lines, and hydrodynamic singularities. The soft matter mechanics activities focus on correlations between the internal structure of various types of complex fluids ranging from colloidal suspensions to living cells and their macroscopic viscous and elastic properties.

By improving the physical understanding of fundamental phenomena we contribute to the improvement of various technological processes involving fluid motion on small scales, including oil recovery, immersion lithography, and inkjet printing. This work is frequently carried out in collaboration with industrial partners including BP, Shell, ASML, Océ, Liquavista, sometimes within government sponsored consortia such as FOM-IPPs, sometimes in direct collaboration. A major project on enhanced oil recovery started in late 2009 and became fully operational in 2010. In this context, the group intensified its activities in the area of physical chemistry of liquid-liquid and solid-liquid interfaces. In late 2010, Prof. Mugele obtained a NWO-VICI grant to investigate the properties of superhydrophobic surfaces that are functionalized by electric fields. One major goal of the project is to explore various applications of such smart surfaces for microfluidics, ultrasound detection, and in particular optofluidics.

PROJECT AIM

The goal of this project is to improve the understanding of both the physics of pinning and depinning of contact lines on structured surfaces and the dynamics of moving contact lines on such surfaces using electrowetting, with the ultimate goal of improving the performance of both immersion lithography and inkjet printing systems.

PROGRESS

We studied the behavior of small droplets sliding on surfaces and then hitting electrically tunable potential wells, which serve as a model system for defects such as ridges or trenches in a surface.. We study the critical conditions for drop trapping on such potential wells as function of drop size, inclination angle and viscosity. We show a regime where a force balance describes the behavior of the drops, as well as a regime for faster drops where the drop inertia becomes critical. The drop motion can be mapped onto the equation of a harmonic oscillator, where the transition from the force balance to inertial regime is related to critical damping of the oscillator. We used a capillary force sensor consisting of a thin glass capillary inserted into a drop to measure the force exerted by these electric potential wells and other wetting forces. The deflection of the capillary, giving the force, is shown to be consistent with our model for the well.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. H.B. Eral, D.J.C.M. ‘t Mannetje, J.M. Oh, Contact angle hysteresis: a review of fundamentals and applications, Colloid & Polymer Science 2012 (Published online)

PROJECTLEADERS

F Mugele

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

DJCM ‘t Mannetje, CU Murade, HTM van den Ende, F Mugele

COOPERATIONS

FOM IPP

FUNDED

FOM

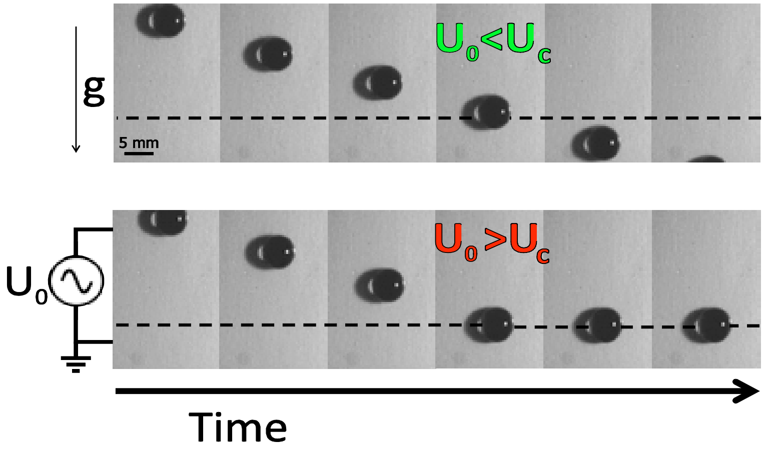
University	-
FOM	100 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2008

INFORMATION

DJCM ‘t Mannetje
053 489 3089
d.j.c.m.tmannetje@tnw.utwente.nl
http://pcf.tnw.utwente.nl/



Ion adsorption at solid-liquid interface

Projectleaders
F Mugele

Researchtheme
Complex dynamics of fluids

Participants
N Kumar, I Siretanu, HTM van den Ende, F Mugele

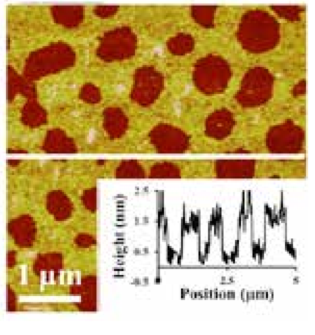
Cooperations
Max Planck Institute for Dynamics and Self-Organization, University of Copenhagen, BP

Funded

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

Start of the project
2011

Information
N Kumar
053 489 3088
n.kumar-1@utwente.nl
http://www.utwente.nl/tnw/pcf/



Project Aim

The project focuses on the influence of the salinity and so-called specific ion effects in controlling the affinity of charged surfactant molecules to charged solid surfaces. These molecules strongly affect the wettability of charged surfaces. The project is motivated by applications in enhanced oil recovery.

Progress

We have developed stearic acid LB-films adsorbed on silica surface as a model oil-rock system. We have studied the stability of these LB-films upon exposure to water and saline solutions. We have demonstrated that the surface wettability and stability of the layers strongly depend on the specific sub-phase counter-ions. LB films deposited in presence of only Na+ ions are highly unstable and are easily removed from the surface upon exposure to water. In contrast, films transferred in the presence of Ca2+ ions are more stable, rearrange only slightly on the molecular scale and display a finite contact angle for an extended period of time (See Fig. below for Ca2+ monolayer exposed to water). Also, we have started the next step of the project, which is measuring quantitatively the interaction forces using force inversion procedures established in our laboratory in recent years. Silicon oxide AFM tip and Kaolinite particles adsorbed on silica will be used as the model system.

Dissertations

-

Scientific Publications

-

Adsorption/desorption of model asphaltene at liquid-solid interfaces

Project Aim

The goal of this project is to understand adsorption and desorption of amphiphilic molecules (fatty acids, fatty amines, aromatic surfactants) on solid substrates, in the context of getting a better understanding of LoSal effects in enhance oil recovery processes.

Progress

In 2012, we have been working on the stability of Langmuir-Blodgett films of stearic acid. It was found that the stability of stearic acid films depends on the ions present in the subphase during the deposition process, and also on the ions present in the aqueous solution it is exposed to. With the combination of techniques such as AFM, Ellipsometry and OCA, we finally conclude that divalent ions play much more roles to keep LB films stable compared to monovalent ions; and the stability of LB film investigated here also depends on the salinity of solution it was exposed to. All these results correspond to the LoSal effects in enhanced recovery. Furthermore, we developed a novel platform combing microfluidics and Surface Plasmon Resonance imaging to increase the efficiency of screening multiple compounds.

Dissertations

-

Scientific Publications

-

Projectleaders

F Mugele

Researchtheme

Complex dynamics of fluids

Participants

L Wang, I Siretanu, MHG Duits,
F Mugele

Cooperations

Max Planck Institute for Dynamics and Self-Organization, University of Copenhagen, BP

Funded

BP

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

Start of the project

2009

Information

L Wang
053 489 3088
l.wang@utwente.nl

Impact and spreading dynamics of drops on model substrates

Projectleaders
F Mugele
Researchtheme
Complex dynamics of fluids
Participants
J de Ruiter, HTM van den Ende, F Mugele
Cooperations
Industrial partners: Océ, TNO, Roth & Rau
Funded
HIPRINS (Pieken in de Delta)

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

Start of the project
2009
Information
J de Ruiter
053 489 3134
j.deruiter@tnw.utwente.nl
utwente.nl/tnw/pcf

Project Aim

High-end printing of graphics and electronics requires a high degree of control of the spreading process of ink on the printing medium. The complex composition of both the surface and the fluid makes spreading and contact line motion a complex problem. The goal of the project is to understand the physical principles of impact and spreading of droplets of various compositions on model surfaces.

Progress

Liquid drops hitting solid surfaces deform substantially under the influence of the ambient air that needs to be squeezed out before the liquid actually touches the solid. We use nanometer- and microsecond-resolved dual wavelength interferometry to reveal the complex evolution of the interface between the drop and the gas layer underneath, in the regime of intermediate impact speeds (We ~ 1 … 10 for millimeter-sized droplets). In absence of nucleation sites, the droplet can bounce on the air layer multiple times, irrespective of surface wettability and nanoroughness. A microstructure (ridge) that is located in the impact zone induces a change in the evolution of the droplet interface, however only close to steep microstructure edges. For sufficiently high microstructures, nucleation of solid-liquid contact is directed toward distinctive single spots on the microstructure edge. With decreasing ridge width-to-height ratio, nucleation is induced at larger mean air film thickness.

Dissertations

-

Scientific Publications

1. Ruiter, J. de, Oh, J.M., Ende, H.T.M van den & Mugele, F. Dynamics of collapse of air films in drop impact. Physical Review Letters 108 (2012) 074505.
2. Ruiter, R. de, Ruiter, J. de, Eral, H. B., Semprebon, C., Brinkmann, M. & Mugele, F., Buoyant droplets on functional fibers, Langmuir 28 (2012) 13300-13306.

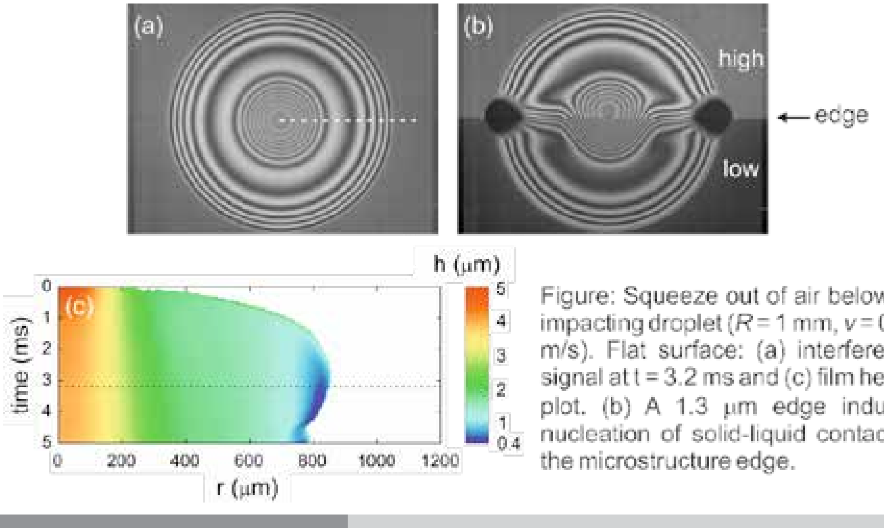


Figure: Squeeze out of air below an impacting droplet (R = 1 mm, v = 0.23 m/s). Flat surface: (a) interference signal at t = 3.2 ms and (c) film height plot. (b) A 1.3 μm edge induces nucleation of solid-liquid contact at the microstructure edge.

Influence of wall roughness and particle adhesion on confined flows

Project Aim

Confined flows of colloidal suspensions occur in biology, chemistry, geology, industrial process and increasingly also in Lab-on-a-Chip applications. Much is still missing from our fundamental understanding. It is not exposed yet how the wall roughness changes the particle behavior . We are keen to investigate the motion of particles inside microchannels at low flow regime. How the wall roughness changes the behavior at the same experimental condition? At the same time, we would like to check the apparent particle diffusivity and the effect of wall roughness and flow rate on it. We also focus on the flow patterns and concentration profiles of the suspensions in the low flow rates inside microchannels.

Progress

Our observations contrast to the findings in literature at larger Peclet numbers(Pe), where the particles migrate from high shear zones to low shear zones, resulting in higher particle concentrations at the channel center. Theoretically, it has been predicted that at low Pe, the particle concentration inside the microchannel should be homogeneous. We found inhomogeneity in concentration profile at the low flow regime. Furthermore we found a reduction in particle concentration at the channel center (as compared to the wall). We also observed that the apparent diffusivity (normal to the flow direction) of the particles at the channel center increases with the flow rate (Pe ~ 0 to 20). And finally we observed that the roughness on the wall reduces the slip.

Dissertations

-

Scientific Publications

-

Projectleaders

F Mugele, MHG Duits

Researchtheme

Complex dynamics of fluids

Participants

S Ghosh, D Wijnperle

Cooperations

-

Funded

NWO

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

Start of the project

2011

Information

S Ghosh
053 489 3089
s.ghosh@utwente.nl
http://www.utwente.nl/tnw/pcf/people/scientific_staff/MichelDuits/

http://www.utwente.nl/tnw/pcf/people/phd_students/ghosh.docx/

Ion adsorption at solid-liquid interfaces

Projectleaders
F Mugele

Researchtheme
Complex dynamics of fluids

Participants
N Kumar, L Wang, B Bera,
F Mugele, HTM van den Ende

Cooperations
Max Plank Institute for Dynamics and Self-Organization, University of Copenhagen

Funded

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

Start of the project
2012

Information
I Siretanu
053 489 3089
i.siretanu@utwente.nl
www.utwente.nl/tnw/pcf/

Project Aim

The aim is to study the effect of salinity, electrolyte type, concentration, and carboxylic materials from the crude oil on the wettability alteration of rock and clay particles surface. This work will provide better understandings of mechanisms involved in low salinity waterflood enhanced oil recovery (EOR) process.

Progress

In order to demonstrate that Low Salinity water flooding is caused by the destabilization of organic layers that are bound to the rock surface, we made steric acid Langmuir-Blodgett (LB) films on silica substrate as model oil-rock system. We studied the stability of these LB films of stearic acid (mimicking polar components of the oil) upon exposure to water as a function of the presence of Na+ and Ca2+ ions. The effect of the ions was investigated during two separate stages of the experiment: (i) LB films were transferred to solid silica surfaces from aqueous subphases containing variable amount of salts, and (ii) they were subsequently exposed to electrolyte drops with a variable salt content. Using macroscopic contact angle goniometry, imaging ellipsometry, and atomic force microscopy, we consistently found that the presence of Ca2+ ions enhances the stability of the LB layers and increases the water contact angle on the surfaces. Our findings demonstrate that stearic acid layers follow the scenario proposed above to explain low salinity water flooding.

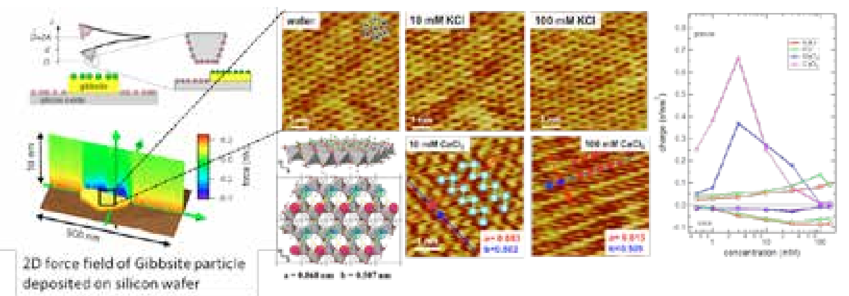
Additionally, unprecedented high resolution measurements of the ion adsorption and charge distribution on composite silicon oxide/gibbsite nanoplatelet surfaces using atomic force spectroscopy with sharp tips have been obtained. For the specific system of silica surfaces covered by Gibbsite nanoparticles in aqueous electrolytes comparison we demonstrate a much stronger affinity of divalent Ca2+ and Mg2+ ions to both materials as compared to monovalent Na+ and K+ ions. On the crystalline gibbsite nanoparticles we find a well-defined lattice of adsorbed Ca2+ and Mg2+ ions at moderate CaCl2 and MgCl2 concentrations. For high salt concentrations atomic scale imaging, surface charge measurements and surface speciation modeling provide consistent evidence for co-adsorption of Cl- anions onto preadsorbed cations.

Dissertations

-

Scientific Publications

-



Rheological study of jamming and glass transition in dense suspensions of soft particles

Project Aim

The aim of the project is to study the jamming and glass transition in dense microgel suspension using active and passive microrheological techniques. We tried to probe the jamming of soft microgel particles at an oil water interface.

Progress

We show for the first time the reversible nature of these particles' adsorption at oil/water interfaces independently of the temperature and contrarily to previous conception of irreversible adsorption. We measured the dynamic surface tension of PNIPAM particles in a drop-shape tensiometer. We found that the adsorption of these particles at the decane/water interface varies with the temperature, also indicated by studying the thickness of these interfacial layers by ellipsometry. However, observing the surface tension variation in experiments consisting in compression/expansion volume cycles we can demonstrate the reversible adsorption of PNIPAM particles independent of the temperature.

Further, we also measure the dilatational rheology using the oscillating drop technique and the interfacial shear rheology by particle tracking methodology. These measurements not only provide new insights into the interfacial microstructure of these soft microgels but also confirm our hypothesis about their reversible adsorption. They also rule out the possibility of multilayers existing at the interface. Finally, this universal evidence of reversible adsorption of PNIPAM molecules at fluid interfaces opens up the question about the interfacial microstructure of the particles and its relation to their efficient stabilization of the emulsions.

Dissertations

-

Scientific Publications

-

Projectleaders

F Mugele

Researchtheme

Complex structures of fluids

Participants

OS Deshmukh, HTM van den Ende, F Mugele

Cooperations

-

Funded

FOM

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

Start of the project

2009

Information

O Deshmukh
053 489 4236
o.s.deshmukh@utwente.nl
www.utwente.nl/tnw/pcf/

PROJECTLEADERS
F Mugele
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
HTM van den Ende, A Giraldo, I Roghair
COOPERATIONS
Samsung LCD Netherlands R&D Center
FUNDED
Samsung LCD Netherlands R&D Center

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

START OF THE PROJECT
2012
INFORMATION
I Roghair
053 489 3019
i.roghair@utwente.nl
http://www.utwente.nl/tnw/pcf/

PROJECT AIM

Displays based on electrowetting make use of pixels filled with an electrolyte and a tiny amount of oil. By applying an electric potential in the pixel, the position of the oil droplet can be controlled, either opening or closing the pixel. Such displays have several advantages compared to LCD displays. The reflective nature of the pixels makes the image on the display clear to see, even in direct sunlight. Therefore, a back-light is not generally required and energy consumption is strongly reduced. In order to optimize the development and design of the pixels, numerical simulations will be performed. To investigate the interaction between the electric field and the oil-electrolyte interface, an electrohydrodynamics (EHD) model has to be implemented. The OpenFOAM framework was chosen to be used for the simulations and EHD implementation.

PROGRESS

An extended amount of simulations have been performed of the pixel closing behaviour (i.e. simulations of the oil droplet spreading from a retracted, cornered droplet to an oil film spread over the pixel bottom). The effect of pixel size, satellite droplets, oil filling level, physical properties (dynamic viscosity, liquid density) and other parameters have been thoroughly investigated.

In addition, an EHD model was implemented in OpenFOAM. The model is capable to simulate any combination of dielectric and conductive liquids, including non-perfect ones, and has been validated with several analytical relations. Also, the model results have been compared with several realistic cases described in the literature.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Ion-induced wetting transition on mica in n-Decane

Project Aim

From Oil-extraction point of view, wetting of rock surfaces in oil/water environment is very crucial. Both the content of water and oil govern this wetting, as ion-ion interactions near the surface control the free energy of it, and hence the wetting. Both the surface chemistry and the electrostatics thus play a crucial role. This project aims to experimentally simulate such incidents in an oil-reservoir and then propose a model for such ionic interactions. Complete understanding of this phenomenon is the purpose, by combining macroscopic and microscopic analysis.

Progress

In the experimental part, mica and n-Decane are taken as the representatives of reservoir-rock and oil, respectively. Macroscopically contact angle measurement is done with various salts, concentrations and pH of aqueous solution (on mica in n-Decane). A Theoretical model has been proposed to explain the wetting pattern, based on thin film theory. Theoretical calculations are being carried out for the surface charge of mica for various cases of wetting, based on this thin film of aqueous solution. Microscopic characterizations (with Ellipsometry and ZetaCAD) are also being performed to support the theoretical model, and obtain more information about the thin film and how it controls the wetting.

Dissertations

-

Scientific Publications

-

Projectleaders

F Mugele

Researchtheme

Complex dynamics of fluids

Participants

B Bera, CU Murade, I Siretanu, AM Maestro, M Duits, D van den Ende

Cooperations

-

Funded

British Petroleum (BP)

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

Start of the project

2012

Information

B Bera
053 489 3105
b.bera@utwente.nl
http://www.utwente.nl/tnw/pcf/people/phd_students/bera.docx/

Cell-SPREAD

Projectleaders
LWMM Terstappen, F Mugele, MHG Duits

Researchtheme
Complex dynamics of fluids

Participants
AM Pit, I Stojanović

Cooperations
-

Funded
STW

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

Start of the project
2011

Information
AM Pit
053 489 3093
a.m.pit@utwente.nl

Project Aim

To detect the presence and affinity of therapeutic targets on circulating tumor cells (CTC). Digital microfluidics is used to create drops containing 1 CTC and guide the drop over a gold substrate patched with specific ligands targeting specific molecules. Using surface plasmon resonance imaging (SPRi) the binding processes of cell excreted proteins are quantified, effectively characterizing the cancer cell. This will allow for a quick diagnostic tool to administer the right type of medicine.

Progress

Digital microfluidic devices have been created to control drops in a microchannel. Using the gap between two electrodes to create a potential well when a voltage is applied over the electrodes, the drop is controllably trapped, guided, sorted, coalesced, or split in two depending on the electrode configuration.

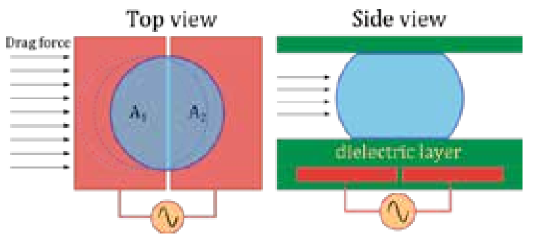
Expression of specific cell membrane molecules has been measured using SPRi on SKBR3 cancer cells, and also excretion of antigens by hybridoma has been observed.

Dissertations

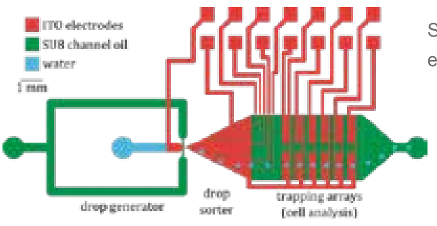
-

Scientific Publications

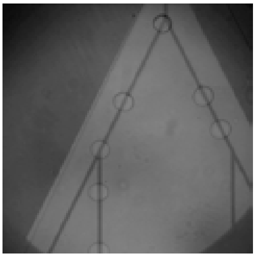
-



Schematic of drop on gap between electrodes



Schematic of channel and electrode design



Measurement of drops inside a microchannel being guided over the gap between electrodes by applying a voltage over the gap.

Stability of confined water layers in hydrophobic nanochannels

Project Aim

To study the effect of confinement on phase transitions of fluids. To investigate the stability of confined water layer in hydrophobic/philic channels in the context of phase-equilibrium. To develop theoretical understanding for the effect of surface wettability on phase-equilibria. Catalysis of formic acid at small scale is another aspect that would be explored, our main objective is to study in well-defined geometries at nanoscale pores to improve understanding of processes under different wettability.

Progress

1) A chip consisting of bridging nanochannels has been designed and fabricated. Our current focus is on evaporative processes in 2D slit geometry at small scales.

2) A new Catalysis chip has been designed and fabricated to study catalysis of formic acid at nanoscale in well degined geometry.

Dissertations

-

Scientific Publications

-

Projectleaders

M Duits, F Mugele

Researchtheme

Complex dynamics of fluids

Participants

D Tiwari, R Brunet Espinosa,
M Duits, L Lefferts, F Mugele

Cooperations

Roger Brunet Espinosa , Leon Lefferts Catalytic Processes and Materials, TNW University of Twente

Funded

NWO

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

Start of the project

2010

Information

D Tiwari
053 489 4236
d.tiwari@utwente.nl
www.utwente.nl/tnw/pcf/

Imbibition of water into oil-filled microchannels with complex wall properties

Projectleaders
F Mugele

Researchtheme
Complex dynamics of fluids

Participants
R de Ruiter, MHG Duits, F Mugele

Cooperations
Max Planck Institute for Dynamics and Self-Organization, University of Copenhagen, BP

Funded
BP

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

Start of the project
2009

Information
R de Ruiter
053 489 3093
r.deruiter-1@utwente.nl
http://www.utwente.nl/tnw/pcf/

Project Aim

At the level of individual pores, the efficiency of oil recovery is governed by the spontaneous and pressure driven imbibition of brine and the subsequent mobilization and flow of oil (and water) through the complex pore network. Chemical heterogeneity and topographic roughness control the initial distribution of oil and water in the pore space as well as the flow resistance experienced by mobilized oil. We will generate microfluidic channels with specifically designed and controllable wall patterns to elucidate the fundamental physical processes underlying the mobilization of oil in porous media.

Progress

We investigating the use of various two-electrode geometries in the walls of oil-filled microchannels to manipulate confined aqueous drops. A gain in electrostatic energy yields an electrical force that can be used to trap the conductive drop at the electrodes. The trapping strength is tunable via the voltage, allowing for on demand trapping and release of drops (Fig. 1). We investigated the critical conditions for drop trapping, which includes the effects of e.g. flow velocity, drop size, and potential applied across the electrodes.

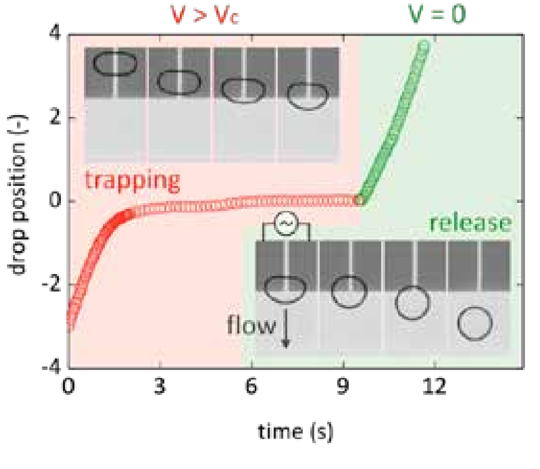
We study the symmetry breaking of capillary bridges in between a sphere and a plane as a model for drops being released from pore throats. Dependent on drop size and sphere/ plane separation, we find a critical contact angle above which the drop is continuously released from the geometry.

Dissertations

-

Scientific Publications

1. Ruiter, R. de, Wennink, P., Banpurkar, A.G., Duits, M.H.G. & Mugele, F. Use of electrowetting to measure dynamic interfacial tensions of a microdrop. Lab on a Chip 12 (2012) 2832-2836.
2. Ruiter, R. de, Ruiter, J. de, Eral, H. B., Semprebon, C., Brinkmann, M. & Mugele, F., Buoyant droplets on functional fibers, Langmuir 28 (2012) 13300-13306.



On demand trapping and release of a drop in a microchannel.

Electrically switchable Super-hydrophobic surfaces

Project Aim

The goal of project is to develop topographically structured super-hydrophobic surfaces and three-dimensional structures using embedded electrodes in such a way that reversible switching of the competing wetting states between Cassie and Wenzel and the accompanying physical properties becomes possible. The primary focus is on applications in optofluidics.

Progress

Current objective is to fabricate electrostatically tunable perfect aspherical lens with minimum spherical aberration and to demostrate its functionality by optical characterization

1.Experiments are conducted by creating a liquid meniscus in an aperture and changing its curvature by applying electric field. The curvature at zero voltage can be controlled by hydrostatic head or by electrowetting.

2.Characterization of aspherical lenses. This is done by fitting the profile obtained from experiment with the standard conic surface equation. The fit will fetch us the value of eccentricity from which the nature of conic section can be inferred. Perfect lens is obtained when relative value of refractive index matches with the eccentricity of the fitted profile.

3. Electrowetting driven synchronous modulation of focallengths at frequency above 1kHz by actuating microlenses in parallel.

Dissertations

-

Scientific Publications

1. C.U. Murade, D. van den Ende and F. Mugele, 'High speed adaptive liquid microlens array'. Optics Express 20 (2012)), 18180-18187.

Projectleaders

F Mugele, HTM van den Ende

Researchtheme

Complex dynamics of fluids

Participants

Kartikeya Mishra, Ivo Roghair
Arun Gnanappa, Chandra Murade

Cooperations

-

Funded

NWO, VICI

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

Start of the project

2011

Information

K Mishra
053 489 3134
k.mishra@utwente.nl
http://www.utwente.nl/tnw/pcf/people/phd_students/mishra.docx/

Force spectroscopy in liquid by atomic force microscope

Projectleaders
F Mugele
Researchtheme
Complex dynamics of fluids
Participants
F Liu, F Mugele, HMT van den Ende
Cooperations
-
Funded
FOM

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

Start of the project
2011
Information
D Tiwari
053 489 4236
d.tiwari@utwente.nl
www.utwente.nl/tnw/pcf/

Project Aim

We use atomic force microscope to probe dynamics of liquids at solid-liquid interface. The aims are to explore atomic force microscope techniques for understanding dynamics of liquids at solid-liquid interface and investigate the properties of novel materials, for example, the effect of graphene coating on water dissipation at interface.

Progress

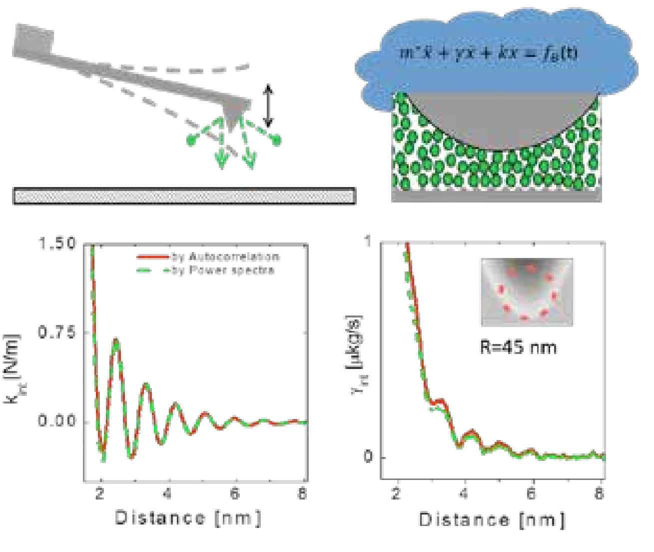
Characterized distance-dependent conservative forces and dissipation in confined liquids by using thermal fluctuations of cantilevers of atomic force microscope. The thermal fluctuations of the tip at different distances are recorded and analyzed by power spectrum and autocorrelation. The technique is validated by measuring the bulk viscosity with a blunt tip. Then the experiment is done with sharp tips. It is observed that the interaction stiffness matches well with theory prediction- exponentially decaying oscillatory cosine function w.r.t tip-surface distance. The damping displays non-monotonic behavior and thus deviates from continuum hydrodynamics.

Dissertations

-

Scientific Publications

-



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.

Microreactor chips with integrated work-up functionality

Project Aim

The aim of this project is to investigate on-chip integration of a liquid-liquid extraction step in-line with a chemical reaction. In the developed two-phase reaction-separation system either the reaction occurs between components of two immiscible liquid phases, or the separation by extraction will be performed after completion or equilibration of the reaction. The approach for the liquid-liquid extraction is to generate a well-defined emulsion in order to enhance mass transfer of reactants and/or products between two immiscible liquid phases. The emulsion is quantitatively separated after transfer of the desired component has been completed or when equilibrium between the phases has been established. This is achieved either by integration of a selective membrane or a nano or microstructured surface "coalescer".

Progress

A new set of microfluidic chips for liquid-liquid extraction has been developed, and their performance is being tested by the extraction of several solutes, e.g. phenol, from water to toluene, using UV/VIS spectroscopy for analysis of solute content in the solvents. New method for surface hydrophobization of channel walls, based on the use of silicon oil, plasma activation and UV exposure, has been successfully implemented in our chips, with enhanced stability and contact angles similar to these obtained with chlorosilanes. A device for measuring the pressure drop of two-phase plug flows has been developed. The device relies on a series of tapered channels where Laplace pressure at a fluidic interface serves as indicator of local pressure. The operation of the device has been successfully demonstrated qualitatively.

Projectleaders
RGH Lammertink, JGE Gardeniers

Researchtheme
Complex dynamics of fluids

Participants
Roland Blanch Ojea

Cooperations
-

Funded
NWO / Poac

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

Start of the project
2009

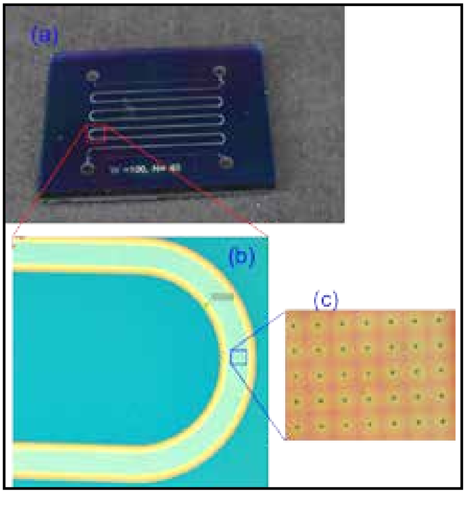
Information
RGH Lammertink
053 489 2063
r.g.h.lammertink@utwente.nl
www.utwente.nl/tnw/sfi/people/staff/lammertink

Dissertations

-

Scientific Publications

1. R. Blanch-Ojea, R.M. Tiggelaar, J. Pallares, F.X. Grau, J.G.E. Gardeniers, Flow of CO2–ethanol and of CO2–methanol in a non-adiabatic microfluidic T-junction at high pressures, Microfluidics and Nanofluidics, vol. 12, issue 6, p.p. 927-940, 2012.



Projectleaders
RGH Lammertink
Researchtheme
Complex dynamics of fluids
Participants
Elif Karatay
Cooperations
-
Funded
NWO / Poac

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

Start of the project
2009
Information
RGH Lammertink
053 489 2063
r.g.h.lammertink@utwente.nl
www.utwente.nl/tnw/sfi/people/staff/lammertink

Project Aim

The goal of this project is to demonstrate an approach re-shaping the scene: perform chemical conversions that are not reasonable without the use of multifunctional micro reactors. In this concept, G/L contacting and electrokinetic separations will be developed on chip.

Progress

Up to this phase of the project, experimental studies are finalized for the G/L contacting part of the project. We have investigated the oxygen saturation of aqueous based solutions in two different configurations. 1- Integration of a polymeric, hydrophobic, porous G/L contacting membrane to microfluidic devices. 2- Fabrication of microfluidic devices that mimic a porous membrane permitting direct contact between gas and liquid. Our experimental and numerical results reveal the applicability of both of the configurations for G/L contacting in a tunable, controllable manner. Both of the configurations can be used for gassing/ degassing irrespective of the gas and the content of the aqueous solution.

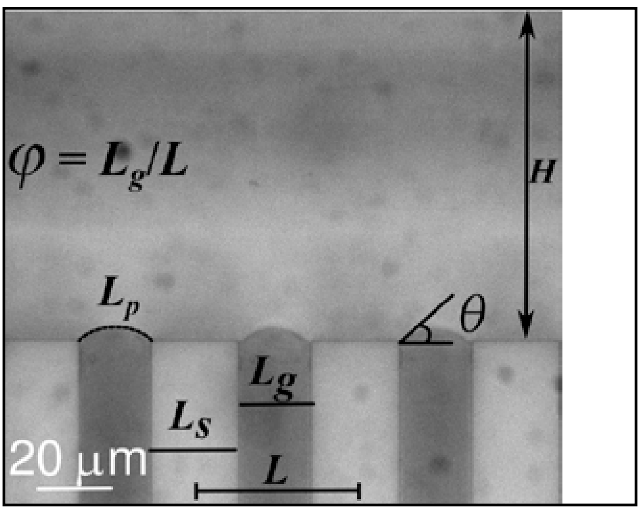
For the continuous removal of reaction product, we aim to investigate two different systems 1- over-limiting current behaviour of glass nanochannels for an arbitrary salt solution. Experiments on the glass micro/nanofluidic devices are ongoing. 2- Fabrication of ion selective membranes on chip, investigating the performance of these membranes under ohmic/limiting/over-limiting regions. In this phase of the project dedicated microfluidic devices are fabricated. Two kinds of ion exchange membranes are successfully produced off the chip. We currently work on fabrication of these membranes on chip.

Dissertations

-

Scientific Publications

1. Karatay, E. and Lammertink, R.G.H. (2012) Oxygenation by a superhydrophobic slip G/L contactor. Lab on a chip, 12 . 2922 - 2929. ISSN 1473-0197.



TRAM = Transport At the Microscopic interface

Project Aim

The focus of this project lies on interfacial transport phenomena that occur in e.g. membrane processes, and in particular on those phenomena that often form a limiting factor in these processes such as concentration polarization. By investigation of these phenomena in well-defined systems, in microfluidic devices for example, we aim to acquire a deeper and more fundamental understanding of interfacial transport phenomena.

Progress

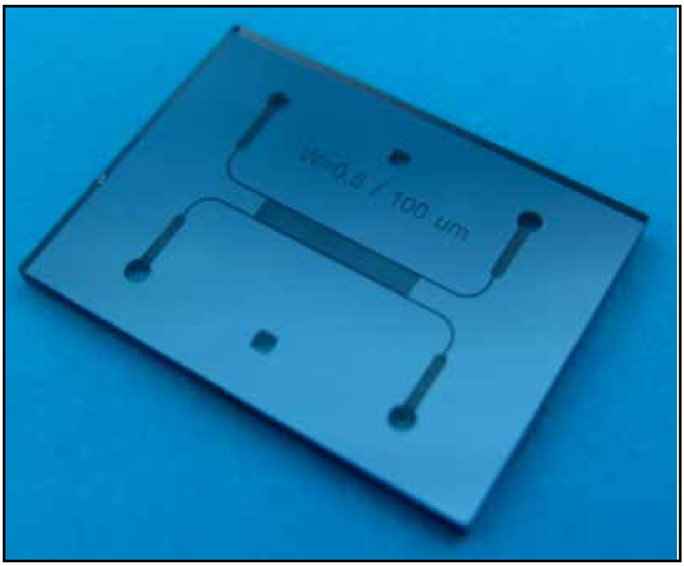
Last year's research was mainly directed on the understanding of both momentum and mass transport over a bubble mattress, which can be considered as a kind of one-dimensional membrane. It has experimentally been quantified using μPIV how the amount of slip depends on the microscopic interface geometry by establishing a bubble mattress in a chip. Besides that, it has been shown numerically that momentum and mass transport can be enhanced simultaneously when employing slippery interfaces. The establishment of a controllable and stable bubble mattress in a chip is a first step in the development of devices displaying both reduced friction towards fluid flow and increased mass transport.

Dissertations

-

Scientific Publications

-



Projectleaders

RGH Lammertink

Researchtheme

Complex dynamics of fluids

Participants

Sander Haase

Cooperations

-

Funded

EU (ERC)

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

Start of the project

2012

Information

RGH Lammertink
053 489 2063
r.g.h.lammertink@utwente.nl
www.utwente.nl/tnw/sfi/people/staff/lammertink

Applied Analysis & Mathematical Physics (AAMP)

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

Wave groups propagating in the coastal zone experience combined effects of wave non-linearity, bathymetry, wave-current interaction and wave breaking. Long wave generation is one effect which plays an important role in coastal morphodynamics and the motion of moored ships, just as the large spatial variability of high waves. The aim of this project is to come to improved modeling and understanding of waves in the coastal area, including aspects of tsunami waves.

PROGRESS

The optimization of dispersive properties in Variational Bousinesq Models was achieved by using an optimal kinetic energy principle. Various applications above flat and varying bottom, in coastal zone and harbours showed the applicability of the FE-codes. In the project on effective boundary conditions we prepared a publication on 1D simulations with a Variational Boussinesq Model. A tsunami investigation has been performed to see possible effects on a planned sea-dike in the Jakarta harbour. In a new IOP project 'Promised' the aim is to predict in real time the surface elevation at the position of a radar that senses the surrounding seas. First results with synthetic data have been achieved for single and multi-modal seas.

DISSERTATIONS

1. Ivan Lakhturov, Optimization of Variational Boussinesq Models, 9 November 2012.
2. Didit Adytia, Coastal zone simulations with Variational Boussinesq Modelling, 24 May 2012.

SCIENTIFIC PUBLICATIONS

1. D. Adytia and E. van Groesen, Optimized Variational 1D Boussinesq modelling of coastal waves propagating over a slope, Journal Coastal Engineering, 64 (2012) pp. 139-150.
2. I. Lakhturov, D. Adytia & E. van Groesen, Optimized Variational 1D Boussineq modelling for broad-band waves over flat bottom, Wave Motion, 49(2012)309-322.
3. D. Adytia, M. Woran & E. van Groesen, Effect of a possible Anak Krakatau explosion in the Jakarta Bay, Proceedings Basic Science International Conference 2012, Malang Indonesia, K1-5, ISBN 978-979-25-6033-6.
4. D. Adytia, M. Ramdhani & E. van Groesen, Phase resolved and averaged Wave Simulations in Jakarta Harbour, Proceedings 6th Asia-Pacific Workshop on Marine Hydrodynamics-APHydro2012, Johor Baru Malaysia, 3-4 September 2012. pp. 218-223.

PROJECTLEADERS

EWC van Groesen

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

I Lakhturov, D. Adytia, W Kristina, AP Wijaya, Andonowati

COOPERATIONS

LabMath-Indonesia, Bandung Indonesia, MARIN Wageningen, TUD

FUNDED

UT, STW, NWO-ALW, IOP

University	15 %
FOM	-
STW	25 %
NWO Other	30 %
Industry	-
TNO	-
GTI	30 %
EU	-
Scholarships	-

START OF THE PROJECT

2003

INFORMATION

E van Groesen
053 489 3413
groesen@math.utwente.nl

Generation of deterministic extreme waves in hydrodynamic laboratories

Projectleaders
EWC van Groesen

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
Lie She Liam, I. Lakhturov and A. Latifah (PhD-UT); Dr. Andonowati (LabMath-Indonesia & ITB)

Cooperations
LabMath-Indonesia, Bandung Indonesia, MARIN Wageningen

Funded
UT, STW, MARIN

University	20 %
FOM	-
STW	75 %
NWO Other	-
Industry	-
TNO	-
GTI	5 %
EU	-
Scholarships	-

Start of the project
2002

Information
E van Groesen
053 489 3413
groesen@math.utwente.nl

Project Aim

The study of deformations of surface waves is focused on 'extreme waves'. The motivation comes from generating large amplitude waves in hydrodynamic laboratories. We investigate the maximal amplification factor that can be obtained from nonlinear effects in various wave groups (BF-instability, bi-harmonic deformations, soliton interactions), and properties of `extremal waves' for increasingly more complicated model equations.

Progress

A breaking model has been implemented in the nonlinear (second, third and fourth order) AB equations in 1D, and its performance has been tested against experiments at MARIN. The numerical implementation of nonlinear 2D Hamiltonian AB-equations above flat and varying bottom was finished, and supplemented with efficient and accurate influx methods, which may also be used to simulate (partially) reflective walls. Research on the characterization and prediction of freak waves, including those that were found in wind-wave experiments of MARIN, was published. A start was made to explain the appearance in wind waves (for relatively low Benjamin-Feir index) by investigating the energy flux.

Dissertations

-

Scientific Publications

1. A.L. Latifah & E. van Groesen, Coherence and Predictability of Extreme Events in Irregular Waves, Nonlin. Processes Geophys, 19 (2012)199-213, ISSN 1023-5809.
2. E. van Groesen & I. van der Kroon, Fully dispersive dynamic models for surface water waves above varying bottom, Part 2: Hybrid spatial-spectral implementations, Wave Motion 49 (2012) 198-211.

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.

Complex wave-current interactions in a numerical wave tank

Project Aim

Our aim is to develop novel space-time (dis)continuous Galerkin methods based on variational principles to model nonlinear free-surface waves. The advantage is that the resulting numerical discretization will preserve energy, phase-space structure and variational structure. Further, the numerical scheme will show no decay in amplitude and will be suitable for long time simulations. A 2D potential flow solver is already developed, and its extensions to accommodate a wave maker and subsequently to explore a 3D potential flow solver are now in progress. Numerical results will be compared with laboratory datasets from: 3D inertial waves generated by The Royal Netherlands Institute of Sea Research (NIOZ), wave tank data of the Maritime Research Institute Netherlands (MARIN) and the Bore–Soliton–Splash (BSS) experiment performed here at the University of Twente.

Progress

A variational finite element method based on Luke variational principle has been developed for nonlinear free-surface waves. The method results in a space-time discretization. The resulting numerical scheme conserves discrete energy and shows no amplitude decay. The method is accommodated with the wave maker movement and extensively validated against experimental data. These results show that the newly developed numerical discretization is very accurate and stable for strongly non-linear potential flow water waves.

Next to the non-linear potential flow waves we have also developed a linear numerical model based on a Hamiltonian framework, which includes the vorticity component of the velocity field in a domain with possible background rotation. The structure preserving, compatible numerical model allows the simulation of inertial (linear) waves in the interior of the fluid and provides a possibility to model wave and current interactions. The current set-up enabled various studies on an inertial wave attractor formation in a slightly tilted rectangular domain. Additionally, further research was conducted in understanding and creating a semi-analytical reference solution for the inertial waves in a rectangular parallelepiped.

Dissertations

-

Scientific Publications

1. Elena Gagarina, Jaap J.W. van der Vegt, Vijaya Ambati, Onno Bokhove (2012): A Hamiltonian Boussinesq model with horizontally sheared currents. In: Proc. 3rd Int. Symp. On Shallow Flows, Iowa, USA, June 4-6, 2012.

Projectleaders

O Bokhove, JJW van der Vegt

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Nurijanyan, VR Ambati, E Gagarina

Cooperations

A Thornton, M Robinson
MARIN, NIOZ, Delft Hydraulics, Alkyon Hydraulic Consultancy & Research, and TU Delft Marine Technology

Funded

STW/NWO

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

Start of the project

2008

Information

o.bokhove@math.utwente.nl
www.math.utwente.nl/~bokhoveo/

v.r.ambati@math.utwente.nl
www.math.utwente.nl/~ambativr

S.Nurijanyan@math.utwente.nl
www.math.utwente.nl/~nurijanyans

e.gagarina@math.utwente.nl
www.math.utwente.nl/~gagarinae

www.woutzweers.nl/text%202010/2010%20soliton%20splash.html

www.youtube.com/user/BoreSolitonSplash

HP MULTIGRID AS SMOOTHER ALGORITHM FOR HIGHER ORDER DISCONTINUOUS GALERKIN DISCRETIZATIONS OF ADVECTION DOMINATED FLOWS

PROJECTLEADERS
JJW van der Vegt

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
T Julianto

COOPERATIONS
S Rhebergen University of Minnesota, Mineapolis, USA and Oxford University, Oxford, UK.

FUNDED
DIKTI Fellowship

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

START OF THE PROJECT
2009

INFORMATION
JJW van der Vegt
053 489 5628
j.j.w.vandervegt@math.utwente.nl
www.home.math.utwente.nl/~vegtjjw/

PROJECT AIM

Multigrid methods are an important technique to solve the algebraic equations resulting from a dicontinuous Galerkin finite element discretization. For lower order accurate DG discretizations of advection dominated flows this results in an efficient numerical algorithm, but with increasing order of accuracy this performance rapidly decreases. This project aims at developing new multigrid algorithms using a theoretical analysis of the error transformation operator for higher order accurate DG discretizations. This is important for many fluid dynamics problems which frequently occur at high Reynolds numbers.

PROGRESS

New optimized multigrid smoothers based on semi-implicit Runge-Kutta methods were developed using three-level Fourier analysis of the complete hp-multigrid algorithm for fourth order accurate DG discretizations of 2D advection dominated flows. These algorithms, in combination with semi-coarsening multigrid, result in a large improvement of multigrid efficiency for higher order accurate DG discretizations. The multigrid performance remains very good even on highly stretched meshes. The newly devolped algorithm has been implemented and tested in the general purpose hpGEM finite element package. Recently, the multigrid algorithms have been extended to unstructured mixed hexahedral and prismatic meshes. On this type of meshes also very good multigrid performance is obtained for advection-dominated flows with this boundary layers.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. J.J.W. van der Vegt and S. Rhebergen, (2012) HP-Multigrid as Smoother algorithm for higher order discontinuous Galerkin discretizations of advection dominated flows. Part II: Optimization of the Runge-Kutta smoother. Journal of computational physics, 231 (22). pp. 7564-7583.
2. J.J.W. van der Vegt and S. Rhebergen, (2012) hp-Multigrid as Smoother algorithm for higher order discontinuous Galerkin discretizations of advection dominated flows: Part I: Multilevel analysis. Journal of computational physics, 231 (22). pp. 7537-7563.

Discontinuous Galerkin methods for phase transitional flows

Project Aim

The numerical simulation of phase transitional flows is very challenging. It requires an accurate description of the physical phenomena at the interface between different phases and the capturing of the generally thin interface in between the phases for which we will use the diffusive interface method. In addition, the equations governing phase transitional flows frequently have a hyperbolic-elliptic character for which many of the numerical schemes developed for hyperbolic partial differential equations are not suitable. In this project a discontinuous Galerkin finite element method will be developed for hyperbolic-elliptic partial differential equations governing phase transitional flows. Due to its local element-wise discretization the discontinuous Galerkin method is well suited for local mesh refinement, which will be used to improve the capturing of the phase transition interface in the diffusive interface method.

Progress

We applied a Local Discontinuous Galerkin (LDG) method to equations modeling the propagation of phase transition in solids and fluids in one-dimension. These equations have as special feature that they constitute a hyperbolic-elliptic system. The results obtained with the new LDG scheme have less spurious oscillations compared to those resulting from a finite difference method. Also, we prove the L2-stability of the LDG method for general stress-strain relations and an error estimate for tri-linear stress-strain relations. Moreover, we used the LDG method to solve the non-isothermal Navier-Stokes-Korteweg (NSK) equations, which are more challenging because of higher order nonlinear terms and the van der Waals equation of state. Our next step will be to prove L2-stability of the LDG discretization for the NSK equations and to investigate the mathematical properties of the LDG scheme for this non-isothermal system.

Dissertations

-

Scientific Publications

-

Projectleaders

JJW van der Vegt

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

L Tian, Prof. Yan Xu (USTC, China)
Prof.dr. JGM Kuerten

Cooperations

University of Science and Technology of China (USTC), Hefei, China

Funded

CSC Fellowship China

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

Start of the project

2011

Information

L Tian
L.Tian@utwente.nl

Multi-scale discrete and discontinuous Galerkin FEM for granular flows

Projectleaders
O Bokhove, A R Thornton
J van der Vegt, S Luding

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
DR Tunuguntla

Cooperations
T Weinhart

Funded
STW

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

Start of the project
2011

Information
D Tunuguntla
053 489 5591
D.R.Tunuguntla@utwente.nl

Project Aim

The primary goal of the project is to investigate dry polydispersed, in size and density, granular flows in inclined channels with local constrictions and obstacles including segregation. To achieve this we develop a new multiscale-method (HMM) model for granular flow, coupling a micro-scale discrete particle model (DPM) to the macro-scale continuum Discountinous Galerkin Finite Element Method (DGFEM) granular flow model. This project also runs in close collaboration with an industrial partner, Tata Steel, allowing access to large-scale real industry complex granular flows. Additionally, an investigation of segregation, driven by size and density, in granular flows will be undertaken.

Progress

Dry granular flow over an inclined channel with a localized constriction was investigated using both continuum methods and particle simulations. Initially, depth-averaged equations of motion containing an unknown friction law were considered. The shallow-layer model for granular flows was closed with a friction law obtained from particle simulations of steady flows (Weinhart et al. 2012) undertaken in the open source package Mercury DPM (Mercury 2010). The closed two-dimensional (2D) shallow-layer model is then width-averaged to obtain a novel one-dimensional(1D) model, which is an extension of the model for water flows through a contraction (Akers & Bokhove 2008). Different flow states were predicted by this novel one-dimensional theory. Flow regimes with distinct flow states were determined as a function of upstream channel Froude number F and channel width ratio Bc. The latter being the ratio of the channel exit width and upstream channel width. Existence of multiple steady states were predicted in a certain regime of F - Bc parameter plane, which is in agreement with experiments previously undertaken by (Akers & Bokhove 2008) and for granular flows (Vreman et al. 2007).

Dissertations

-

Scientific Publications

1. Weinhart, T. and Thornton, A.R. and Luding, S. and Bokhove, O. Closure Relations for Shallow Granular Flows from Particle Simulations. Granular Matter 14(4), 531-552 (2012).
2. Bokhove, O. and Thornton, A.R. (2012) Shallow granular flows. In: Handbook of Environmental Fluid Dynamics, Volume One: Overview and Fundamentals. CRC Press, pp. 545-556. ISBN 978-1-43981-669 1.
3. Thornton, A.R. and Weinhart, T. and Luding, S. and Bokhove, O. (2012) Frictional dependence of shallow-granular flows from discrete particle simulations. European physical journal E, 35 (12). 127.
4. Thornton, A.R. and Weinhart, T. and Luding, S. and Bokhove, O. (2012) Modeling of particle size segregation: Calibration using the discrete particle method. International Journal of Modern Physics C, 23 (8). 1240014.
5. Weinhart, T. and Thornton, A.R. and Luding, S. and Bokhove, O. (2012) From discrete particles to continuum fields near a boundary. Granular matter, 14 (2). pp. 289-294.
6. Woodhouse, M.J. and Thornton, A.R. and Johnson, C.G. and Kokelaar, B.P. and Gray, J.M.N.T. (2012) Segregation-induced fingering instabilities in granular free-surface flows. Journal of fluid mechanics, 709. pp. 543-580.

Discontinuous Galerkin method for inkjet flow simulations

Project Aim

Inkjet flow simulations require the accurate computation of the free surface at the liquid-air interface, and in particular the break-up into small droplets and the effect of air on the droplet motion. In order to achieve these goals a new discontinuous Galerkin finite element discretization will be developed which can accurately compute the droplet formation and droplet motion. The use of a discontinuous Galerkin method in this project is motivated by the possibility to obtain higher order accurate numerical discretizations on solution adaptive locally refined meshes which opens new ways to accurately simulate inkjet flows.

Progress

Recently, a new higher-order accurate local discontinuous Galerkin finite element method was developed for the one-dimensional lubrication model derived by Eggers and Dupont. This model is currently extensively tested on a number of inkjet problems, including breakup into droplets. Also, comparisons with other existing inkjet models are being conducted.

Dissertations

-

Scientific Publications

-

Projectleaders

JJW van der Vegt

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

T Medvedeva, O Bokhove

Cooperations

Océ Technologies

Funded

HIPRINS

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

Start of the project

2011

Information

JJW van der Vegt
053 489 5628
j.j.w.vandervegt@math.utwente.nl
www.home.math.utwente.nl/~vegtjjw/

Multiscale modeling & simulation

Prof.dr.ir. BJ Geurts

Prof.dr. HJH Clercx

Prof.dr. JGM Kuerten

I am a scientist, trained as theoretical physicist and applied mathematician, holding the chair for Multiscale Modeling and Simulation at the University of Twente and for Anisotropic Turbulence at Eindhoven University of Technology. My research focus is on mathematics, physics and numerics of multiscale problems in turbulence, mixing, complex fluids and biology. I try to find simplicity behind complexity, find structures and what combines, rather than what separates. I contribute to 3TU.AMI, ERCOFTAC, TGS Computational Science and act as HoD of Applied Mathematics in Twente.

Turbulent droplet-laden flow with phase transition

Project Aim

Develop an accurate method with which evaporation and condensation of water in air can be simulated for dispersed droplet-laden turbulent flow in a channel. Understand turbulence-phase transition interactions.

Progress

A simulation study was performed comparing incompressible with low-Mach compressible formulations for the case of turbulent channel flow. The dependence on Mach number was investigated. A specialized low-Mach algorithm was developed in 1D and tested for flow with phase transition.

Dissertations

-

Scientific Publications

1. Bukhvostova, A. and Russo, E. and Kuerten, J.G.M. and Geurts, B.J. Comparison of dns of compressible and incompressible turbulent droplet-laden heated channel flow with phase transition In: Proceedings of the 9th International ERCOFTAC Symposium on Engineering Turbulence Modelling and Measurements (ETMM9), June 2012.

Projectleaders

BJ Geurts

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Anastasia Bukhvostova, Hans Kuerten

Cooperations

-

Funded

FOM

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

Start of the project

2011

Information

A Bukhvostova
053 489 3384
a.bukhvostova@utwente.nl

PROJECTLEADERS
BJ Geurts
RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
DJ Lopez Penha, S Stolz, BJ Geurts
COOPERATIONS
-
FUNDED
Philip Morris International S.A.

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

START OF THE PROJECT
2008
INFORMATION
DJ Lopez Penha
053 489 3460
d.j.lopezpenha@utwente.nl

PROJECT AIM

Develop an efficient numerical method for accurately computing three-dimensional, time-dependent transport phenomena in moderate-Reynolds-number flows through geometrically complex domains. A method will be sought utilizing immersed boundary (IB) techniques. We apply this simulation strategy to understand aerosol transport through biomass.

PROGRESS

The volume penalizing immersed boundary method was applied to flow through a realistic porous medium, of which the inner structure was known from recorded micro-CT imagery. Excellent agreement for the permeability of the material was obtained from comparision with experimental data. A thesis was completed and defended successfully.

DISSERTATIONS

1. Lopez Penha, D.J. Simulating microtransport in realistic porous media
27 September 2012, PhD Thesis.

SCIENTIFIC PUBLICATIONS

1. Lopez Penha, D.J. and Geurts, B.J. and Nordlund, M. and Kuczaj, A.K. and Zinovik, I. and Winkelmann, C. and Mikhal, J. Tomographic immersed boundary method for permeability prediction of realistic porous media: Simulation and experimental validation. In: Proceedings of the 4th International Conference on Porous Media and its Applications in Science, Engineering and Industry (2012).
2. Lopez Penha, D.J. and Stolz, S. and Kuerten, J.G.M. and Nordlund, M. and Kuczaj, A.K. and Geurts, B.J. Fully-developed conjugate heat transfer in porous media with uniform heating. In: International journal of heat and fluid flow, (2012).

Simulation of multi-species aerosol

Project Aim

Develop an accurate method with which nucleation, coalescence, break-up, evaporation and condensation of multi-species aerosol can be simulated, involving Euler-Euler, Euler-Lagrange multi-phase flow in complex porous media.

Progress

A literature and on-site visit were conducted to start up the project.

Dissertations

-

Scientific Publications

-

Projectleaders

BJ Geurts

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Edo Frederix, Arek Kuczaj

Cooperations

-

Funded

Philip Morris International S.A.

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

Start of the project

2012

Information

E Frederix
053 489 3414
e.m.a.frederix@utwente.nl

Mathematical analysis and classification of flow topologies in cerebral aneurysms

Projectleaders
BJ Geurts
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
Julia Mikhal
Cooperations
Prof. Dr. Ir. C. H. Slump, SAS Group, EEMCS Department, University of Twente
Funded
University of Twente

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

Start of the project
2008
Information
J Mikhal
053 489 3414
j.mikhal@ewi.utwente.nl

Project Aim

Perform computational modeling, analysis and classification of flow topologies that occur in aneurysms in the human brain. Evaluation of the probability of rupture, and long-time stability are important factors.

Progress

The developed simulation method was applied to realistic cerebral aneurysms. Steady and pulsatile flow conditions were investigated and transition to complex flow was observed with growing size of the aneurysm. A thesis was completed and defended successfully.

Dissertations

1. Mikhal, J. Modeling and simulation of flow in cerebral aneurysms. 19 October 2012, PhD Thesis.

Scientific Publications

1. Mikhal, J. and Slump, C.H. and Geurts, B.J. Simulation of Pulsatile Flow in Cerebral Aneurysms: From Medical Images to Flow and Forces. In: Aneurysm. August 2012.
2. Lopez Penha, D.J. and Geurts, B.J. and Nordlund, M. and Kuczaj, A.K. and Zinovik, I. and Winkelmann, C. and Mikhal, J. Tomographic immersed boundary method for permeability prediction of realistic porous media: Simulation and experimental validation. In: Proceedings of the 4th International Conference on Porous Media and its Applications in Science, Engineering and Industry June 2012.

Aerosol particle motion in porous media

Project Aim

The target of the project is to understand aerosol particle dynamics in porous media. This will be done by performing numerical simulations and analysis of aersol property evolution in complex geometries due to evaporation, condensation and collision.

Progress

A paper was written and accepted for publication, detailing the development of a no-slip consistent particle-tracking method for volume penalizing immersed boundary methods. A Brownian motion model was developed for tracking small aerosol droplets in porous media. A nucleation model was developed with which the evolution of virgin aerosol under supersatured, strongly cooled flow conditions can be simulated.

Dissertations

-

Scientific Publications

-

Projectleaders

BJ Geurts

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Lilya Ghazaryan

Cooperations

Philip Morris International – Dr. Steffen Stolz

Funded

Philip Morris International S.A.

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

Start of the project

2008

Information

L Ghazaryan
053 489 3414
l.ghazaryan@utwente.nl

Prof.dr.ir. HWM Hoeijmakers

Prof.dr.ir. A Hirschberg

Research within the group Engineering Fluid Dynamics deals with theoretical, numerical and ex¬peri-men¬tal studies, aimed for applications in Mechanical Engineering. The reseach focuses on the following fields:

FLUID MECHANICS OF ROTATING FLOW MACHINERY

The flow in centrifugal pumps and around wind turbine blades is studied experimentally and numerically, with the objective of developing methods for predicting the performance of these machines. This relates to head, efficiency and cavitation characteristics for pumps and generated power for wind turbines. The meth¬ods are used as tools for improving the design of these rotating machines. Also methods for inverse design and optimalisation are considered. A new rotating test-rig has been developed for experimental studies of the flow in impeller channels.

AERO-ACOUSTICS

For Computational Aeroacoustics Discontinuous Galerkin finite-element methods for unstructured grids are developed for computing sound propagation in fluids. The capabilities of these methods are analysed ana¬lyt¬ically.
Witin the field of Experimental Aeroacoustics the generation of sound by objects is studied. For this an aero-acoustic test facility has been developed that is based on a closed circuit wind tunnel. The (0.7x0.9 m2) free-jet test-section (maximum velocity 65 m/s) of the silent wind tunnel is enclosed by a 6x6x4m3 anechoic chamber.

MULTI-PHASE FLOWS AND FLOWS WITH PHASE TRANSITION

Models and unstructured-grid computational methods are developed for high-speed, swirling or non-swirl¬ing, condensing flows of mixtures of gases and liquids in complex geometries. Topics of interest are slip¬ping droplets in turbulent flow and the prediction of the evolution of droplet radius distribution. Models and unstructured-grid computational methods are developed for liquid flows with unsteady sheet cavitation and vortex cavitation.
Phase transition is a driving mechanism in the study of ice accretion on aircraft wings in flight. Separation of oil/water mixtures (bulk separation and water treatment) is considered within a centrifugal force field generated in swirling pipe flows. Finally dense-phase fluid-particulate flow is studied with application to dredging type of flows.

FLUID-STRUCTURE INTERACTION AND FLOW CONTROL

Research on fluid-structure interaction focuses on the flow-induced vibrations of compressor valves and on the unsteady motion of bluff bodies, in particular of gas bubbles and solid spheres induced by vortex shedding. Also investigated is flapping-wing lift/propulsion for robot-bird configurations. Flow control is developed for application to wind turbine blades and diffusers, employing synthetic jets and plasma actuators. Both numerical and experimental investigations are conducted.

THIN-FILM FLOWS

The flow in narrow domains between deforming surfaces under extreme conditions is studied theoretically as well as experimentally. An example is the lubricant film in roller bearings, i.e. Elasto-Hydrodynamic Lu¬bri¬cation.

The theoretical research involves modeling, development of efficient numerical solution al¬go¬rithms and the use of these tools to derive general design rules for practical use. The experimental research employs a ball-on-disk apparatus and involves validation of predictions as well as the study of grease lu¬bri¬cation phenomena.

Bio-physical flows

This research deals with the flow in lungs, in particular the flow-induced deformation of the elastic lung tubes and the deposition of aerosols in lungs. Research is aimed at developing new diagnostic and thera¬peutic tools.

Prediction of the hydraulic performance of centrifugal pumps

Projectleaders
NP Kruyt, HWM Hoeijmakers

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
RW Westra, NP Kruyt, K van Andel, HWM Hoeijmakers

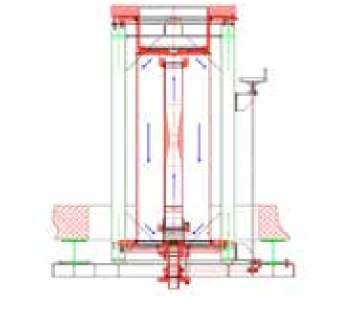
Cooperations
Flowserve BV

Funded
Senter, UT

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

Start of the project
1998

Information
NP Kruyt
053 489 2528
n.p.kruyt@utwente.nl



Project Aim

The hydraulic performance of pumps is studied both numerically and experimentally. For the numerical flow simulation a potential-flow method has been developed for the flow inside centrifugal and mixed-flow pumps. The 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

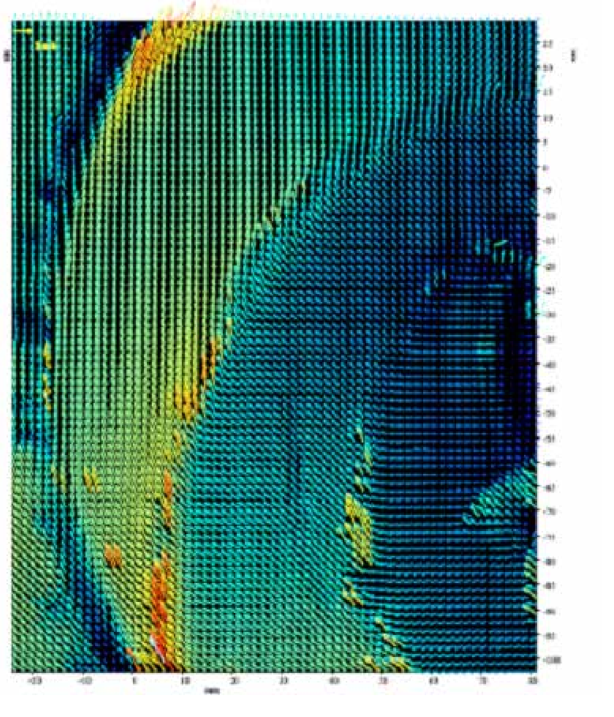
In 2012 further work has been carried out and publication of results has been realized. The Rotating Flow facility is being redesigned so that higher rotational speeds become possible.

Dissertations

-

Scientific Publications

-



Inverse design and optimisation methods for centrifugal pumps and fans

Project Aim

Using the augmented potential-flow method developed for the prediction of the hydraulic performance of centrifugal and mixed flow pumps two types of design methods for three-dimensional configurations are investigated: (i) inverse-design methods and (ii) optimization methods. The validation of the computational methods has been carried out in the newly developed Rotating Flow facility, by PIV-measurements of the relative velocity field.

Progress

A three-dimensional inverse-design method for impellers of centrifugal pumps has been developed, by which an impeller geometry is obtained that meets the prescribed hydraulic characteristics (rotational speed, flow ate, 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. A publication has been effected.

Dissertations

-

Scientific Publications

-

Projectleaders

NP Kruyt, HWM Hoeijmakers

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

RW Westra, NP Kruyt, K van Andel, HWM Hoeijmakers

Cooperations

Flowserve BV, Urenco Aerospace, Johnson Pump, IHC Parts & Services, NLR, Marin

Funded

STW, UT

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

Start of the project

2003

Information

NP Kruyt
053 489 2528
n.p.kruyt@utwente.nl

Aerodynamics of flexible wind turbine blades

Projectleaders
HWM Hoeijmakers, A Hirschberg

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
H de Vries, ETA van der Weide, A Hirschberg, HWM Hoeijmakers

Cooperations
ECN

Funded
ECN, UT

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

Start of the project
2000

Information
HWM Hoeijmakers
053 489 4838
h.w.m.hoeijmakers@utwente.nl

Project Aim

CFD methods for unsteady flows are developed for the aero-elastic behavior of flexible wind turbine blades. The methods considered range from inviscid flow methods coupled to boundary-layer methods to time-accurate RANS methods. The flow conditions to be considered include cases with dynamic stall. Means for flow control are explored, both experimentally and computationally.

Progress

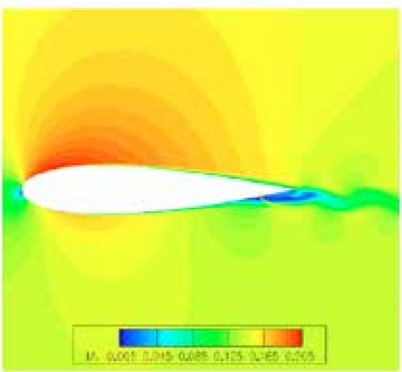
In 2012 the research into the application of flow control devices, such as synthetic jets as well as plasma actuators, on wind turbine rotor blades has continued, both experimentally and computationally. On the computational side of the research, the Unsteady Reynolds-averaged Navier-Stokes (URANS) method, which was developed in this project, has been combined with boundary conditions to simulate synthetic jet actuation. Subsequently, a parameter study of synthetic jet actuation for load control on a NACA 0018 airfoil has been started. Besides main-flow parameters and geometry parameters, this study includes actuation parameters such as the dimensionless actuation frequency and the dimensionless momentum addition by the jet. The URANS method is characterized by 2nd order accurate discretisations in space and time, an edge-based finite-volume formulation on unstructured, hybrid, two- or three-dimensional grids, parallelization using domain decomposition and an implicit solution method using algebraic agglomeration-based multigrid. On the experimental side of the research, the developed experimental set-up to test synthetic jet actuation on a NACA 0018 in Twente's silent wind tunnel has been adapted to include improved actuators. Furthermore a preliminary investigation into plasma actuators has been performed.

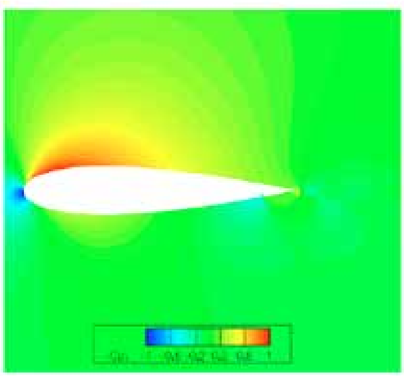
Dissertations

-

Scientific Publications

1. SMD Widjanarko, IJAK Geesing, H de Vries, HWM Hoeijmakers: Experimental/Numerical Investigation Airfoil with Flow Control by Synthetic Jets (CD) (paper ICAS 2012-3.7.5). In I. Grant (Ed.), Proceedings of the 28th Congress of the International Council of the Aeronautical Sciences (ICAS 2012) (pp. paper ICAS 2012-3.7.5/1-paper ICAS 2012-3.7.5/20). Edinburgh, UK: Optimage Ltd (science@optimage.co.uk) (ISBN 978-0-9565333-1-9).





PROJECT AIM

Development of an aerodynamic analysis tools and integration of these tools into a gradient based optimization framework such that the performance of wind turbine blades can be optimized according to a (user defined) objective function.

PROGRESS

Optimization tests in terms of drag minimization have been carried out for both 2D and 3D transonic flows as well as for 3D subsonic flows. These tests show that the method performs as expected, although care must be taken that during the iteration process the geometry remains valid. The figure below shows the inverse design of a given pressure distribution, which is accomplished by a minimization of the L2 norm of the difference between the given and final pressure.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS

HWM Hoeijmakers, ETA van der Weide

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

SH Jongsma, ETA van der Weide, HWM Hoeijmakers

COOPERATIONS

Suzlon Blade Technology

FUNDED

Suzlon Blade Technology

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

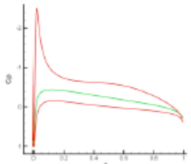
START OF THE PROJECT

2008

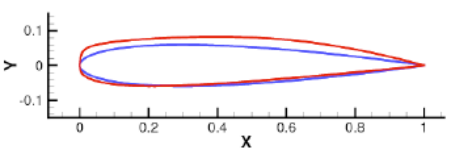
INFORMATION

ETA van der Weide
053 489 2593
e.t.a.vanderweide@utwente.nl

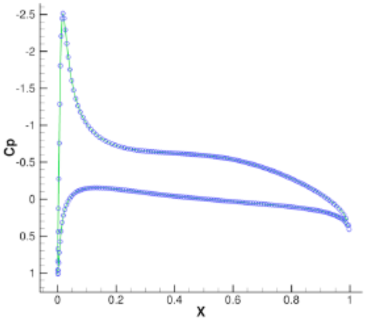
- Target and initial c_p-distribution



- Final and initial geometry



Final and target c_p-distribution



PROJECTLEADERS
HWM Hoeijmakers, ETA van der Weide

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
H de Vries, ETA van der Weide, HWM Hoeijmakers

COOPERATIONS
-

FUNDED
EU (CleanSky Project)

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

START OF THE PROJECT
2009

INFORMATION
ETA van der Weide
053 489 2593
e.t.a.vanderweide@utwente.nl

PROJECT AIM

Investigate the possibility to apply synthetic jet flow control on the flaps of aircraft wings in order to increase the lift during take off and landing. The goal of this research is to determine the specifications of a synthetic jet flow control device in order to accomplish the desired effects.

PROGRESS

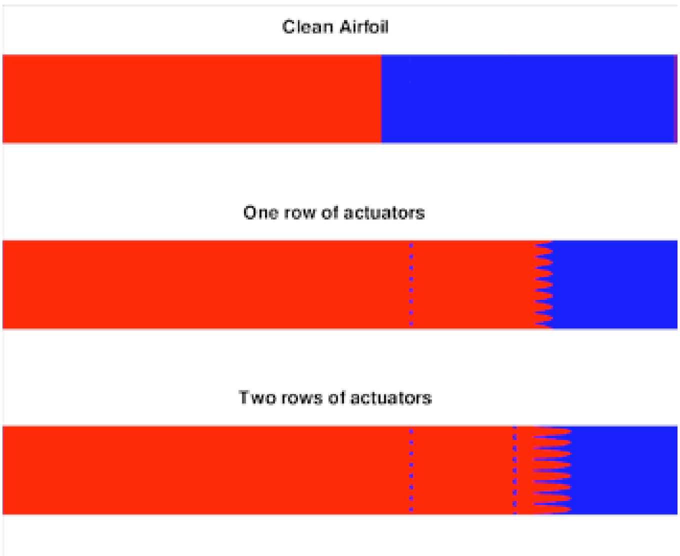
3D simulations with actuation via a continuously blowing jet actuation have been carried for the IACD (Integrated Active Component Demonstrator), the demonstrator of the Dutch consortium within the CleanSky project. The goal of these simulations is to find out the location of the actuators such that separation can be reduced as much as possible. It was found that for representative flow conditions one row of actuators can reduce the separation length significantly, but it cannot remove the separation completely. Furthermore, two rows of actuators do not seem to perform significantly better than one row, at least not for the configuration and flow conditions considered.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



Top view of the separation length for the clean airfoil, one row of actuators and two rows of actuators. Red is attached flow, blue is separated flow. The flow is from left to right.

Computational aero-acoustics

Project Aim

Computational Fluid Dynamics methods for unsteady flows are extended to numerically simulate flows including sound waves. Configurations aimed for are the flow over discontinuities, cavities, airfoils, blunt bodies, etc. Validation of computational results is pursued employing the Aero-Acoustic Test facility with a 0.9*0.7 m2 (65 m/s) open-jet test section within an anechoic room of 6x6x4 m3.

Progress

-

Dissertations

1. A Mueller: Large Eddy Simulation of cross-flow around a square rod at incidence with application to tonal noise prediction.

Scientific Publications

-

Projectleaders

HWM Hoeijmakers, A Hirschberg

Researchtheme

Complex dynamics of fluids

Participants

CH Venner, A Hirschberg, HWM Hoeijmakers, ETA van der Weide, G Guilloud, C Schram, D Marx

Cooperations

TNO, TU/e, VKI, LEA (Université Poitiers)

Funded

UT, EU (Aether project)

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

Start of the project

1999

Information

HWM Hoeijmakers
053 489 4838
h.w.m.hoeijmakers@utwente.nl

PROJECTLEADERS
HWM Hoeijmakers, A Hirschberg
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
A Mueller, E van der Wijden, J Dorneanu, A Hirschberg, P Rambaud, F Scarano
COOPERATIONS
VKI, TUDelft, LMS (Be)
FUNDED
UT, EU (Aether project)

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

START OF THE PROJECT
1999
INFORMATION
HWM Hoeijmakers
053 489 4838
h.w.m.hoeijmakers@utwente.nl

PROJECT AIM

Investigate experimentally the flow over discontinuities, cavities, airfoils, blunt bodies, etc. For this purpose the existing 0.9*0.7 m2 (50 m/s) closed test section aerodynamic wind tunnel has been developed to an Aero-Acoustic Test facility (silent wind tunnel) with 0.9*0.7 m2 (65 m/s) open jet test section within a 6x6x4m3 anechoic chamber.

PROGRESS

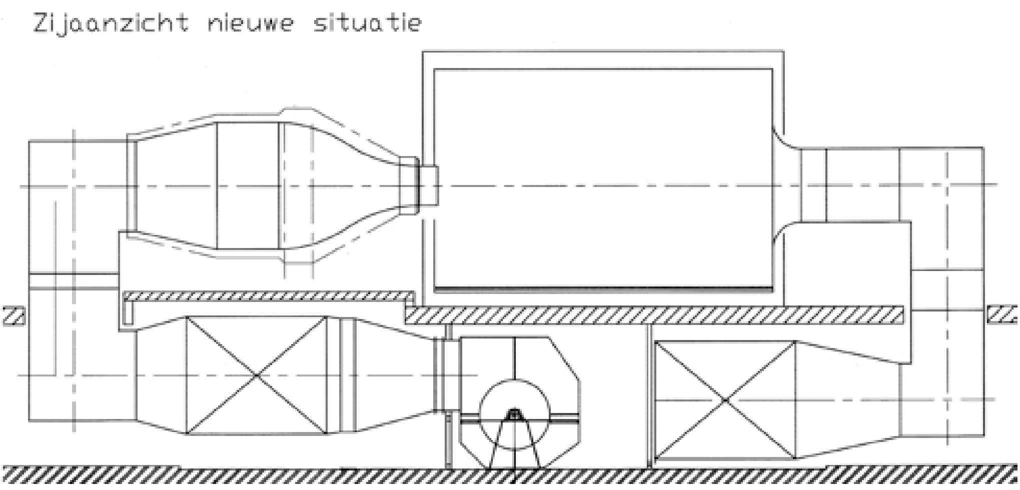
A. Mueller has finalized her PhD thesis (defense 20-1-2012). Results have been submitted for publication in journal.

DISSERTATIONS

1. A. Mueller: Large Eddy Simulation of cross-flow around a square rod at incidence with application to tonal noise prediction.

SCIENTIFIC PUBLICATIONS

1. B Fabre, J Gilbert, A Hirschberg, X Pelorson: Aeroacoustics of Musical Instruments. Annual review of fluid mechanics, (ISSN 0066-4189), 44, 1-25.
2. G Nakiboglu, HBM Manders, A Hirschberg: Aeroacoustic power generated by a compact axisymmetric cavity: Prediction of self-sustained osciallation and influence of depth. Journal of fluid mechanics, (ISSN 0022-1120), 703, 163-191.
3. G Nakiboglu, A Hirschberg:: Aeroacoustic power generated by multiple compact axisymmetric cavities: effect of hydrodynamic interference on the sound production. Physics of fluids, (ISSN 1070-6631), 24(6), 067101-1-067101-18.
4. G Nakiboglu, O Rudenko, A Hirschberg:: Aeroacoustics of the swinging corrugated tube: Voice of the Dragon. Journal of the Acoustical Society of America, (ISSN 0001-4966), 131(1), 749-765. EMT Moers, D Tonon, A Hirschberg: Sound absorption by perforated walls with bias / grazing flow: experimental study of the influence of perforation angle. In Proceedings of the Acoustics 2012 Nantes Conference (23-27 April 2012, Nantes, France (pp. 3443-3447) (ISBN 978-2-919340-01-9).



COPA-GT, Study of higher order energy-stable discretization technique for turbomachinery applications

Project Aim

The research is theoretical/numerical and focuses on the development of an highly efficient parallel multiblock structured code for turbomachinery applications. The goal is to assess whether or not high order energy stable schemes are more efficient for such problems. In fact, the most widely used commercial codes typically provide a 2nd order accurate discretization of the Navier-Stokes equations. The question is if it possible to obtain the same solution making use of high order (≥ 3rd) numerical methods and at the same time reducing the number of points of the numerical grid. This would lead to large saving in terms of computational time.

Progress

Particular effort has been spent on code parallelization and on developing various types of boundary conditions, including internal block interface, periodic, inviscid wall, viscous adiabatic wall and far field. In addition, the calculation of forces and moments has been fully implemented. Using explicit time integration schemes, both steady and unsteady, viscous (laminar only) and inviscid, problems have been studied and good results have been obtained. The figure below shows the enstrophy evolution in time for the Taylor-Green Vortex (viscous unsteady DNS) test case obtained with different schemes and different grids; a reference 'exact' solution is also shown. The schemes considered look promising: no stability issues have arisen with any combination of boundary conditions and the use of high order schemes seems to allow a reduction in the number of grid points without compromising the quality of the solution.

Dissertations

-

Scientific Publications

-

Projectleaders

HWM Hoeijmakers, ETA van der Weide

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

G Giangaspero, ETA van der Weide, HWM Hoeijmakers

Cooperations

VKI, Cerfacs, RWT, Turbomeca, BSC, Siemens, Loughborough Univ

Funded

EU

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

Start of the project

2012

Information

ETA van der Weide
053 489 2593
e.t.a.vanderweide@utwente.nl

The structure of unsteady 3D sheet cavitation

Projectleaders
HWM Hoeijmakers, GH Schnerr
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
AH Koop, GH Schnerr, HWM Hoeijmakers
Cooperations
UT, TUD, TU Munchen, Marin, Wartsila, Flowserve, IHC, Holland Roer Propellers, RNN
Funded
STW, UT

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

Start of the project
2003
Information
HWM Hoeijmakers
053 489 4428
h.w.m.hoeijmakers@utwente.nl

Project Aim

Three-dimensional flows with steady and unsteady sheet cavitation are considered such as occur on hydrofoils. Computational methods are developed based on an unstructured-grid finite-volume method coupled to a dispersed-bubble model for cavitation as developed in prof. Schnerr's group in München. The project is a cooperation between the group at the UT and the group of prof. van Terwisga at Delft University of Technology where experiments are designed and carried out for obtaining data for validation of the computational results.

Progress

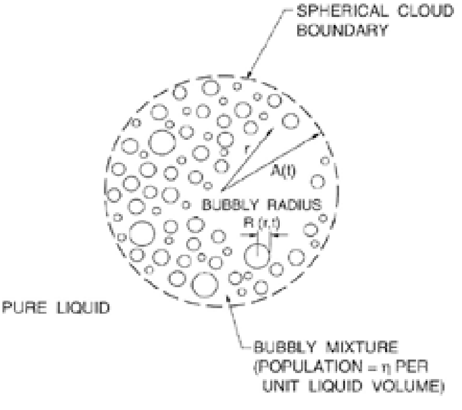
An unstructured-grid Euler method for compressible flow has developed for flows with cavitation. The method assumed the liquid and the vapor to be compressible and the liquid-vapor mixture to be in mechanical and thermal equilibrium. Various upwind schemes have been implemented. Results show that the method gives promising results for the flow around 2D and 3D hydrofoils. The latter results are compared with experimental results obtained by Foeth & Terwisga in the Delft Cavitation Tunnel. In 2012 a dynamic cavitating cloud model has been implemented for matching with results of CFD methods.

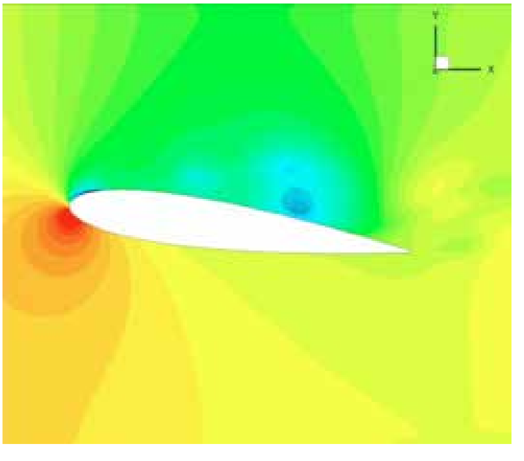
Dissertations

-

Scientific Publications

1. S van Loo, TJC van Terwisga, HWM Hoeijmakers, M Hoekstra: Numerical Study on Collapse of a Cavitating Cloud of Bubbles (USB stick). In Claus-Dieter Ohl, Evert Klaseboer, Siew.Wan Ohl, Shi.Wei Gong & Boo.Cheong Khoo (Eds.), Proceedings of the Eighth International Symposium on Cavitation (CAV 2012) (pp. 227-239). Singapore: Research Publishing Services (ISBN 978-981-07-2826-7).





DYNVOR : The dynamics of vortex cavitation on ship propulsors and pump impellers

Project Aim

The aim of this project is: (i) to enhance the understanding of the contribution of cavitating vortices to cavitation vibration and cavitation erosion and (ii) to develop a simulation code capable of predicting flows with cavitating vortices. It is believed that Large Eddy Simulation (LES) for the modeling of turbulence is a key tool for the success of such a simulation code. Typical applications where this type of flow occurs are flows around ship propulsors and flows in pumps.

Progress

It turned out that the thermodynamic tables developed last year were quite inaccurate in phase transition regions. This problem has been solved by using the POITC (Phase Oriented Interpolation in Transition Cells) approach, which leads to more accurate interpolation and much smaller tables than the standard approach. An initial study has been carried out on the performance of the high order schemes for LES test cases, which is very good. However, the shock capturing capabilities of the high order schemes remain a challenge.

Dissertations

-

Scientific Publications

1. F Khatami, AH Koop, ETA van der Weide, HWM Hoeijmakers: Efficient numerical simulation of unsteady cavitating flows using thermodynamic tables, Proceedings of the Eighth International Symposium on Cavitation (CAV 2012), Singapore, August 2012. Paper 098 (pp. 595-600). ISBN: 978-981-07-2826-7.

Projectleaders

HWM Hoeijmakers, ETA van der Weide

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

F Khatami, ETA van der Weide, HWM Hoeijmakers

Cooperations

Wärtsilä, IHC Merwede, Flowserve

Funded

AgentschapNL

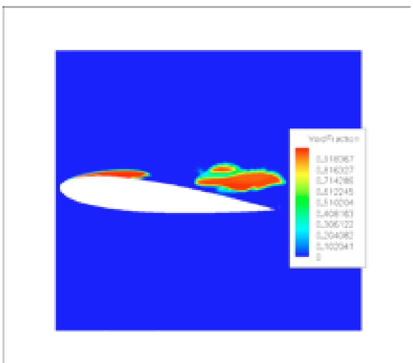
University	-
FOM	-
STW	-
NWO Other	-
Industry	25 %
TNO	-
GTI	-
EU	75 %
Scholarships	-

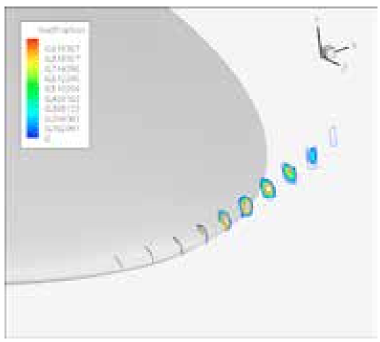
Start of the project

2011

Information

ETA van der Weide
053 489 2593
e.t.a.vanderweide@utwente.nl





Centrifugal separation of oil/water mixtures

Projectleaders
HWM Hoeijmakers
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
JJ Slot, HWM Hoeijmakers
Cooperations
TUD, Tue, Shell, FMC Separation Systems, Frames, Wintershall, WUR
Funded
ISPT, UT

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

Start of the project
2008
Information
HWM Hoeijmakers
053 489 4428
h.w.m.hoeijmakers@utwente.nl

Project Aim

Modeling and numerical simulation of swirling flow of oil/water mixtures aimed at separation. An experimental set-up is developed at TU Delft for experimental investigation of these flows and providing data for validation. At Wageningen University the behavior of oil-water mixtures is studied at the micro-scale, including droplet coalescence and the effect of surfactants.

Progress

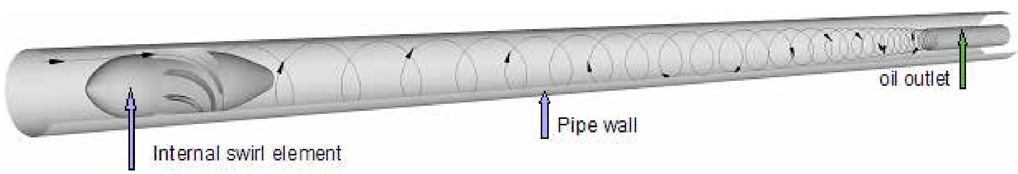
Using CFD, the single-phase swirling water flow in the inline bulk oil-water separator has been considered in detail and agree with experimental measurements. The results show a complex flow pattern with regions of reversed flow. Two-fluid models are employed to study the flow field and separation characteristics. Two-phase experiments are carried out and it will be used to validate the numerical models for these flows. Evolution of the droplet size distribution of the dispersed oil phase will be computed using populations balance models.

Dissertations

-

Scientific Publications

1. LJAM van Campen, RF Mudde, JJ Slot, HWM Hoeijmakers: A numerical and experimental survey of a liquid-liquid axial cyclone. International journal of chemical reactor engineering (electronic), (ISSN 1542-6580), 10(1).



Multiphase flow effects in compact produced-water treatment equipment

Project Aim

The physical phenomena occurring during produced-water treatment are studied numerically. Oil droplet, and gas bubble trajectories will be predicted employing Lagrangian particle tracking for both swirling flow and settling conditions. Influence of effects such as a history term are required for prediction of trajectories. Collision and coalescence are important factors for advanced compact produced-water treatment. Occurrence of such effects is predicted making use of droplet and bubble trajectories.

Progress

A Lagrangian particle tracking method has been developed for generic flow fields. Both implicit Crank-Nicolson, and explicit fourth order Runge-Kutta schemes have been implemented. History force has been identified as force that needs to be investigated. A new expression for the history kernel has been obtained using experimental data from literature to improve existing Reynolds dependent kernel. Efficient collision detection has been implemented in particle tracking code. Two Lattice Boltzmann Methods for liquids have been developed, one using a BGK approach with a body force pressure correction, the other using a BBGKY approach, to investigate the history force in detail. Both explicit and implicit schemes have been implemented. 2-D flow about a cylinder has been investigated to explore the method, and the method has been extended to 3-D flow about a sphere.

Dissertations

-

Scientific Publications

1. DF van Eijkeren, HWM Hoeijmakers: History force and inertia effects applied to swirling flow produced water treatment, in Proceedings of the 9th International Conference on Computational Fluid Dynamics in the Minerals and Process Industries, Melbourne, Australia, Dec 10-12, 2012. 044EIJ:1-6. ISBN 978-1-922173-01-0, www.cfd.com.au/cfd_conf12/PDFs/044EIJ.pdf.

Projectleaders

HWM Hoeijmakers

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

DF van Eijkeren, HWM Hoeijmakers

Cooperations

FMC Technologies – Separation Systems, FACE (SINTEF)

Funded

FMC Technologies – Separation Systems, FACE (SINTEF)

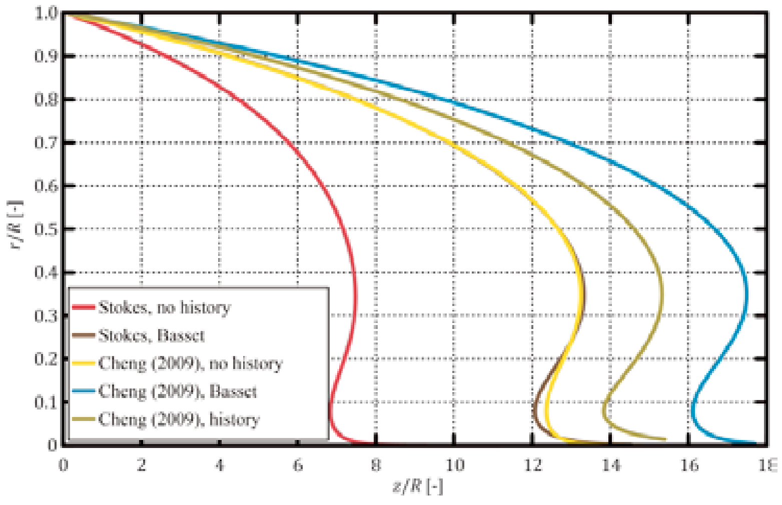
University	-
FOM	-
STW	-
NWO Other	-
Industry	100 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2009

Information

DF van Eijkeren
053 489 2482
d.f.vaneijkeren@utwente.nl



Thin layer flow

Projectleaders
HWM Hoeijmakers, CH Venner

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
CH Venner, HWM Hoeijmakers, S van Loo, H Boffy, M van Zoelen (SKF) PM Lugt (SKF), J Snoeijer (PoF, UT), J Wang (Qingdao), AA Lubrecht (INSA)

Cooperations
INSA-de Lyon, France, Technical University of Brno, Czechia Qingdao Technolgical University, PR. China, SKF ERC, Netherlands, Howden Thomassen Compressors

Funded

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

Start of the project
2007

Information
CH Venner
053 489 2488
c.h.venner@utwente.nl

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.

Progress

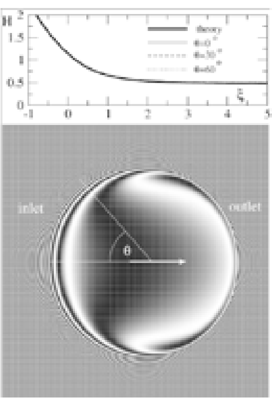
A self similartiy theory has been developed for EHL line and point contacts. The self similar solution can be obtained from a localized problem. The local scale, explains the emperical concept of inlet length introduced in engineering. Thin layer flow models for film decay in EHL contacts (bearings) have been generalized to grease lubrication. The effect of surface roughness on the performance of a cam-follower pair was studied. A Multigrid/Multlevel method was developed for the fast simulation of journal paths in linear compression systems including elastic deformation of the bearing shells. A new approach was developed to obtain high pressure rheological information of lubricants from the (measured) film thickness in single EHL contacts. For advanced material optimization of rolling bearings an optimally efficient multigrid algorithm has been developed for 3D stress simulation in heterogeneous (granular/ graded) materials with interstitial layers (ceramics).

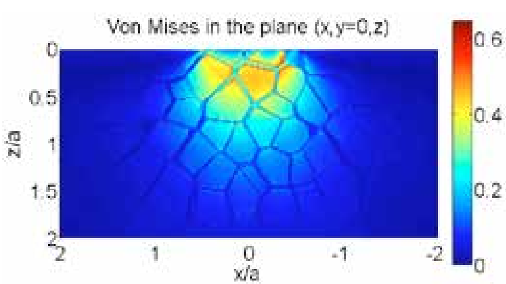
Dissertations

-

Scientific Publications

1. MP Noutary, CH Venner, AA Lubrecht: Grid Generation in HL and EHL using AMG, Proc. ImecheE, J. of Engineering Tribology, V. 226, 5, pp. 343-349. DOI:10.1177/1350650111432998.
2. CH Venner, MT van Zoelen, PM Lugt: Thin Layer Flow Modeling and Film Decay for Grease Lubricated Bearings, Tribology International, V. 47, ppl 175-187, DOI:10.1016/j.triboint.2011.10.019.
3. P Duineveld, B Brogle, CH Venner, S van Loo: Development of Advanced Multilevel Solution for Journal Paths including Bearing Deformation, proceedings 8th EFRC Conference for reciprocating compressors, Germany, sept. 27-28 2012, pp. 25-32.
4. Noutary, M. P., Venner, C. H. & Lubrecht, A. A. (2012). Grid Generation in HL and EHL, using AMG. In Proceedings of the ImechE Vol. 226. Proceedings of the Institutions of Mechanical Engineers. Part J: Journal of engineering tribology, (ISSN 1350-6501) (pp. 242-349).





Self similarity solution EHL Point contact (left) and von Mises stresses in granular material subjected to EHL contact pressure in extremely thin film regime (right)

Multiscale islands mixed lubrication modeling

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

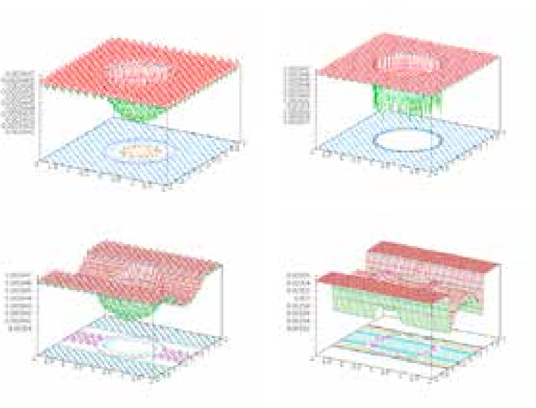
- Development of a concept for mixed contact modeling and a multigrid algorithm for the efficient numerical solution. The model is based on a “bottom-up” approach, from dry contact to fully lubricated situation. The dry contact model uses linear elasticity theory. Ultra thin visco-elastic layer(s) are added to the dry contact model and representing a precursor film. The layer geometry can be varied and the material behaviour is modeled by a Maxwell element. The next step is to add a flow equation describing the behaviour of the liquid oil.
- Experiments are carried out in a controlled single contact setting using optical interferometry and high speed camera equipment to study aspects of flow and lubricant distribution around an EHL contact. Furthermore data is generated for validation and guide for the mixed contact model development.
- A “vision” image analysis method with particular emphasis is on multiscale image segmentation [1] is implemented in c to. The next step is to customize this method to suit our applications, identify phenomena in images from experimental data.
  [1] Inglis, T., De Sterck, H. et al, 2010, “Multilevel Space-Time Aggregation for Bright Field Cell Microscopy Segmentation and Tracking”, International Journal of Biomedical Imaging, V.2010, ID 582760.

Dissertations

-

Scientific Publications

-



Deformed film (with roughness) at the start and after some time. Maxwell element with constant viscosity (left) and pressure dependent viscosity (right).

Projectleaders

CH Venner, HWM Hoeijmakers

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

E van Emden, CH Venner, HWM Hoeijmakers, GE Morales-Espejel (SKF)

Cooperations

SKF

Funded

SKF

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

Start of the project

2009

Information

CH Venner
053 489 2488
c.h.venner@utwente.nl

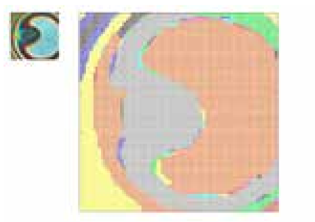


Image segmented with ”Vision” (above)..Optical interferometry image of scarcely lubricated contact moving at low velocity (below).

Slow flows of granular materials

Projectleaders
NP Kruyt

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
NP Kruyt

Cooperations
University of Waterloo, Canada, University of Leeds, Université Joseph Fourier, Grenoble, France

Funded

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

Start of the project
2003

Information
NP Kruyt
053 489 2528
n.p.kruyt@utwente.nl

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

The accuracy of three-dimensional, micromechanical expressions for the strain tensor have been investigated. The most accurate one, due to Bagi, has been used to study the deformation characteristics of granular materials from the micromechnical viewpoint. Elastic properties of granular materials in the isotropic state have been investigated theoretically. Links between macroscopic plasticity and microscopic behaviour have been studied.

Dissertations

-

Scientific Publications

1. NP Kruyt: Micromechanical study of dispersion and damping characteristics of granular materials. Journal of Mechanics and Materials of Structures 7 347–361.
2. NP Kruyt: Micromechanical study of fabric evolution in quasi-static deformation of granular materialsMechanics of Materials 44 120–129.
3. NP Kruyt, L Rothenburg: On shear strength and fabric of granular materials (Paper 36086)(CD-rom). In G.A. Holzapfel & R.W. Ogden (Eds.), Proceedings 8th European Solid Mechanics Conference (pp. 36086-1-36086-2). Graz, Switserland: TU Graz (ISBN 978-85125-223-1).

Flow and aerosol deposition in human lungs

Project Aim

Inhalation of therapeutic aerosols to treat lung diseases (e.g. asthma) is a problem since the upper airways (nose/mouth region) acts as a natural fiter (especially for small subjects (e.g. children). Results of in vitro measurements and CFD calculations show considerable differences. More over the difficult geometry and non stationair breathing patterns complicate the calculations. The ultimate aim is to predict how and which aerosols should be inhaled to maximize deposition in the required regions and avoid uper airway deposition in the individual patient.

Progress

In the last year a master student (T. Huijgen) worked on his master thesis on CFD calculations for the flow and spray in inhalers and comparison with experiments.

Dissertations

-

Scientific Publications

1. JM Driessen, J van der Palen, WM van Aalderen, FHC de Jongh, BJ Thio: Respir Med. 2012 Oct;106(10):1362-8. doi: 10.1016/j.rmed.2012.06.017. Epub 2012 Jul 11.
2. M Miedema, FHC de Jongh, I Frerichs, MB van Veenendaal, AH van Kaam: Eur Respir J. 2012 Aug;40(2):479-84. doi: 10.1183/09031936.00138311. Epub 2012 Feb 23.
3. ET Kersten, JC van Leeuwen, PL Brand, EJ Duiverman, FHC de Jongh, BJ Thio, JM Driessen: Pediatr Pulmonol. 2012 Jan;47(1):27-35. doi: 10.1002/ppul.21511. Epub 2011 Aug 24.
4. M Miedema, FHC de Jongh, I Frerichs, MB van Veenendaal, AH van Kaam: Intensive Care Med. 2012 Feb;38(2):294-9. doi: 10.1007/s00134-011-2410-2. Epub 2011 Nov 29.

Projectleaders

HWM Hoeijmakers, FHC de Jongh

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

FHC de Jongh, HWM Hoeijmakers

Cooperations

MST, UVA-AMC, Medspray

Funded

UT

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

Start of the project

1998

Information

FHC de Jongh
053 489 4428
f.h.c.dejongh@utwente.nl

CFD Methods for dense-phase suspensions.

Projectleaders
NP Kruyt, HWM Hoeijmakers

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
BJ Konijn, NP Kruyt,
HWM Hoeijmakers

Cooperations
TUD, IHC

Funded
Agentschap NL, IHC

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

Start of the project
2011

Information
NP Kruyt
053 489 2528
n.p.kruyt@utwente.nl

Project Aim

Aim of the project is to develop a CFD method for the modeling of dense-phase fluid-particulate flow. Firstly, experiments are 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

A literature study on fluid-particulate flow modeling and fluid-particulate flow experiments has been carried out. A rheometer is selected and acquired. Tests on flow behavior dependence on liquid and particle properties have been made. The influence of particle diameter, solid fraction, viscosity of carrying liquid on the effective viscosity has been determined. An outline of a CFD method for dense-phase suspensions has been developed.

Dissertations

-

Scientific Publications

-

Oogspray: sprayen, niet druppelen

Project Aim

The aim of the project is to develop a numerical simulation model for a turbulent spray which is created by the Rayleigh breakup mechanism, and to use this model to improve the understanding of industrially applied sprays and to support the design of a spray device for eye-treatment.

Progress

The project has been completed. A numerical model based on Large -Eddy simulation on a cartesian uniform grid has been developed together with a Lagrangian model for the transported droplets based on Stokes drag force. An investigation in terms of dimensionless numbers has been carried out to support the design of an eye-spray device.

Dissertations

-

Scientific Publications

-

Projectleaders

R Hagmeijer, FHC de Jongh

Researchtheme

Complex dynamics of fluids

Participants

PJ van Dijk, R Hagmeijer

Cooperations

Medspray BV

Funded

Medspray BV

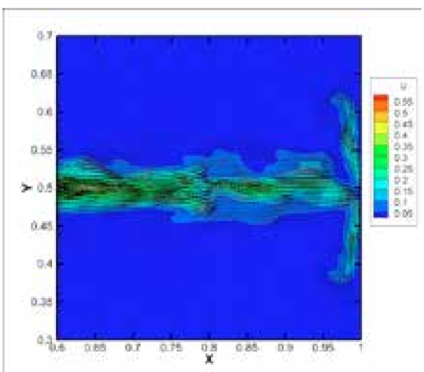
University	50 %
FOM	-
STW	-
NWO Other	-
Industry	50 %
TNO	-
GTI	-
EU	-
Scholarships	-

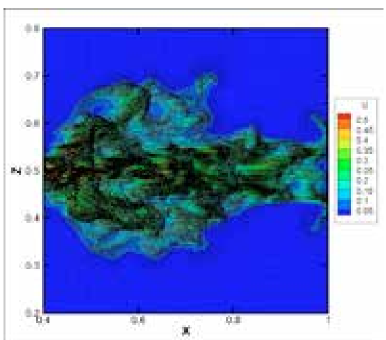
Start of the project

2011

Information

R Hagmeijer
053 489 5605
r.hagmeijer@utwente.nl





PROJECTLEADERS
HWM Hoeijmakers
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
RJ Musters, HWM Hoeijmakers, ETA van der Weide
COOPERATIONS
-
FUNDED
UT

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

START OF THE PROJECT
2012
INFORMATION
HWM Hoeijmakers
053 489 4838
h.w.m.hoeijmakers@utwente.nl

PROJECT AIM

Investigate experimentally and numerically the flow about nature-inspired configurations, such as the Robot Birds of Robert Musters. These nature-inspired copies of real birds combine lift and propulsion by flapping wings. In the project (scale-models of) these, and others, configurations are investigated in the wind tunnel and numerically.

PROGRESS

Wind-tunnel experiments have been carried out for a rigid, stationary model of the wing of the peregrine bird. Results have been presented at an AIAA conference. A start has been made on numerical simulations and on the design of a set-up for wind-tunnel experiments on a configuration with rigid flapping wings.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. SA Hartman, HWM Hoeijmakers, RJ Musters: Experimental Investigation of Flow about Wing of Robot Bird (on line) (Paper no. AIAA 2012-0055). In Conference Proceedings 50th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition (pp. 1-19). Reston, Virginia, USA: AIAA.

Robot-birds created by Robert Musters. From left to right: the Bald Eagle, the Peregrine Falcon and the Hawk.
Source: http://www.greenx.nl

PROJECT AIM

Numerical simulation of ice accretion on aircraft wings in flight at (extreme) icing conditions, including effects of splashing of large super-cooled droplets on impact, droplet breakup in high-shear regions of the flow, droplet coalescence.

PROGRESS

Starting point has been a potential flow method coupled to a Lagrangian method to predict the water collection efficiency and to Messinger's model for the freezing thin layer of water along the surface. This method has been extended to poly-disperse droplet distributions and the capability to treat multi-element airfoil sections. Also a splashing-droplet model as well as a bouncing-droplet model has been adapted and implemented. Furthermore an Eulerian method for predicting the water collection efficiency has been developed, which is more suitable for complex configurations. Furthermore an unstructured-grid Euler method for compressible flow has adapted for coupling to the ice-accretion models. The method has been extended to ice accretion on 3D swept wings.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. JM Hospers, HWM Hoeijmakers: Numerical Method for Ice Accretion on 3D Wings (CD) (Paper ICAS Paper 2012-1.4.3). In I. Grant (Ed.), Proceedings of 28th Congress of the International Council of the Aeronautical Sciences (ICAS 2012) (pp. paper 2012-1.4.3/1-Paper 2012-1.4.3/7). Edinburgh, UK: Optimage Ltd (science@optimage.co.uk) (ISBN 978-0-9565333-1-9).

PROJECTLEADERS

HWM Hoeijmakers

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

JM Hospers, HWM Hoeijmakers

COOPERATIONS

TU Darmstadt, CIRA, INTA, ONERA

FUNDED

EU, UT

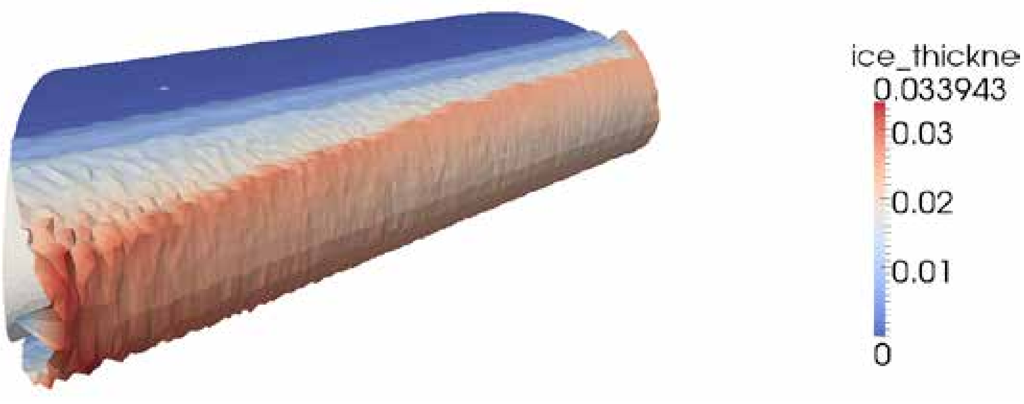
University	20 %
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	80 %
Scholarships	-

START OF THE PROJECT

2008

INFORMATION

HWM Hoeijmakers
053 489 4428
h.w.m.hoeijmakers@utwente.nl



Thermal Engineering

Prof.dr.ir. ThH van der Meer

The research activities of the Thermal Engineering Group mainly concentrate on thermal conversion processes for industrial applications from the disciplines thermodynamics, transport phenomena and fluid mechanics. The research aims at an increasing use of renewable fuels, and at a more efficient and clean utilization of fossil fuels. The projects are organized around three central themes: thermal conversion processes of fuels, turbulent gaseous combustion and thermo-acoustics, and instationary heat transfer.

The research theme thermal conversion processes of fuels is part of the research programme of the OSPT (research school on process technology)

The research theme Turbulent gaseous combustion and thermo-acoustics is related to questions on ignition, extinction, flame stability, pollutant formation, combustion noise and its interaction with the combustion chamber structure. Numerical models are developed (within CFX), and experimental research is done like flow visualisation, acoustic measurements and laser diagnostics like laser induced fluorescence and Ramen/Rayleigh spectroscopy for the in-flame measurements of temperature and species concentrations. the underlying physical-chemical processes. Currently a large EU-project, named LIMOUSINE, with three PhD's and a post doc is ongoing on the topic of thermo-acoustics in gas turbines. Next there are several projects within the STW perspective program Clean Combustion Concepts.

The research theme "instationary heat transfer" is related to heat transfer in piston compressors, a pulsed compression reactor and new materials for enhanced heat transfer in regenerators and heat exchangers based on carbon nano-fibers attached to the heat transfer surface.

The sound solution for small scale residential energy conversion

Project Aim

As efficient usage of resources becomes more and more important because of their finiteness, one way to efficiently use energy is micro combined heat and power generation (micro-CHP). Therefore, Stirling engines raised interest for the domestic use of micro-CHP in recent years. Despite the promise of high efficiency due to the underlying Stirling cycle, these engines often have reliability problems because of their numerous moving parts. The engine under investigation makes use of a thermodynamic cycle similar to Stirling, but with less moving parts, therefore having a much higher reliability. Thus, we focus on the optimization of a thermoacoustic engine for application within a micro-CHP appliance.

Progress

A first step in the optimization of the thermoacoustic engine is to reduce the losses due to steady convection or acoustic streaming. Full CFD simulations of Rayleigh streaming in a closed resonator have been performed. A simulation method has been developed to derive thermoacoustic functions for complex geometries. The functions characterize the heat and momentum transfer in the regenerator of a thermoacoustic engine. Hence, regenerator optimization is ready to be carried out. Furthermore, first steps are performed in the simulation and optimization of a jet pump to reduce possible travelling wave streaming in the device of interest (see Figure 1). An experimental setup is built in order to validate and support the performed simulations at high pressure amplitudes. The next steps are to use the numerical and experimental setups we have so far to optimize the thermoacoustic engine design.

Projectleaders

TH van der Meer

Researchtheme

Complex dynamics of fluids

Participants

S Bühler, JP Oosterhuis

Cooperations

-

Funded

Agentschap NL	60 %
University	-
FOM	-
STW	-
NWO Other	-
Industry	40 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2011

Information

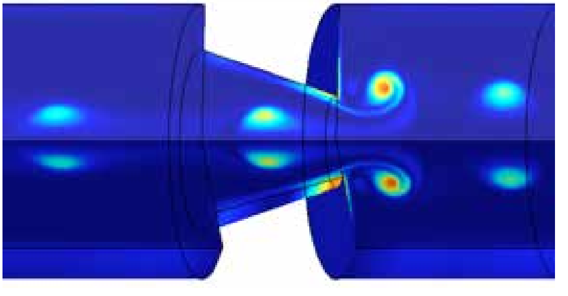
TH van der Meer
053 489 2562
t.h.vandermeer@utwente.nl

Dissertations

-

Scientific Publications

-



Jet pump simulation, vorticity magnitude is shown

HiTAC boiler: heavy fuel-oil combustion in a HiTAC boiler

Projectleaders
TH van der Meer

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
S Zhu

Cooperations
TU Delft, Stork Thermeq, Shell Global Solutions Int.

Funded
STW, Nederlandse Vlamvereniging

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

Start of the project
2009

Information
TH van der Meer
053 489 2562
t.h.vandermeer@utwente.nl

Project Aim

The objective of this project is to investigate computationally the combustion of heavy fuel oil with high temperature air in conditions representative for oil combustion in a boiler. Spray combustion models will be developed and validated by a literature flame, by a laboratory flame at Delft University, and by an industrial field test in a 9 MW boiler performed at Stork Thermeq. The gathered knowledge will be used to exploit the principles of HiTAC to create conditions with low NOX formation, uniform heat flux and to optimize the water-steam cycle to create an economically attractive, robust and reliable boiler system.

Progress

The simulation of a well-documented methanol spray flame was finished and the results were further compared with other researchers' numerical investigations for a proposed paper. It will be submitted soon. For the simulation of the Delft spray flame, analysis of the boundary conditions was done according to the preliminary measurement. Base on that, hybrid models were developed and the numerical results showed good agreement with the preliminary measurement. The influence of different co-flow conditions were then further investigated numerically. The results showed that increased temperature of the co-flow leads to a higher peak temperature, while lowered O2% in the co-flow leads to a lower peak temperature. It was also shown that thermal NOX is dominant in the NOX emission of this flame, and it is reduced with the enlarged flame zone and the corresponding lower peak temperature. For the simulation of the boiler with heavy fuel-oil, five cases with different O2% of primary and secondary air, which are possible for application in the field test, were numerically studied. The case with the lowest O2% in the primary air has the most enlarged combustion zone and thus leads to the most uniform temperature distribution. It was also shown that fuel NOX is dominant in the NOX emission in our cases and the interaction between soot and radiation has considerable influence on the predicted temperature profiles.

Dissertations

-

Scientific Publications

-

COPA-GT : Coupled parallel simulation of gas turbines

Project Aim

Until now, gas turbines have been designed following individual pathways for each component and each physical phenomenon. Nevertheless, the behavior of the individual components can be very different from their behavior when mounted together in an engine. To overcome this disadvantage, 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

In the project European wide 13 PhD students and 5 Post Docs work under coordination of CERFACS in Toulouse. At the UT 3 PhD students are active. The project task of Virginia Fratalocchi focuses on large scale parallel modelling of transient behaviour of liquid fuel sprays. The SAS-SST turbulence model, the CFI reaction progress model and a Lagrangian spray model will be implemented in the ALYA compressible FEM fluid simulation code of the Barcelona Super Computing Center. These models will be tested on the ethanol spray flame experimental data of Masri and subsequently applied on an industrial engine design. Since she only worked 3 month in 2012, only a literature study was performed and some CFD work to become acquainted with ANSYS-CFX.

Dissertations

-

Scientific Publications

-

Projectleaders

JBW Kok

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

V Fratalocchi, JBW Kok

Cooperations

CERFACS, RWTH Aachen University, Von Karman Institute, Loughborough University, Turbomeca, Siemens, Barcelona Supercomputing Center, Jülich computational center, Bull, Ansys.

Funded

European Union Marie Curie ITN

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

Start of the project

2012

Information

JBW Kok
053 489 2582
j.b.w.kok@utwente.nl
www.thw.ctw.utwente.nl/

LIMOUSINE : Limit cycles of pressure oscillations in gas turbine combustors

Projectleaders
JBW Kok

Researchtheme
Complex dynamics of fluids

Participants
JC Roman Casado, JBW Kok, ThH van der Meer

Cooperations
Project in cooperation with DLR, CERFACS, Imperial College, Keele University, University of Zaragoza, University of Brno, Siemens Muelheim, Ifta Muenchen, Ansys Abingdon.

Funded
European Union: Marie Curie ITN program

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

Start of the project
2008

Information
JBW Kok
053 489 2582
j.b.w.kok@utwente.nl
www.thw.ctw.utwente.nl

Project Aim

LIMOUSINE aims at the development of analytical and numerical tools to predict the chain of events leading to mechanical failure of gas turbine combustors due to limit cycles of low frequency pressure oscillations. Explored is the interaction and the feed back mechanisms between combustion dynamics, acoustics, aerodynamics and structural vibration. Essential is that not only the operating points with linear instability are identified, but also the nonlinear mechanisms leading to amplitude saturation.

Progress

In the European wide project, 17 PhD students are active and coordinated by the university of Twente. At the UT, 5 PhD students are employed in the area of fluid mechanics, structural vibration and mechanical failure. They key element in the project of J.C. Roman is a custom made laboratory combustor that is operated in limit cycle of pressure oscillations. The modified burner operating behavior was investigated thoroughly in limit cycles behavior around 240 Hz at 160 dB saturated SPL. For the limit cycle point the non linear flame deriving function was established by means of a new approach. The nonlinear amplitude depence was measured for a transfer function in the time domain. Also the flame describing function in the frequency domain was measured. These data were incorporated in a network model to predict the instability. By means of new post processing methods the deterministic behavior of the combustor was explored. It appeared that in stable mode the system was chaotic and in limit cycle deterministic. The fractal dimension for both cases was calculated.

Dissertations

-

Scientific Publications

1. Roman Casado, J.C., Kok, J.B.W., Flame describing function measurements for limit cycle characterization, proc. 19th Int. Congr. Sound and Vibration, Vilnius 8-12 July 2012, ISBN 978-609-459-079-5, 2012.
2. Roman Casado, J.C., Kok, J.B.W., Combustor eigen frequencies of pressure oscillations and their dependence on the burner impedance and adimensional numbers, GT2012-69164, Proceedings ASME Turbo Expo 2012, June 11-15, 2012, Bella Center, Copenhagen, Denmark, 2012.

LIMOUSINE : Limit cycles of pressure oscillations in gas turbine combustors

Project Aim

LIMOUSINE aims at the development of numerical tools to predict the chain of events leading to mechanical failure of gas turbine combustors due to limit cycles of low frequency pressure oscillations. Explored is the interaction and the feed back mechanisms between combustion dynamics, acoustics, aerodynamics and structural vibration. Essential is that not only the operating points with linear instability are identified. But also the nonlinear mechanisms leading to amplitude saturation.

Progress

In the project European wide 17 PhD students are active, coordinated by the University of Twente. At the UT 5 PhD students and one Post Doc are employed in the area of fluid mechanics, structural vibration and mechanical failure. Key element in the project is a UT designed generic lab scale combustor that is operated in limit cycle pressure oscillation. The project task of M.Shahi focuses on the fluid-structure-interaction between the pressure oscillations in the flue gas and the liner structure. To see the structural response during combustion transient CFD and CSD analysis using ANSYS workbench V13.0, was carried out. The transient information (pressure and displacement) is exchanged between the fluid and structural domain by means of 2-way coupling. The preliminary results show that the maximal displacement exhibited by the structure are very small, a fraction of a millimetre. Such displacements are extremely small but can act like a strong acoustic source due to the high acceleration rate of the structure. The modeling effort focuses hence on describing small amplitude high frequency structural vibrations and their impact on acoustics in the combustor.

Dissertations

-

Scientific Publications

1. Shahi, M., Kok, J.B.W., Fluid-structure interaction on combustion instability to derive lifing, proc. 19th Int. Congr. Sound and Vibration, Vilnius 8-12 July 2012, ISBN 978-609-459-079-5, 2012.
2. Shahi, M., Kok, J.B.W., Alemela, P.R., Simulation of 2-way fluid structure interaction in a 3d model combustor, GT2012-69681, Proceedings ASME Turbo Expo 2012, June 11-15, 2012, Bella Center, Copenhagen, Denmark, 2012.

Projectleaders

JBW Kok

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

M Shahi, JBW Kok, ThH van der Meer

Cooperations

Project in cooperation with DLR, CERFACS, Imperial College, Keele University, University of Zaragoza, University of Brno, Siemens Muelheim, Ifta Muenchen, Ansys Abingdon

Funded

European union: Marie Curie Initial Training network program

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

Start of the project

2011

Information

JBW Kok
053 489 2582
j.b.w.kok@utwente.nl
www.thw.ctw.utwente.nl

LIMOUSINE : Limit cycles of pressure oscillations in gas turbine combustors

Projectleaders
JBW Kok

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
SK Tarband Veeraraghan, JBW Kok, ThH van der Meer

Cooperations
Project in cooperation with DLR, CERFACS, Imperial College, Keele University, University of Zaragoza, University of Brno, Siemens Muelheim, Ifta Muenchen, Ansys Abingdon

Funded
European Union: Marie Curie ITN program

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

Start of the project
2008

Information
JBW Kok
053 489 2582
j.b.w.kok@utwente.nl
www.thw.ctw.utwente.nl

Project Aim

LIMOUSINE aims at the development of numerical tools to predict the chain of events leading to mechanical failure of gas turbine combustors due to limit cycles of low frequency pressure oscillations. Explored is the interaction and the feed back mechanism between combustion dynamics, acoustics, aerodynamics and structural vibration. Essential is that not only the operating points with linear instability are identified, but also the nonlinear mechanisms leading to amplitude saturation.

Progress

In the project European wide 17 PhD students are active, coordinated by the University of Twente. At the UT 5 PhD students and are employed in the area of fluid mechanics, structural vibration and mechanical failure. Key element in the project task of S. K. Tarband Veeraraghan is the numerical modeling of limit cycle oscillations in the generic turbulent combustor developed in the framework of the Limousine project. The performance of the Burnt Velocity model and the CFI model (Developed at UT) for predicting nonlinear response of turbulent combustion fluctuations was compared on several characteristic conditions of the UT generic limit cycle combustor. It appeared that the CFI model predicted correctly stable or unstable cases, while the BVM model tended to always predict stability. Studies were made of the performance of the CFD boundary conditions modeling, by means of calculation of the impedance and reflection coefficient of the obtained solution to the transient flow.

Dissertations

-

Scientific Publications

1. Tarband, S.K., Kok, J.B.W., Alemela, P.R., Numerical modeling of limit cycle oscillations in a model combustor: coupling combustion processes and pressure fluctuations, GT2012-69710, Proceedings ASME Turbo Expo 2012, June 11-15, 2012, Bella Center, Copenhagen, Denmark, 2012.
2. Tarband, S.K., Kok, J.B.W., Numerical simulation of stable/unstable combustion in a bluff-body stabilized combustor, proc. 19th Int. Congr. Sound and Vibration, Vilnius 8-12 July 2012, ISBN 978-609-459-079-5, 2012.

LIMOUSINE : Limit cycles of pressure oscillations in gas turbine combustors

Project Aim

LIMOUSINE aims at the development of numerical tools to predict the chain of events leading to mechanical failure of gas turbine combustors due to limit cycles of low frequency pressure oscillations. Explored is the interaction and the feed back mechanism between combustion dynamics, acoustics, aerodynamics and structural vibration. Essential is that not only the operating points with linear instability are identified, but also the nonlinear mechanisms leading to amplitude saturation.

Progress

In the project European wide 17 PhD students are active, coordinated by the University of Twente. At the UT 5 PhD students and are employed in the area of fluid mechanics, structural vibration and mechanical failure. Key element in the project task of M.Kapucu is the UT elevated pressure (1-5 bar) 100kW/bar, combustor that is operated with preheated air. Target is to bring the combustor in limit cycle pressure oscillation and investigate the saturated amplitude behavior. The acoustic end condition of the combustor has been changed to by highly reflective, also at low frequencies. The combustor showed limit cycle oscillations of combustion and pressure of high amplitude. These were compared with the numerical predictions on basis of the network model with a linear flame transfer function. By means of measurements the nonlinearity of the transfer function was explored and a flame describing function established for certain operating conditions. The describing function showed good comparison with numerical predictions by means of CFD.

Dissertations

-

Scientific Publications

1. Kapucu, M., Kok, J.B.W., Alemela, P.R., Comparison of two methods for flame transfer function measurements: moog valve or siren and the impact of results on the instability analysis in a high pressure combustor, GT2012-69250, Proceedings ASME Turbo Expo 2012, June 11-15, 2012, Bella Center, Copenhagen, Denmark, 2012.
2. Kapucu, M., Kok, J.B.W., How to achieve higher levels of excitation in the fuel line of a high pressurized combustor?, proc. 19th Int. Congr. Sound and Vibration, Vilnius 8-12 July 2012, ISBN 978-609-459-079-5, 2012..

Projectleaders

JBW Kok

Researchtheme

Complex dynamics of fluids

Participants

M Kapucu, JBW Kok, ThH van der Meer

Cooperations

Project in cooperation with DLR, CERFACS, Imperial College, Keele University, University of Zaragoza, University of Brno, Siemens Muelheim, Ifta Muenchen, Ansys Abingdon

Funded

European Union: Marie Curie ITN program

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

Start of the project

2008

Information

JBW Kok
053 489 2582
j.b.w.kok@utwente.nl
www.thw.ctw.utwente.nl

COPA-GT (Coupled Parallel Simulation of Gas Turbines)

Projectleaders
JBW Kok

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
S Gövert, JBW Kok

Cooperations
CERFACS, RWTH Aachen University, Von Karman Institute, Loughborough University, Turbomeca, Siemens, Barcelona Supercomputing Center, Jülich computational center, Bull, Ansys

Funded
European Union Marie Curie ITN

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

Start of the project
2012

Information
JBW Kok
053 489 2582
j.b.w.kok@utwente.nl

Project Aim

Until now, gas turbines have been designed following individual pathways for each component and each physical phenomenon. Nevertheless, the behavior of the individual components can be very different from their behavior when mounted together in an engine. To overcome this disadvantage, 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. The project is financed in the Marie Curie ITN framework. In this task of the project numerical models are developed that describe the high frequency/ low displacement amplitude of a structure (eg the liner) in a combustor and its strong coupling to thermo acoustic fluid phenomena.

Progress

In the project European wide 13 PhD students and 5 Post Docs work under coordination of CERFACS in Toulouse. At the UT 3 PhD students are active. The project task of S. Gövert focuses on computationally efficiently and accurately modelling fluid structure interaction (FSI) in a gas turbine combustor as embedded in full engine computations. In the first year emphasis was set on the definition of suitable combustor test cases for FSI applications. The Limousine combustor (developed at the UT) was adapted to FSI investigations by the reduction of the structural stiffness of the liner. Numerical simulations of the coupled FSI problem where carried out using the ANSYS simulation environment. In the case of a very flexible structure interacting with a compressible flow, strong coupling characteristics have been observed. As the applied partitioned coupling procedure showed diverging behaviour for this case, the further work will be focused on a monolithic FSI approach.

Dissertations

-

Scientific Publications

-

PROJECT AIM

The aim of the project is to study in depth the effect of carbon nano-fibers deposited on heat transfer surface for heat transfer to/ from a fluid. At first materials will be synthesized in a very controlled manner by growing carbon nano-fibers with in situ measurements of the weight increase and the heat of reaction of the synthesis process. Heat transfer to/from the new materials will be determined experimentally. Structural and morphological effect of the CNFs on heat transfer will be studied and optimal configuration will be derived. A production facility for the synthesis of carbon nano-fibers will be designed and built. Finally the performance of the new materials can be determined at ECN in test rigs of a thermo-acoustic and a thermo-chemical heat pump.

PROGRESS

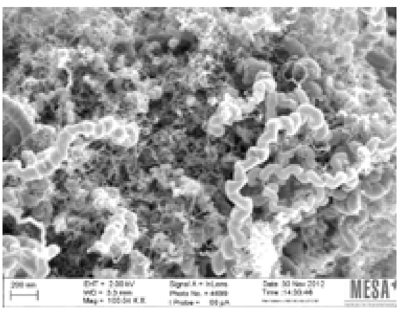
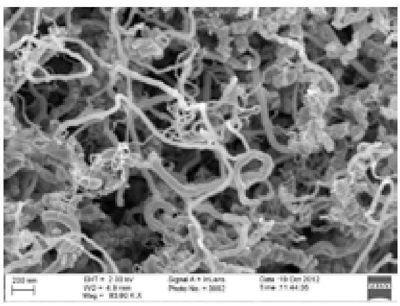
Using catalytic vapor deposition technique, successful synthesis of carbon nano-fibers on the surface of the nickel wire is made and parameter adjustments for different morphologies and topologies of the carbon nano-fibers are studied. The various surface morphology and topology of the CNF layer on 50μm nickel wire were tested for their heat transfer performance. Results shows that open structural arrangement of the CNF-layer enhanced the heat transfer surface up to 40%. However, densely populated surfaces hindered the heat transfer to up -20%. Furthermore, the influence of carbon layer and CNFs layer thickness on heat transfer performance was measured. Experimental investigation shows the existence of optimum thickness ratio of CNF-layer to carbon-layer which gives best heat transfer performance.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. T J Taha, D B Thakur and T H Van der Meer ,“Towards convective heat transfer enhancement: surface modification, characterization and measurement techniques”, (2012), J. Phys.: Conf. Ser. 395 012113.

CNFs layer on 50μm nickel wire closed (a) and open structures (b).

PROJECTLEADERS

ThH van der Meer

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

TJ Taha, ThH van der Meer

COOPERATIONS

ECN

FUNDED

EL&I

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

START OF THE PROJECT

2010

INFORMATION

TJ Taha
053 489 2559
t.j.taha@ctw.utwente.nl

MoST : Multi-scale modification of swirling combustion for optimized gas turbines

Projectleaders
ThH van der Meer

Researchtheme
Complex dynamics of fluids

Participants
AA Verbeek

Cooperations
Dr.ir. RJM Bastiaans, Prof.dr.ir. BJ Geurts

Funded
STW, Electrabel Nederland, Laborelec, TTS/Ansaldo

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

Start of the project
2010

Information
ThH van der Meer
053 489 2562
t.h.vandermeer@ctw.utwente.nl

Project Aim

The idea of this project is to optimize low swirl burners by adding resonant mixing perturbations. To that end both practical and fundamental research is needed. Physical experiments are crucial to find out a priori the resonant regimes in actual combustors under realistic conditions, in which the low swirl stabilization concept works with good specifications. The experiments will provide data for validation of the findings of the numerical simulations. Numerical simulation by means of DNS and LES, is an essential tool to understand the complex flame dynamics.

Progress

In the past year the flame-front curvature measurement method was completed. This method enables us to autonomously process OH-LIF data of premixed flames and to extract the flame-front curvature distribution, the flame surface density (FSD) and mean progress variable even for poor image quality data. Besides the active grid method to enhance the turbulent premixed combustion also static multi-scale grids are now investigated. With the design of a static flow agitation we move towards a more industrial applicable solution to increase the power-density of a Low Swirl Flame. OH-LIF measurements show that the FSD is increased up to 50% creating a more compact flame. Much finer flame front wrinkles are observed. This significant combustion enhancement is accompanied by only 30% higher pressure drop.

Dissertations

-

Scientific Publications

1. Verbeek, A.A. and Pos, R.C. and Stoffels, G.G.M. and Geurts, B.J. and Meer van der, Th.H. (2012) The generation of resonant turbulence for a premixed burner. In: 9th International ERCOFTAC Symposium on Engineering Turbulence Modeling and Measurements, ETMM 2012, 6-8 June 2012, Thessaloniki, Greece.

ULRICO : Ultra rich combustion of hydrocarbons and soot formation

Project Aim

This project generates knowledge needed in the design and operation of ultra clean, efficient and reliable natural gas partial combustion systems to produce syngas. Computational fluid dynamics modeling is applied to predict fuel rich turbulent combustion at elevated pressure. The modeling involves prediction of major and minor chemical species, radiative heat loss and soot precursor species. These are linked to a soot formation and transport model for particle size distribution. Multiple combustion regimes are explored. The CFD model is validated by 6 bar/300 kW laboratory tests, including gas composition, soot particle size, nature and number density.

Progress

A MILD-combustor for ultra rich combustion of natural gas has been designed and manufactured. The designed combustor was numerically simulated and analyzed with CHEMKIN PSR and ANSYS CFX. The simulations show that the formation of acetylene, the most important soot precursor, was reduced and that the output of syngas was improved. Experiments with a premixed swirled combustor were performed. The gas composition and soot particle size distribution were measured for different operating conditions. The soot particle size distribution was parameterized in terms of 2 control scalars and used for improvement of the custom soot formation model.

Dissertations

-

Scientific Publications

-

Projectleaders

JBW Kok

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

MHF Woolderink, JBW Kok, ThH van der Meer

Cooperations

Shell Global Solutions, Amsterdam. Aalborg Industries, Nijmegen. Automotive Technology Centre, Eindhoven. DAF Trucks, Eindhoven. ANSYS UK, Abingdon, UK.

Funded

STW, Shell Global Solutions Amsterdam, ANSYS UK

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

Start of the project

2009

Information

JBW Kok
053 489 2582
j.b.w.kok@utwente.nl
www.utwente.nl/ctw/thw

Multi Scale Mechanics (MSM)

Prof.dr.rer.nat. S Luding

The Multi Scale Mechanics group (MSM) is part of the cluster Fluid and Solid Mechanics and Engineering in the Faculty of Engineering Technology 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; sticky powders; wave-propagation in disordered media; solid concrete; avalanche flows of grains, snow or soil; 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 and wave-propagation. Finally, on the macroscopic level, a granular material behaves as a fluid with complex flow behavior involving anisotropy. 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 previous and the next levels.

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 Multi Scale Mechanics 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 improving our fundamental understanding of fluids and solids, the results find applications in the improvement of industrial processing procedures for granular matter, as well as contributing to the design of advanced materials, processes and equipment.

Modeling of long-range interaction forces and clustering phase diagram

Project Aim

The objective of this Ph.D. project is to understand the interactions between particles in granular systems from discrete element simulations. The aim is to model long range attractive / repulsive interactions in homogeneous systems, and segregation of particles by size in granular flows. The results will be compared with theoretical work.

Progress

In the last year, we finalized the study of the clustering phase diagram for granules with long-range interactions. We found that the combination of dissipation and long-range attraction (or repulsion) results in a rich phase behavior, determined by the ratio of dissipative and long-range forces. The figure shows the evolution for two systems with distinct dissipation strengths: in the first row, the dissipation is small and the emerging clusters are of limited size; in the second row, the dissipation is large and extensive clusters are formed. Similar clustering behavior can be seen in various processes, ranging from coating of nano-particles, nano-particle agglomeration and even to interstellar gasses.

Dissertations

-

Scientific Publications

1. A. R. Thornton, T. Weinhart, S. Luding, and O. Bokhove, Modeling of particle size segregation: Calibration using the discrete particle method, Int. J. Mod. Phys. C 23(8), 1240014, 2012.

Projectleaders

S Luding

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Gonzalez, A Thornton, S Luding

Cooperations

-

Funded

FOM

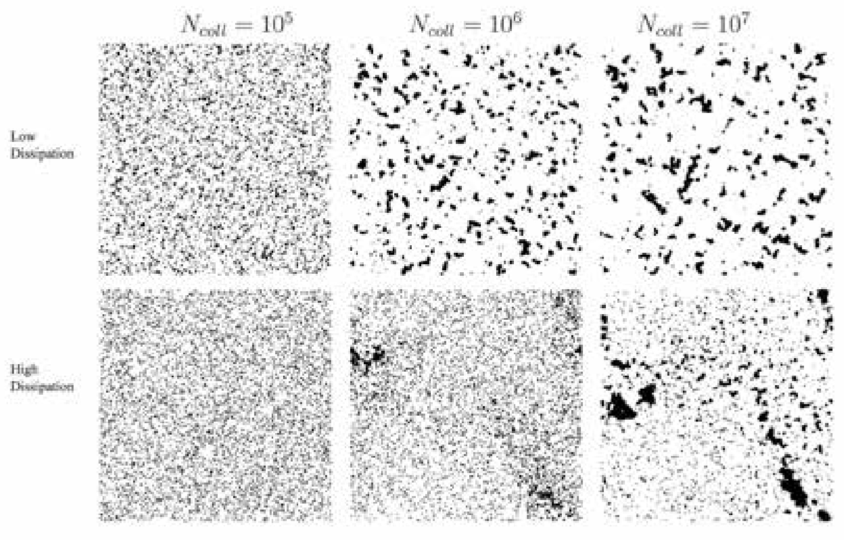
University	-
FOM	100 %
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2009

Information

S Gonzalez
053 489 3371
j.s.l.gonzalezbriones@utwente.nl



Computational modeling of micro-flows

Projectleaders
S Luding

Researchtheme
Complex dynamics of fluids

Participants
RM Hartkamp, A Ghosh, S Luding

Cooperations
BD Todd (Swinburne University of Technology), PJ Daivis (RMIT), S Bernardi (Griffith University), AP Markesteijn (TUD), J Westerweel (Delft University of Technology), TA Hunt (UTwente)

Funded
MicroNed, UT & NWO VICI

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

Start of the project
2006

Information
S Luding
053 489 4212
s.luding@utwente.nl

Project Aim

During the past few years molecular dynamics has been a widely applied tool to simulate fluids confined in micro/nano geometries. What makes interfacial fluids fundamentally different from bulk fluids is the fact that their density varies considerably over microscopic distances. Fluids confined by solid boundaries to very narrow spaces are strongly inhomogeneous. The goal of the present project is to study the stresses and shear viscosity of such fluids, and to investigate the effects of walls on the local properties of the fluid, both at rest and under a driving force.

Progress

In this project we simulate planar Poiseuille flow of a Lennard-Jones fluid in channels of various widths in the nanoscale regime. Atoms arrange in layers parallel to the channel walls, such that the density of the fluid is an oscillating function of the position. Consequently, other quantities also vary with position, since they are related to the density. We obtain average stress and strain rate profiles across the channel. Anisotropy in stress is found near the walls; the influence of various parameters on the layering and anisotropy are studied. Understanding and quantifying the non-Newtonian behavior is a first step towards deriving a constitutive model that governs the behavior of a strongly confined fluid. A constitutive framework is proposed to quantify the relation between stress tensor and strain rate, temperature, density and other profiles in homogeneous and inhomogeneous fluids.

Dissertations

-

Scientific Publications

1. R. Hartkamp, S. Bernardi and B. D. Todd, Transient-time correlation function applied to mixed shear and elongational flows, J. Chem. Phys. 136, 064105 (2012).
2. A. P. Markesteijn, R. Hartkamp, S. Luding and J. Westerweel, A comparison of the value of viscosity for several water models using Poiseuille flow in a nano channel, J. Chem. Phys. 136, 134104 (2012).
3. R. Hartkamp, A. Ghosh, T. Weinhart and S. Luding, A study of the anisotropy of stress in a fluid confined in a nanochannel, J. Chem. Phys. 137, 044711 (2012).

Signal propagation in disordered granular systems

Project Aim

Characterization of the connection between the structure of dry granular media and the signal transmission behavior; understanding the role of contact and micro-structure details on the bulk behavior is important for a general understanding of the physics of such systems. Propagation of stress and energy in granular systems is sensitive to even small amounts of disorder in either mass or the contact network. We numerically and analytically study the effects of isolated mass-disorder and anisotropy on the energy transfer and frequency content of signals propagated in these systems.

Progress

In one phase of the project a convenient one-dimensional system has been employed to quantify the effects of mass-disorder ξ and relate the behavior to localization effects for linear and pre-compressed non-linear systems. In the figure below, saturation of disorder is observed beyond a certain threshold and it is shown that the bulk transmission behavior is not dependent on the details of the mass distribution. Such systems are observed to act as low-pass filters, attenuating the higher frequencies through mode localization. In a related project, numerical wave propagation results on three-dimensional packings of weakly and fully disordered, polydisperse packings of frictional spheres show that structure anisotropy can lead to enhanced energy conversion. Energy contained in uniaxial translational motion (e.g. P-wave) is quickly scattered to shear and rotational modes; following the initial excitation, the distribution of energies reaches a steady-state.

Dissertations

1. Lisa de Mol, MSc-thesis, RUBochum, Germany + UTwente, Netherlands
   Wave propagation in granular material: Theoretical and numerical analysis.

Scientific Publications

-

Projectleaders

S Luding, V Magnanimo

Researchtheme

Complex dynamics of fluids

Participants

BP Lawney, L de Mol

Cooperations

RUBochum

Funded

STW-VICI Project No. 10828

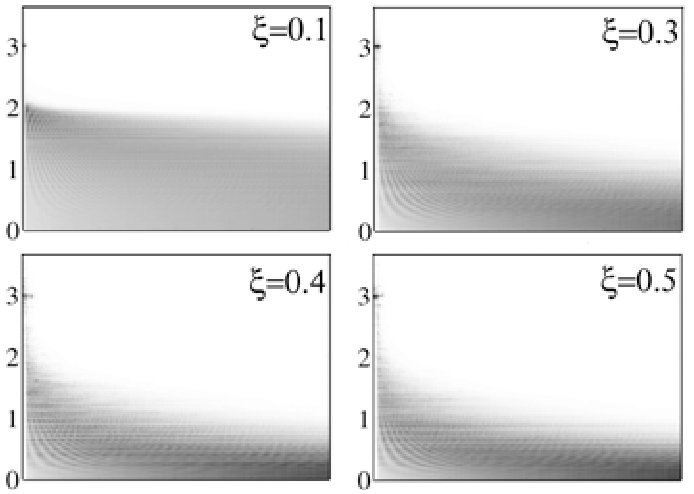
University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2011

Information

S Luding
s.luding@utwente.nl



Frequency spectrum versus distance from the source for different magnitudes of disorder.

Micro-macro modeling for critical state and flowing of dense granular materials

Projectleaders
S Luding

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
N Rivas, A Thornton, A Meheboob (Bangalore), D van der Meer (PoF, UT)

Cooperations
-

Funded

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

Start of the project
2011

Information
N Rivas
nicorivas@gmail.com

Project Aim

Two general approaches are used to model granular materials: microscopic, where information is taken from individual particles, and macroscopic, where continuum fields are considered. In this project we apply and compare both approaches to a driven granular system, consisting in a vertically shaken shallow box filled with grains. This system presents many distinct inhomogeneous stable states as the energy injection, geometry, grain properties and grain numbers are varied. Studying the stability of these states and the transitions between them, from both a microscopic and macroscopic approach, may lead to a better understanding of the out-of-equilibrium statistical physics behind complex granular systems. We also focus on the development and comparison of a set of simulation tools, both microscopic (molecular dynamics) and macroscopic (granular-hydrodynamics equations solver), to establish the limits and advantages of each approach in different scenarios.

Progress

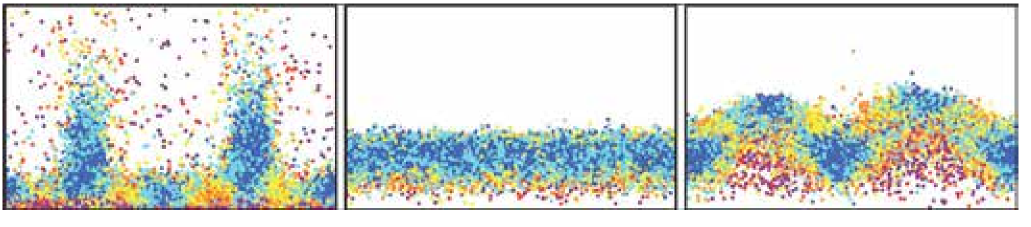
Last year was devoted to the study of new interesting granular phenomena discovered in the shallow vibrated geometry. This was done using event-driven molecular dynamics simulations, which showed a remarkable agreement with previous experimental data on similar setups, and also with a continuum theory developed for the system. Furthermore, the study of binary systems of particles with different size and/or mass was carried further, to find a remarkable agreement with ongoing experiments. Finally, considerable progress was made on the simulation tools needed for solving the complete hydrodynamic system, which will finally allow the comparison of microscopic and macroscopic approaches for granular materials modeling.

Dissertations

-

Scientific Publications

1. N. Rivas, P. Cordereo, D. Risso, R. Soto, Characterization of the energy bursts in vibrated shallow granular systems, Granular Matter 14, 157-162, 2012.



Bridging the gap between particulate systems and continuum theory

Project Aim

The gap between discrete (micro) and continuum (macro) concepts for the modeling and understanding of particulate systems is bridged by micro-macro transition methods. Modern discrete particle-based models describe the particles in detail, but are of limited value for studying industrial processes and natural phenomena since too many particles are involved. Continuum methods, on the other hand, are readily applied in engineering applications. However, continuum methods rely on empirical constitutive laws with phenomenological parameters that disregard both the discrete nature of particles and the micro-structure. Micro-macro transition methods are being developed to combine the advantages of discrete and continuum models.

Progress

A novel local constitutive model based on observations from discrete element simulations has been developed for small-scale deformations of a quasi steady bi-axial geometry. The model consists of nonlinear evolution equations for both shear stress and anisotropy during deviatoric (shear) deformations, to model the history dependence, with only four material parameters. Several simulations were performed to test the model's accuracy for various deformation modes (see figure). Future work will include extending the model to generic three-dimensional cases and implementing it in a finite element method. The objective is to predict stresses and strains in macro scale applications, taking into account the evolution of the microscopic material structure.

Dissertations

-

Scientific Publications

-

Projectleaders

S Luding, V Magnanimo

Researchtheme

Complex structures of fluids

Participants

D Krijgsman

Cooperations

RP Behringer (Duke, NC, USA)

Funded

NWO-STW VICI

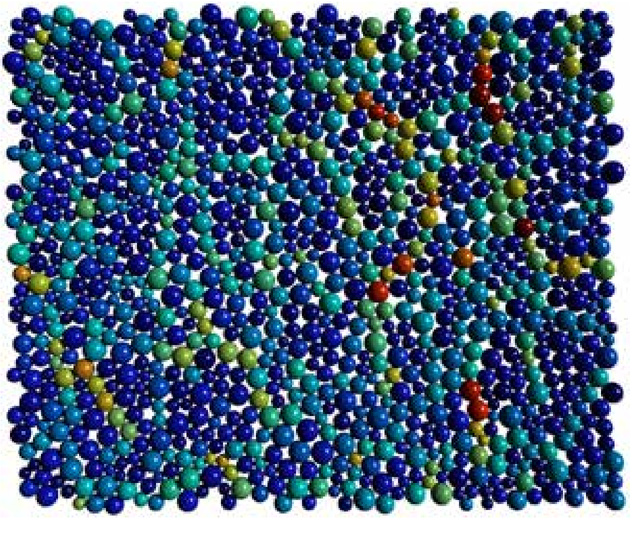
University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2010

Information

D Krijgsman
053 489 4732
d.krijgsman@utwente.nl



Snapshot of a 2D shear deformation experiment in a periodic box. Particles are colored by potential energy. Some particles have a much higher potential energy (and thus contribution to the stress field) than their neighboring particles. These groups of particles are called stress-chains and are frequently observed in granular materials as 1D-chains.

Projectleaders
S Luding, M Ramioli

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
M Robinson

Cooperations
Nestlé Research Center

Funded
Marie Curie Initial Training Network

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

Start of the project
2010

Information
S Luding
s.luding@utwente.nl

Project Aim

A validated CFD-DEM simulation is developed and used to analyse the decompaction and dispersion of the powder bed by a water jet. For a wet particle bed, the challenges will include the correct modelling of the liquid-particle coupling over a wide range of porosities. For the dry particle bed there will also be a wide range of particle saturation (relative ratio of interstitial liquid and air). Goal is to determine which operating conditions giving rise to particular dynamical regimes and to understand the temporal and spatial distribution of the particles in the cell.

Progress

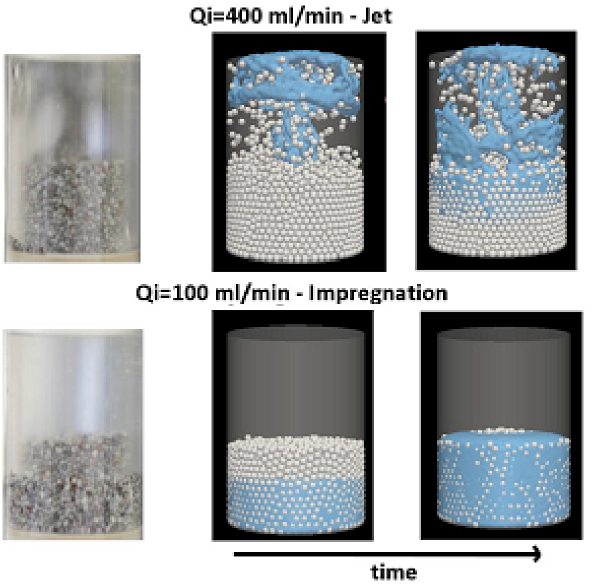
A two-way coupled SPH-DEM simulation tool has been developed, based on the locally averaged Navier Stokes equations preseted by Anderson and Jackson (1967). This has been applied to single and multiple particle sedimentation test problems. Some initial simulations of a water jet impacting on a granular bed have been performed. The relative strengths of the various drag terms (e.g. Added mass force, history force, lift force etc) have been compared using a simple analytical model and the same physical parameters as the experimental results. Quantitative comparison to experiments on powder dispersion are in progress, see the figure below.

Dissertations

-

Scientific Publications

1. Fluid-particle flow modelling and validation using two-way-coupled mesoscale SPH-DEM,Martin Robinson, Stefan Luding, Marco Ramaioli, http://lanl.arxiv.org/abs/1301.0752.



Dispersion of a dry granular bed of poppy seeds by a 1mm central injection hole. Left: Experimental dispersion patterns shortly after liquid injection starts. Center and Right: Three-phase SPH-DEM simulations, two snapshots are shown in order of increasing time. Grains are represented using white spheres and the water free-surface is colored in blue. Top row: A 400 ml/min inlet flow rate generates a jet. Bottom row: A 100 ml/min flow rate induces a bottom-up impregnation

Bridging the gap between particulate systems and continuum theory

Project Aim

Particulate systems or granular materials consist of discrete particles. These systems display a broad range of poorly understood phenomena like segregation, structure formation and failure of structures due to (granular) flow. Generations of scientists and engineers have developed a basic understanding and found practical recipes for the handling and processing of granular systems. In the last 20 years, theoretical physics and computer simulations have made significant contributions by explaining many topics in particulate systems. The goal of this project is to bridge the gap between discrete and continuum concepts and methods.

Progress

Jamming is a universal feature of a vast range of materials, including both thermal and a-thermal systems, in which the material constituents are arrested in rigid disordered states. Jamming transitions of a-thermal systems, e.g. granular materials, are governed by the density. Various physical quantities display critical behavior near the jamming point, i.e. the critical density. We investigate the jamming transition of bidisperse granular particles by a two-dimensional discrete element method (DEM). Above the jamming point the inter particle forces are distributed along a force chain network, as shown in the figure (left). The excess coordination number and the pressure scale as power laws in the distance from the jamming point. We find a critical slowing down of energy as shown in the figure (right), where the relaxation time diverges as approaching the jamming (from left to right, the relaxation happens later and later – note the logarithmic axis).

Dissertations

-

Scientific Publications

1. K. Saitoh, V. Magnanimo and S. Luding, "Slow dynamics near jamming", AIP. Conf. Proc. 1501, 1038, 2012.
2. K. Saitoh and H. Hayakawa,"Time dependent Ginzburg-Landau equation for sheared granular flow",AIP. Conf. Proc. 1501, 1001, 2012.

Projectleaders

S Luding

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Kuniyasu Saitoh

Cooperations

-

Funded

VICI-STW

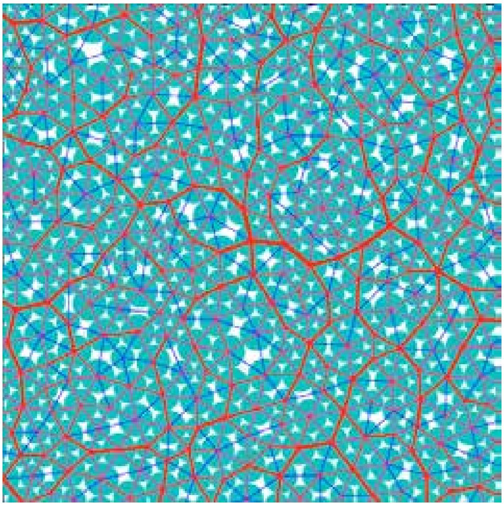
University	-
FOM	-
STW	-
NWO Other	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

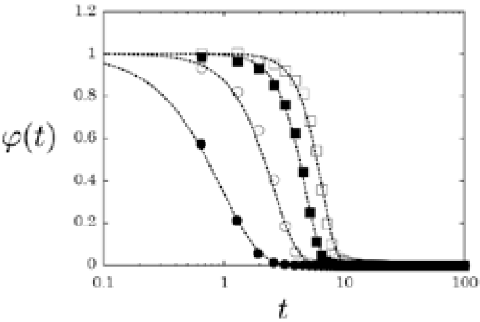
Start of the project

2011

Information

K Saitoh
053 489 5363
k.saitoh@utwente.nl
www2.msm.ctw.utwente.nl/saitohk/





PROJECTLEADERS
S Luding
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
A Singh, V Magnanimo
COOPERATIONS
-
FUNDED
FOM

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

START OF THE PROJECT
2009
INFORMATION
A Singh
053 489 2694
A.Singh@ctw.utwente.nl

PROJECT AIM

To probe the connections between jamming, shear banding and microstructure in numerical simulations of Brownian and non-Brownian systems for various interaction forces, shear rates and stress regimes.

PROGRESS

Discrete element simulations are used to study shear banding in a split-bottom ring shear cell. For low driving rates the shear bands are found to collapse to a single function. We observe that frictionless particle contacts produce a finite macroscopic friction coefficient, due to interlocking of particles. The macroscopic friction coefficient increases rapidly for low particle friction and saturates for high particle friction (see the left figure). The contact density, structural anisotropy and shear stress also increase with the friction. The shear stress becomes non-linear with the normal stress upon the introduction of contact cohesion (see the right figure). Astonishingly, cohesion does not affect the contact density, but is found to decrease the anisotropy (data not shown).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. S. Luding About contacts of adhesive, elasto-plastic, frictional powders: New trends in contact mechanics, M. Raous and P. Wriggers, Euromech 514, LMA Marseille, 2012, pages 19-22.

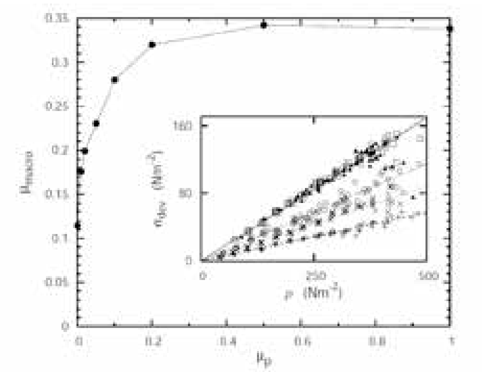
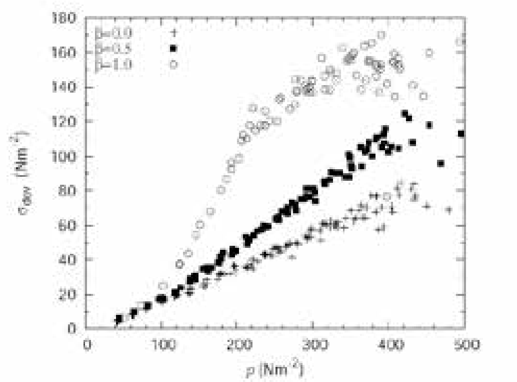


Figure 1 (a) Macroscopic friction coefficient plotted against particle friction coefficient, the inset shows shear stress plotted against normal stress for different particle friction (b) Shear stress plotted against normal stress, different symbols correspond to simulations using different strength of cohesive parameter.



Multi-scale coupling of FEM/DEM for fluid-particle interactions

Project Aim

Our aim in this project is to develop a multi-scale computational framework for modeling fluid-particle interactions for industrially relevant problems e.g. flow through porous media and fluidized beds. The key component of this framework is a Delaunay triangulation which is used both as an efficient contact detection tool for moving particles and for solving flow using unstructured finite element method. This approach reduces the data structure and computational overhead for storing both particles and triangulation and efficiently couples the particle motions with a fluid solver.

Progress

A new method of coupling fluids with particles using Delaunay triangulation is being developed. The model has now been validated for static particles for both random and ordered packings using various empirical drag model(s) which allow for explicit coupling between fluid and particles.

Dissertations

1. K. Yazdchi. Micro-Macro relations for flow through fibrous media. 2012

Scientific Publications

1. K. Yazdchi, S. Srivastava, and S. Luding, Micro-macro relations for flow through random arrays of cylinders, Composites A 43(11), 2007-2020, 2012.
2. K. Yazdchi, and S. Luding, Towards unified drag laws for inertial flow through fibrous media, Chemical Engng. J. 207, 35-48, 2012.

Projectleaders

S Luding

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Srivastava, K Yazdchi, V Ogarko

Cooperations

CeParTec GmbH (Dr. Katterfeld)

Boehringer Ingelheim (Dr. Wachtel)

Funded

STW-MUST (Project No. 10120)

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

Start of the project

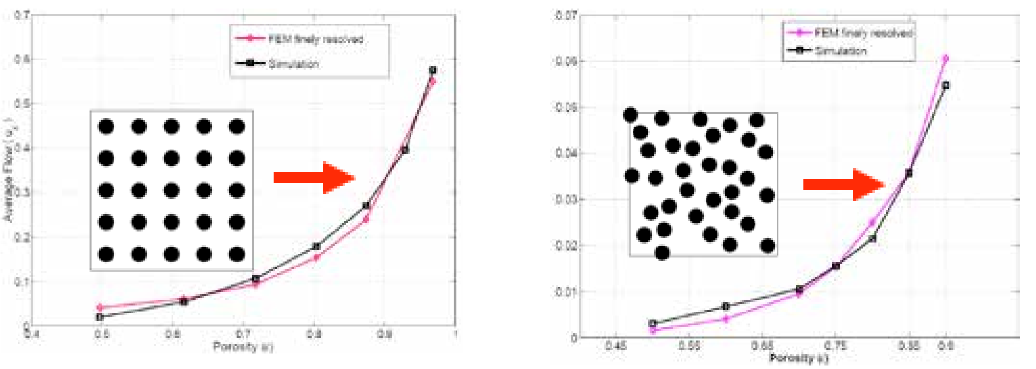
2008

Information

S Srivastava

053 489 3345

s.srivastava@utwente.nl



(a) Flow computed through an ordered packing. (b) Flow through a disordered array of particles – where the arrow indicates the flow direction and the Asnsys FEM solution is compared to the DEM-FEM coupled model.

Hierarchical multi-scale modeling

Projectleaders
S Luding
Researchtheme
Complex structures of fluids
Participants
V Ogarko, K Yazdchi, S Srivastava
Cooperations
M van der Hoef (UT), Boehringer Ingelheim (Dr. Wachtel), CSIRO (Dr. Cleary)
Funded
STW, Industry

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

Start of the project
2008
Information
V Ogarko
v.ogarko@utwente.nl

Project Aim

Goal of the project is to develop a multi-scale computational method that uses a single hierarchical data-structure as basis – involving also multiple fields. Starting from meso-scopic structures (particles or domains) a grid is constructed on a hierarchical, tree-based data structure. The hierarchical approach allows for micro-macro transition, coupling of different fields, and coarsening or refinement – where possible or needed, respectively.

Progress

The equilibrium equation of state of a fluid mixture of polydisperse hard spheres is well described by considering only the first three moments of the size distribution function. Consequently, the thermodynamic properties of a polydisperse fluid can be reproduced by a well-chosen bidisperse fluid. In this study we ask the question: How many moments are needed to predict the pressure and the jamming density of poly-disperse mixtures in compressed non-equilibrium glassy states? We find that five moments suffice to describe the properties of polydisperse mixtures for all densities, including glassy, non-equilibrium states and the maximal jamming density. Hence, this behavior can be reproduced by a well-chosen tridisperse system. The volume fraction of rattlers is also well predicted, and the system's behavior is shown to be controlled by the non-rattlers.

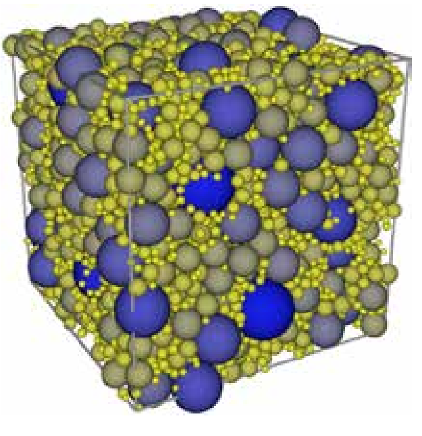
Dissertations

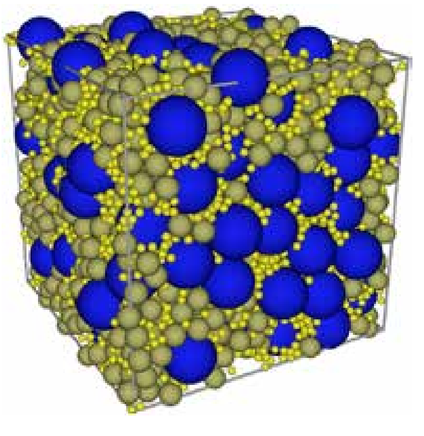
-

Scientific Publications

1. V. Ogarko and S. Luding, Equation of state and jamming density for equivalent bi- and polydisperse, smooth, hard sphere systems, J. Chem. Phys. 136, 124508, 2012.
2. V. Ogarko, and S. Luding, A fast multilevel algorithm for contact detection of arbitrarily polydisperse objects, Comp. Phys. Communications 183(4), 931-936, 2012.

A polydisperse system with uniform volume radii distribution (left) and the equivalent tridisperse system (right). The 8192 particles are colored by size





Sintering – Modeling of Pressure-, Temperature-, or Time-Dependent Contacts

Project Aim

The goal of this project is to model particles in contact, in particular for particles that melt and sinter when heated melt and thereby lose their identity. For this, temperature- and pressure-dependent contact models have to be developed in parallel to contact-measurements in the group of dr. Kappl (Mainz). The resulting many- particle simulation model will be experimentally validated against bulk experiments by the group of prof. Tomas (Magdeburg). This model will be used for the micro-macro transition: based on the microscopic contact-mechanics and –physics between particles, deduce constitutive relations for the macroscopic description of sintered materials.

Progress

Work on contact modelling and simulations of sintered material are currently in progress. In collaboration with dr. Staedler (Siegen), the rolling, sliding and torsion properties of silica microspheres are being investigated. In collaboration with M. Kappl (Mainz), Atomic Force Microscopy is used to study sintering of μm-sized particles. Further, a novel expression for the stress tensor of granular systems was developed [4] that is applicable near boundaries and interfaces and in mixtures. These expressions allow for accurate and reliable micro-macro transition methods. A shallow-layer model for granular flows was completed with macro-scale closure relations obtained from micro-scale Discrete Particle Method (DPM) simulations of steady uniform flow [1,2,3]. A complete description of the stress tensor under shear was developed both for molecular [5] and granular flows.

Dissertations

-

Scientific Publications

1. Thornton, A.R., Weinhart, T., Luding, S., Bokhove, O., Friction dependence of shallow granular flows from discrete particle simulations , Eur. Phys. J. E (2012) 35: 127.
2. Thornton, A.R., Weinhart, T., Luding, S., Bokhove, O., Modeling of particle size segregation: Calibration using the discrete particle method, Int. J. Mod. Phys. C 23, 1240014 (2012)
3. Weinhart, T., Thornton, A.R., Luding, S., Bokhove, O., Closure Relations for Shallow Granular Flows from Particle Simulations, Granular Matter 14(4), 531-552 (2012).
4. Weinhart, T., Thornton, A.R., Luding, S., Bokhove, O., From discrete particles to continuum fields near a boundary, Granular Matter 14(2), 289-294 (2012).
5. R. Hartkamp, A. Ghosh, T. Weinhart and S. Luding, A study of the anisotropy of stress in a fluid confined in a nanochannel", J. Chem. Phys. 137, 044711 (2012) .

Projectleaders
S Luding

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
T Weinhart, F Goncu, T Ormel

Cooperations
M Kappl (MPIP Mainz), J Tomas (Uni Magdeburg), T Staedler (Uni Siegen)

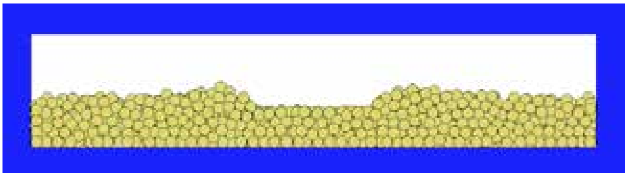
Funded

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

Start of the project
2011

Information

S Luding
053 489 4212
s.luding@utwente.nl



Indenting of a weakly sintered granular bed (in cross-section). The sintering is so weak that particle contacts easily break (for an animation, see www2.msm.ctw.utwente.nl/weinhartt)

Detection and guidance of nanoparticles for enhanced oil recovery

Projectleaders

S Luding, H Steeb, J Harting

Researchtheme

Complex structures of fluids

Participants

I Guven

Cooperations

Shell-FOM IPP

Funded

Shell-FOM IPP

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

Start of the project

2012

Information

H Steeb
+49(0)234 32 23080
holger.steeb@rub.de

S Luding
053 489 4212
s.luding@utwente.nl

Project Aim

The project aims to investigate the behavior of oil-water mixtures in porous media by means of combined electromagnetic-acoustic wave propagation. As surfactants for emulsions ferromagnetic nanoparticles will be used. We want to find out whether ferromagnetic can be a suitable alternative to conventional EOR techniques, and whether pulsed electromagnetic fields could be used to guide these particles into regions of interest.

Progress

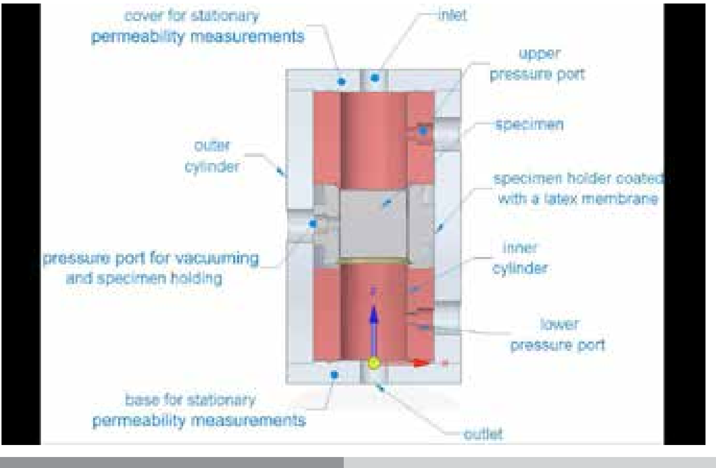
The first year of the project was focused on the design and development of an experimental set-up for the investigation of oil-water emulsions (stabilized by nanoparticles) in porous media. For this purpose a hydraulic multi-task measuring cell was developed and successfully tested (see illustration below). It allows carrying out simple Darcy and challenging electro-acoustic experiments in porous media saturated with complex fluids. As porous probe materials, cylindrical sintered glass bead samples with different particle diameters, degrees of dispersion and porosity values were used. In the first phase of our experiments, hydraulical and acoustical measurements of sintered glass bead samples were performed in order to determine their intrinsic permeabilities and effective ultrasound velocities. The intrinsic permeability as a coupling parameter between the solid material, has a huge influence on wave propagation in fluid-saturated porous media. The permeability results showed good agreements with theoretical predictions according to Kozeny-Carman.

Dissertations

-

Scientific Publications

1. I. Güven, P. Kurzeja, H. Steeb. Experimental evaluation of phase velocities and tortuosity in fluid-saturated porous and high-porous media; publication of the talk at the GAMM conference in the J. PAMM, 2012
2. B. Quintal, H. Steeb, S. Schmalholz. Effects of permeability barriers and pore fluids on S wave attenuation; in Proceedings of EAGE Conference & Exhibition incorporating SPE EUROPEC 2012, Copenhagen, Denmark, (Jun 2012).
3. M. R. Shaebani, M. Madadi, S. Luding, and D. E. Wolf. Influence of polydispersity on micromechanics of granular materials, Phys. Rev. E 85, 011301, 2012.



Water Engineering and Management

Prof.dr. SJMH Hulscher

The work of the “Water Engineering and Management (WEM) group was originally mainly devoted to the modelling of sand waves on the seabed. First it was shown, that the seabed patterns in the North Sea can be explained as free instabilities of the seabed. Subsequently, the modelling of sand waves was extended and refined. The group has worked on a scientific and practical tool for fully nonlinear modelling of sand waves. Over the last five years, the offshore morphodynamic work has broadened to rivers, coasts and blue-ice. Alternate bars in a flume were compared with (Ginzburg-)Landau-type models. The group was the first to explore data assimilation for morphodynamic predictions. Further work concentrated on using data assimilation to combine field data with sand wave amplitude models for maintenance dredging management of navigation channels and sand wave-related pipeline problems. Also, North Sea data were analysed and a new bed mode, called long bedwaves, was discovered. The origin of nearshore bars was addressed. A method was developed for modelling human interferences in a morphodynamic setting. This has opened perspectives for a new approach towards modelling large-scale sand mining in shallow seas. A project for developing tools for evaluation of human interference in the North Sea for optimal management of the seabed started recently and sediment transport concerning near-shore sand pits is being investigated. Since 2000 the group has studied the use of morphodynamical models in a societal context. Recently, a method for decision making based on quantitative information including uncertainties was developed in the multidisciplinary project Flyland, which opens the field of designing an assessment framework for appropriate modelling.

Uncovering inherent dynamics in coupled bio-geomorphodynamic systems offshore

Project Aim

On the bed of the North Sea sand waves are present, which grow up to 25% of the water depth and migrate at a speed of tens of meters per year. These sand waves can pose a hazard to offshore constructions, navigation, pipelines and telecommunication cables. On the other hand, bed forms can protect the coastline against storms. The bottom of the North Sea is also covered by a great number of organisms live in and on the bottom of the sea. These organisms try to optimize their habitat, resulting in bio-geomorphological interactions. The precise interaction between the biological activity and geomorphodynamics is not known at this moment. Such knowledge is of great interest for reliable long-term geomorphodynamic predictions, especially in marine environments with large biological activities.

Progress

Model and flume experiments are executed in which the biogeomrophological interactions are further analyzed. Moreover, model simulations are executed in which sand wave formation is investigated.

Dissertations

1. Borsje, B.W., 2012. Biogeomorphology of coastal seas. University of Twente, PhD thesis, 168 pp.

Scientific Publications

1. Borsje, B.W., Cronin, K., Holzhauer, H., De Mesel, I., Ysebaert, T., Hibma, A., 2012. Biogeomorphological interactions on a nourished tidal flat: lessons learned on building with nature. Aqua et Terra 126, 1-10.

Projectleaders

SJMH Hulscher

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

BW Borsje, PMJ Herman, SJMH Hulscher

Cooperations

Deltares, NIOZ

Funded

STW

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

Start of the project

2007

Information

BW Borsje
053 489 4038
b.w.borsje@utwente.nl

PROJECTLEADERS
SJMH Hulscher

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
W Chen, PC Roos, HM Schuttelaars, SJMH Hulscher

COOPERATIONS
Closely linked to Future Ems project and TU Delft

FUNDED
University of Twente
CSC (China Scholarship Council) scholarship
Future Ems project

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

START OF THE PROJECT
2011

INFORMATION
WL Chen
053 489 2959
w.chen-3@utwente.nl
www.wem.ctw.utwente.nl

PROJECT AIM

The main objective of this project is to understand a scientific problem: how does 'basin-scale' sand extraction affect the set-up at the coast, both in the short term (immediately after extraction) and in the long term (through changes in morphology)? And solve a design problem: to warrant coastal safety, is it possible to shape the sand extractions required for nourishments and land reclamations such that potentially adverse effects of these interventions are minimized? Develop a three-dimensional hydro- and morphodynamic model that allowing for a quick and systematic analysis of residual circulation and set-up at the coast, accounting for the basin`s morphodynamic evolution, the balance is between wind stress, atmospheric pressure gradient, density gradient, and river runoff. This model should (1) provide insight into the physical mechanisms, and (2) serve as a tool to analyze the impacts of various spatial extraction scenarios.

PROGRESS

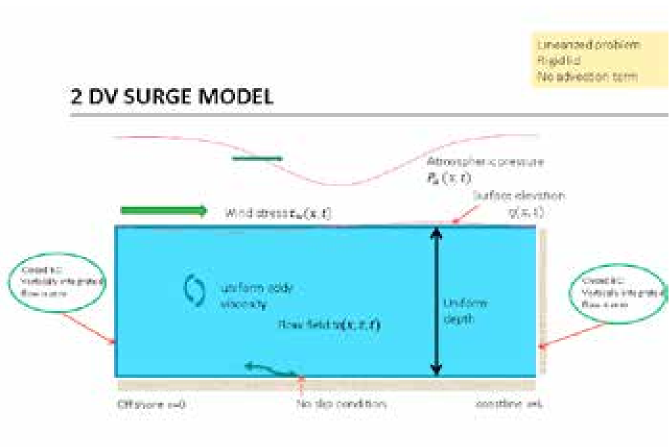
In the year of 2011-2012, I prepared and defended my Phd proposal "sand extraction and coastal afety", developed a 2DV steady model to compare the wind driven density driven and river runoff current, the model was applied to the Ems estuary as pre-study for later on and presented on PECS (NY 2012) in poster. A 2DV surge model was developed to investigate surge problem, part of the work was presented on Burgersdag 2013,next step will be extend this 2DV surge model to arbitrary depth profile and finally extend to 3D, then apply to certain area.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Poster 'Sand Extraction and coastal safety' on PECS (NYC 2012). 2DV steady model.
2. Presentation 'Sand Extraction and coastal safety' on Burgersdag 2013. 2DV surge model.



Short-term biophysical interactions in coastal mangroves

Project Aim

To study in the field how biogeophysical settings control the dissipation of wave energy in coastal mangroves. To quantify the bio-physical interactions that control the dissipation of hydrodynamic energy in coastal mangroves and to use this knowledge for improving a nearshore wave propagation model. To study in the field how enivronmental characteristics control routing of water and sediments through a coastal mangrove forest with variable biogeophysical settings. To quantify the bio-physical interactions that control the routing of water and sediments in these coastal mangroves and to develop a process-based hydrodynamic and morphodynamic model to simulate tidal scale dynamics in this area. To apply this model to study the contribution of different biogeophysical characteristics to the routing of water and sediments through coastal mangroves.

Progress

The past year has been spent on the analysis of an extensive database previously collected in mangroves along the coast of Trang Province, Thailand. Flow routing has been analysed for three different coastal mangrove sites, each with distinct biogeophysical settings. This analysis has shown how the combination of vegetation characteristics, bottom elevation and tidal exposure impacts on the import and export of both water and sediments in coastal mangroves. Next, wave attenuation along two cross-shore transects through coastal mangroves has been analyzed. Along both transects, vegetation densities were variable and incident wave characteristics differed. It was shown how increasing vegetation densities cause a significantly greater reduction in wave energy and how mostly short-period wave components are being attenuated. The next step is to set-up (or improve) models to simulate the processes observed in the field, in order to execute an in-depth sensitivity analysis of the observed processes to different biogeophysical parameters.

Dissertations

-

Scientific Publications

1. Friess, D.A., Krauss, K.W., Horstman, E.M., Balke, T., Bouma, T.J., Galli, D. & Webb, E.L. (2012). Are all intertidal wetlands naturally created equal? Bottlenecks, thresholds and knowledge gaps to mangrove and saltmarsh ecosystems, doi: 10.1111/j.1469-185X.2011.00198.x. Biological reviews, 87(2), 346-366.
2. Horstman, E.M., Dohmen-Janssen, C.M., Bouma, T.J. & Hulscher, S.J.M.H. (2012). Flow routing in mangrove forests: field data obtained in Trang, Thailand, doi: 10.3990/2.186. In W.M. Kranenburg, E.M. Horstman & K.M. Wijnberg (Eds.), NCK-days 2012. Crossing borders in coastal research. Jubilee conference proceedings 20th NCK-days, 13-16 March 2012 Enschede, The Netherlands (pp. 147-151). Enschede: University of Twente.
3. Kranenburg, W.M., Horstman, E.M. & Wijnberg, K.M. (Eds.) (2012). NCK-days 2012 Crossing borders in coastal research. Jubilee conference proceedings 20th NCK-days. Enchede: University of Twente.
4. Horstman, E., Dohmen-Janssen, C., Narra, P., Van den Berg, N., Siemerink, M., Balke, T., Bouma, T., Hulscher, S., 2012. Wave attenuation in mangrove forests; field data obtained in Trang, Thailand. In J. McKee Smith & P. Lynett (Eds.), Proceedings of 33rd International Conference on Coastal Engineering (ICCE), 1 - 6 July 2012, Santander (pp. 1-15). Santander: Coastal Engineering Research Council.

Projectleaders
SJMH Hulscher,
CM Dohmen-Janssen

Researchtheme
Complex dynamics of fluids

Participants
EM Horstman, Dohmen-Janssen, SJMH Hulscher, PMJ Herman, TJ Bouma, EL Webb, DA Friess, C Sudtongkong, D Galli, T Balke

Cooperations
Singapore-Delft Water Alliance, Deltares, National University of Singapore, Public Utilities Board Singapore, Rajamangala University of Technology Srivijaya, Chulalongkorn University

Funded
Singapore-Delft Water Alliance

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

Start of the project
2009

Information

E Horstman
053 489 28 21
E.M.Horstman@utwente.nl
www.utwente.nl/ctw/wem/organisatie/medewerkers/horstman.doc

Coastal mangroves form a highly dynamic interface between land and sea in the (sub-)tropics: waves are being attenuated, water flows are slowed down and sediments are getting trapped.

Process-based modeling of sediment transport under waves in the sheet-flow regime

Projectleaders
SJMH Hulscher

Researchtheme
Complex dynamics of fluids

Participants
WM Kranenburg, JS Ribberink,
RE Uittenbogaard, SJMH Hulscher

Cooperations
University of Aberdeen, UK
University of Delaware, USA

Funded
SANTOSS (STW/EPSCR)
SINBAD (STW/EPSRC)
Hydralab IV-WISE (EU)

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

Start of the project
2008

Information
WM Kranenburg
053 489 2959
w.m.kranenburg@utwente.nl
www.wem.ctw.utwente.nl

Project Aim

In the near-shore zone, energetic sea waves generate sheet-flow sand transport. The mostly progressive nature of the waves also induces an onshore directed current (streaming) near the bed. The aim of this project is to develop process-based numerical models of the wave bottom boundary layer and to investigate progressive wave effects on boundary layer flow, sand transport rates and the details of the sheet-flow layer. Next, to enable implementation of the results into morpho-dynamic models on engineering scale, another aim is to develop parameterizations of the model results.

Progress

In earlier phases, we investigated the influence of progressive wave streaming on boundary layer flow and sediment transport rates with a RANS model with k-ε turbulence closure and advection-diffusion formulation for sediment concentration. To investigate the influence on the details of the sheet-flow layer, we now also developed a two-phase continuum model for sheet-flow of medium to fine sized sand in water. We improved the grain-size dependent behaviour of the model by adaptation of the model-formulations for the grain influence on fluid turbulence. The model has been validated with detailed sheet-flow data and is ready to be used develop parameterizations of bed erosion as function of wave and bed conditions. The project has been finalized with a dissertation: Modeling sheet-flow sand transport under progressive surface waves, to be defended February 15.

Dissertations

1. Kranenburg, W.M. (2013) Modeling sheet-flow sand transport under progressive surface waves. University of Twente, PhD thesis, 174 pp.

Scientific Publications

1. Kranenburg, W.M., J.S. Ribberink, J.L.M. Schretlen and R.E. Uittenbogaard (2012) ‘Sand transport beneath waves: the role of progressive wave streaming and other free surface effects’, accepted for publication in J. Geophys. Res. DOI:10.1029/2012JF002427.
2. Kranenburg, W.M., J.S. Ribberink, R.E. Uittenbogaard and S.J.M.H. Hulscher (2012) ‘Net currents in the wave bottom boundary layer: On waveshape streaming and progressive wave streaming’, J. Geophys. Res., 117, F03005, DOI:10.1029/2011JF002070.

River bed form evolution modeling for flood management

Project Aim

Subproject 1: Dune evolution and transition to plane beds (van Duin)

The overall objective of this subproject is to model and better understand (1) the (processes leading to) the transition to upper-stage plane beds, (2) the evolution and occurrence of specific dune morphologies (e.g. superimposed dunes, low-angle dunes) and (3) the roughness associated with the aforementioned bed configurations.

Subproject 2: The influence of suspended sediment transport on dune evolution (Naqshband) The overall objective of this subproject is to model and better understand the effects of suspended load on (1) dune morphology, (2) dune evolution and (3) transition from dunes to upper stage plane beds.

Subproject 3: Application of bed form roughness in operational flood modelling (Warmink). The objective of this subproject is to apply the knowlegde acquired in subprojects 1 & 2 for operational forecasting of water levels.

Progress

In the past period the main focus for subproject 1 was to 1) test the effect of a simple dune length predictor versus the linear stability analysis (LSA), 2) further investigate pick-up and deposition models and underlying step length models, 3) implement a full pick-up and deposition model and run tests with it. For subproject 2 the main focus was to analyse the dune height and length data collected from literature and describe the processes that are important in the morphological behaviour of dunes to upper stage plane beds. Next to this, a second series of experiments have been carried out in Braunschweig for the last three months (November 2012 to January 2013). The main goal here is to quantify the effect of suspended sediment in changing dune morphology. To this end, two conditions were selected; 1) bed load dominated and 2) suspended load dominated sediment regime. The major difference with the previous series of experiments (summer 2011) is the grain size used. We have used a grain size which is three times smaller than before. This results in a good development of suspended sediment profiles along dunes that is necessary for the dunes to decay and finally wash out.

Subproject 3 was focused on improvement of the water level predictions using an improved bed form evolution model under unsteady discharge in alluvial rivers (assuming alluvial bed forms in the river reach). This requires an improved version of the Paarlberg model that is not available yet. The main challenge is to address the dune length herein, which is for now computed separately using van Rijn model or LSA.

Dissertations

-

Scientific Publications

1. Naqshband, S., Ribberink, J.S., Hulscher, S.J.M.H. & Hurther, D. (2012). Simultaneous, co-located measurements of flow velocity and sediment concentration over mobile dunes. In R.M. Munoz (Ed.), Proceedings of the International conference on fluvial hydraulics, San Jose, Costa Rica, 5-7-September 2012 (pp. 755-760). London, UK: CRC Press Taylor & Francis Group.

Projectleaders

SJMH Hulscher,
CM Dohmen-Janssen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

OJM van Duin, S Naqshband,
JJ Warmink, JS Ribberink,
R Schielen, AJ Paalberg

Cooperations

Deltares, HKV, Rijkswaterstaat, Waterdienst, University of Braunchweig

Funded

NWO/STW, University of Twente, Deltares/RWS, HKV

University	45 %
FOM	50 %
STW	-
NWO Other	-
Industry	5 %
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2010

Information

OJM van Duin
O.J.M.vanDuin@utwente.nl

S Naqshband
S.Naqshband@utwente.nl

2. Naqshband, S., Ribberink, J.S. & Hulscher, S.J.M.H. (2012). Free surface effect on dune morphology and evolution. In R.M.J. Schielen (Ed.), Book of abstracts NCR-days 2012, 4-5 October 2012, Arnhem (pp. 45-46). Arnhem: Rijkswaterstaat.
3. Van Duin, O.J.M., Ribberink, J.S., Dohmen-Janssen, C.M., & Hulscher, S.J.M.H. (2012). Particle step length variation along river dunes. In R.M. Munoz (Ed.), Proceedings of the International conference on fluvial hydraulics, San Jose, Costa Rica, 5-7- September 2012 (pp. 493-497). London, UK: CRC Press Taylor & Francis Group.
4. Warmink, J.J., Straatsma, M.W., Huthoff, F., Booij, M.J., Hulscher, S.J.M.H. (2012). Uncertainty of design water levels due to combined bed form and vegetation roughness in the Dutch river Waal. Journal of Flood Risk Management DOI: 10.1111/jfr3.12014.
5. Warmink, J.J., Booij, M.J., Van der Klis, H., Hulscher, S.J.M.H. (2012). Quantification of uncertainty in design water levels due to uncertain bed roughness in the Dutch river Rhine. Hydrological Processes DOI: 10.1002/hyp.9319.
6. Warmink, J.J. Straatsma, M.W. Huthoff, F. (2012). The effect of hydraulic roughness on design water levels in river models. Proc. of the FloodRisk 2012 conference, Rotterdam, the Netherlands, pp. 157-164.
7. Warmink, J.J., Schielen, R.M.J., Dohmen-Janssen, C.M. (2012). Bed form evolution under varying discharges, flume versus field. Murillo (Ed.) Proc. of the International Conference on Fluvial Hydraulics, River Flow 2012, Costa Rica, pp. 183-190.
8. Warmink, J.J., Schielen, R.M.J., Dohmen-Janssen, C.M. (2012). Bed form evolution under unsteady discharge, flume versus field. Proc. NCR-days 2012, Arnhem, the Netherlands, pp. 79-81.
9. Warmink, J.J. (2012) Uncertainty in design water levels due to hydraulic roughness, a case study for the river Waal in the Netherlands. Abstracts for Workshop on Uncertainty modelling in hydraulics, June 28-29, Stresa, Italy.

Turbidity dynamics in lake Naivasha ecosystem

Project Aim

The main research objective is to enhance the understanding of turbidity dynamics and its effects on Lake Naivasha ecosystem. This will be achived by: investigating spatial-temporal variability of turbidity in Lake Naivasha using field measurements coupled with Earth Observation and Geo-information, identifying the main drivers and mechanisms that Influence the turbidity dynamics in Lake Naivasha, investigating the shift from clear to turbid state in Lake Naivasha and finally by quantifying changes in fish population (in terms of annual fish catches, catch per unit effort (CPUE), length, sex and species) in relation to turbidity changes in Lake Naivasha.

Progress

Data analysis was done and two manuscripts were drafted.

Dissertations

-

Scientific Publications

-

Projectleaders

SJMH Hulscher

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

J Ndungu, D Augustijn, N Kitaka, J Mathooko, SJMH Hulscher

Cooperations

Closely linked to: EOIA Naivasha project: https://sites.google.com/site/eoianaivasha/

Funded

WOTRO

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

Start of the project

2010

Information

J Ndungu
06 476 04589
J.N.Ndungu@utwente.nl;
www.wem.ctw.utwente.nl;

PROJECTLEADERS
SJMH Hulscher, JJ Warmink, RMJ Schielen

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
Ir. J.P. Aguilar López, Dr. J.J. Warmink, Dr. R.M.J. Schielen, Dr. Ir. Dohmen-Janssen, Prof. Dr. S.J.M.H. Hulscher, Prof. Dr. M. Kok

COOPERATIONS
Deltares, HKV, Rijkswaterstaat, Waterdienst, Arcadis

FUNDED
STW-perspectif

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

START OF THE PROJECT
2012

INFORMATION
J Pablo Aguilar
053 489 40 38
j.p.aguilarlopez@utwente.nl
http://www.utwente.nl/ctw/wem/organisatie/medewerkers/aguilar_lopez.doc/

PROJECT AIM

Flood risk safety philosophy is changing more and more in the direction of a system probability of failure approach, which should replace the current overload per dike section approach. The project aims to:

- Verify/update and add actual limit state equations for flood defenses with more than one function.
- Model the main failure mechanisms.
- Validate the updated set of limit state equations.
- Construct a general failure scheme (Fault Tree).

PROGRESS

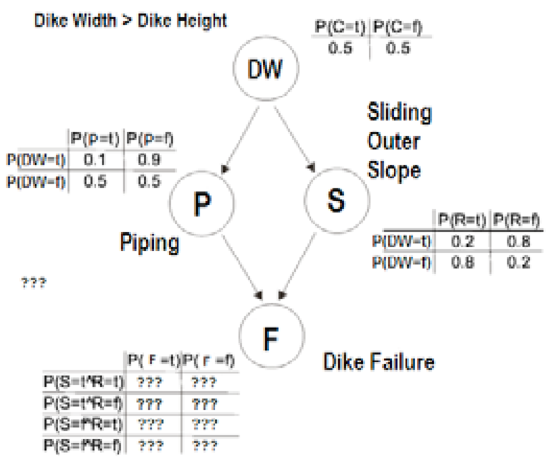
The first part of the study consists on predicting the uncertainty of the main design parameters. Then the propagation on the reliability functions of the failure mechanisms. In order to achieve this Stochastic uncertainty analysis is used to generate large data samples. These samples are going to be classified with a Bayesian Network (Fig.1) method in order to generate a dynamic fault tree based in their conditional probability of occurrence. This method will also give the opportunity to identify which failure mechanisms may influence the occurrence of other mechanisms based on the assumptions of their dependence (Aguilera, Fernández et al. 2011).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Aguilar J.P., Schielen R.M.J.,Warmink J.J. & Hulscher, S.J.M.H. (2012). Safety assessment of multi-functional flood defenses , Book of abstracts Nederlands Centrum voor Riverkunde NCR-days (pp 19-21), 4th October – 5th October 2012, Arnhem-The Netherlands.



Bayesian network of failure mechanism

Sand transport under breaking waves

Project Aim

Current hydromorphological models used by coastal engineers are too inaccurate when it comes to sand transport in the breaker zone. By conducting large-scale wave experiments while using state-of-the-art measuring devices, and through the development of a new process-based model, we aim at extending the current knowledge on hydrodynamics and sediment transport processes under various breaking-wave conditions. This will finally lead to an improved practical sand transport model. The research is part of an international project called SINBAD which aims at studying sand transport under breaking and irregular waves.

Progress

The project was started in early 2012. As a start, relevant literature was studied. Another activity involved a new measuring instrument which is able to measure high concentrations of sediment in the near-bed sheet-flow layer under breaking waves. This CCM Tank was designed and built by the University of Twente and elaborately tested in Enschede during the summer of 2012 and during a flume experiment in Barcelona in October 2012. Finally, progress was made regarding the preparation of 3 series of experiments, which are due in 2013 and 2014, including analysis of preliminary experiments, predictive calculations of different set-ups, and designing measuring frames.

Dissertations

-

Scientific Publications

-

Projectleaders

SJMH Hulscher

Researchtheme

Complex dynamics of fluids

Participants

JS Ribberink, J van der Zanden, WM Kranenburg, JJ van der Werf, RH Buijsrogge

Cooperations

University of Aberdeen, University of Liverpool, Bangor University, Deltares, Universitat Politècnica de Catalunya, Labaratoire des Ecoluments Géophysiques et Industriels (LEGI), National Oceanography Centre

Funded

STW, EU (through Hydralab-IV)

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

Start of the project

2012

Information

J van der Zanden
053 489 4038
j.vanderzanden@utwente.nl

Prof.dr. AEP Veldman

The group Computational Mechanics and Numerical MathemThe 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 thus far mainly mono-disciplinary flow problems 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. atics 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 thus far mainly mono-disciplinary flow problems 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.

Snapshot of a simulated turbulent flow at Re=3900

Direct and large-eddy simulation of turbulence

Project Aim

A main area of research concerns turbulent flow simulation. Turbulence modeling keeps computational effort within reasonable limits, but a price is paid in terms of accuracy. Thus research into direct numerical simulation (DNS) methods that resolve all length and time scales is envisaged. Our group concentrates on improving numerical techniques (space discretization and time integration) with which the price of DNS can be reduced significantly. Additionally, steps towards mathematical-based LES modeling are made.

Progress

The central theme of the \textit{turbulent flow} project is to model and simulate turbulence in such a way that the symmetry and conservation properties of the Navier-Stokes equations are preserved. In cooporation with MARIN a PhD-project was continued which aims to extend the symmetry-preserving discretization method to unstructured grids at high Reynolds numbers. The joint work with prof. Oliva and dr. Trias et al. (from UPC, Barcelona) on symmetry-preserving regularization models for turbulence is continued. In cooporation with NLR a PhD-project was continued in which a detailed numerical simulation method for turbulent flow over aircraft wings will be developed.

Dissertations

1. M. Younas, Scalable parallel Poisson solvers for CFD problems. Promotores: prof.dr. A.E.P. Veldman, prof.dr.ir. H.L. Trentelman; co-promotor: dr.ir. R.W.C.P. Verstappen. University of Groningen, 24 February 2012, 127 pages.

Scientific Publications

1. H. Bandringa, R. Verstappen, F. Wubs, C. Klaij, A. v.d. Ploeg, On novel simulation methods for complex flow in maritime applications, Proceedings NuTTS symposium, 2012.
2. J.E. Jaramillo, F.X. Trias, A. Gorobets, C.D. P\erez-Segarra, and A. Oliva (2012) DNS and RANS modelling of a turbulent plane impinging jet. International Journal of Heat and Mass Transfer, 22, Issue 4:789–801, 2012.
3. J.E. Jaramillo and R.W.C.P. Verstappen, Numerical study of a turbulent lid-driven cavity flow. Models assessment, Conference on Modelling Fluid Flow (CMFF), Proceedings 15th Int. Conf. on Fluid Flow Technologies, Budapest, Hungary, Sep 4-7, 2012.
4. F.X. Trias, R. Verstappen, A. Gorobets, A. Oliva, Spectrally-consistent regularization modeling of turbulent natural convection flows, {\it Journal of Physics: Conference Series (JPCS)} 395, paper 012123, 2012.
5. F.X. Trias, R. Verstappen, A. Gorobets, A. Oliva, Regularization modeling of turbulent natural convection flows, Proceedings 6th European Thermal Sciences Conference, EUROTHERM 2012, Poitiers, 8 pages, Sep 4-7, 2012.
6. R.W.C.P. Verstappen: On a consistent, scale-truncation model for large eddy simulation. In: CD-ROM Proceedings of the 6th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), September 10-14, 2012, Vienna, Austria, Eds.: Eberhardsteiner, J.; Böhm, H.J.; Rammerstorfer, F.G., Publisher: Vienna University of Technology, Austria, ISBN: 978-3-9502481-9-7 (12 pages).

Projectleaders

RWCP Verstappen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

HJ Bandringa, AJA Kort, JA Helder, W Rozema, M Younas, RWCP Verstappen, AEP Veldman, FW Wubs, J Jaramillo (UPC), FX Trias (UPC)

Cooperations

NLR, MARIN, TUD, UT, Politechnical University of Catalunya (Barcelona, E), Stanford University (USA), VORtech

Funded

Agentschap.nl (EZ), Ubbo Emmius Fonds (RUG), AGAUR (Spain)

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

Start of the project

1996

Information

RWCP Verstappen
050 363 3958
R.W.C.P.Verstappen@rug.nl
www.math.rug.nl/~veldman/DNS/dns-home

7. Roel Verstappen, On a consistent scale-truncation model for large eddy simulation, Proceedings European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), J. Eberhardsteiner et al. (eds.), Vienna, Sept. 10-14, 2012.
8. Bas van't Hof and Arthur E.P. Veldman. Mass, momentum and energy conserving (MaMEC) discretizations on general grids for the compressible Euler and shallow water equations. J. Comput. Phys. 231 (2012) 4723-4744. DOI:10.1016/j.jcp.2012.03.005.
9. B. van't Hof, A.E.P. Veldman: Mass-, momentum- and energy conserving discretizations on general grids for the shallow water equations. In: CD-ROM Proceedings of the 6th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), September 10-14, 2012, Vienna, Austria, Eds.: Eberhardsteiner, J.; Böhm, H.J.; Rammerstorfer, F.G., Publisher: Vienna University of Technology, Austria, ISBN: 978-3-9502481-9-7 (20 pages).

Simulation of hydrodynamic wave impact

Project Aim

A fast-growing application area of our ComFlow simulation method is maritime technology. In close cooperation with MARIN, Deltares and the offshore industry, focus is on the numerical prediction of hydrodynamic wave loading (green water, slamming) and sloshing in ship tanks.

Progress

The ComFLOW-3 project on hydrodynamic wave loading by extreme waves was continued (with TU Delft, MARIN, Deltares and FORCE Technology Norway). In the new developments, physical emphasis is on modelling viscous effects during wave impact. Hereto, a regularization model from our turbulent-flow research (see above) has been implemented, extended with a separate model for the near-wall treatment. Numerical efficiency is improved with local grid refinement and parallelization. The TUD-part of the project focusses on improved wave generation and propagation. All the developments are now being merged, and preparations for a few major validation test cases are being made, for which MARIN has finished a set of detailed experiments (moonpools).

Dissertations

1. P.R. Wellens, Wave simulations in truncated domains for offshore applications. Promotores: prof.dr.ir. R.H.M. Huijsmans and prof.dr. A.E.P. Veldman, Delft University of Technology, 13 January 2012, 137 pages.

Scientific Publications

1. Bulent Duz, Rene H.M. Huijsmans, Peter R. Wellens, Mart J.A. Borsboom and Arthur E.P. Veldman, Application of an absorbing boundary condition in a wave-structure interaction problem. In: Proc. 31st Int. Conf. on Ocean, Offshore and Arctic Engineering, 10-15 June 2012, Rio de Janeiro, Brazil. Paper. OMAE2012-83744 (8 pages).
2. R. Luppes, B. Duz, H.J.L. van der Heiden, P. van der Plas, A.E.P. Veldman: Numerical simulations of two-phase flow with ComFLOW:past and recent developments. In: CD-ROM Proceedings of the 6th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), September 10-14, 2012, Vienna, Austria, Eds.: Eberhardsteiner, J.; Böhm, H.J.; Rammerstorfer, F.G., Publisher: Vienna University of Technology, Austria, ISBN: 978-3-9502481-9-7 (16 pages).
3. H.J.L. van der Heiden, P. van der Plas, A.E.P. Veldman, R. Luppes, R.W.C.P. Verstappen: Efficiently simulating viscous flow effects by means of regularization turbulence modeling and local grid refinement. In: CD-ROM Proceedings of the 6th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), September 10-14, 2012, Vienna, Austria, Eds.: Eberhardsteiner, J.; Böhm, H.J.; Rammerstorfer, F.G., Publisher: Vienna University of Technology, Austria, ISBN: 978-3-9502481-9-7 (20 pages).
4. P. van der Plas, H.J.L. van der Heiden, A.E.P. Veldman, R. Luppes and R.W.C.P. Verstappen, Efficiently modeling viscous flow effects by means of regularization turbulence modeling and local grid refinement, Proceedings Seventh International Conference on Computational Fluid Dynamics (ICCFD7), Hawaii, July 9-13, 2012, paperno ICCFD7-2503.
5. R. Wemmenhove, R. Luppes, A.E.P. Veldman and T. Bunnik, Simulation of hydrodynamic wave loading by a compressible two-ophase flow method. In: D. Le Touz'e (ed.) Violent Flows 2012, Editions Publibook, ISBN 978-2-7483-9035-3 (2012) p. 289-296.

Projectleaders

AEP Veldman

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

HJL van der Heiden, P van der Plas, R Luppes, AEP Veldman, B Duz (TUD), RHM Huijsmans (TUD), T Bunnik (MARIN), PR Wellens (Deltares), MJA Borsboom (Deltares)

Cooperations

TU Delft, MARIN, Deltares, FORCE Technology (Norway)

Funded

STW

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

Start of the project

1999

Information

AEP Veldman
050 363 3988
a.e.p.veldman@rug.nl
www.math.rug.nl/~veldman/comflow/comflow.html

Numerical methods for the incompressible Navier-Stokes equations

Projectleaders
FW Wubs

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
S Kotnala, H Kirbas, W Song, FW Wubs, HA Dijkstra (UU), J Thies (DLR)

Cooperations
IMAU (UU), TU Brainschweig (D), DLR (D), RAL (UK), Ege University (Turkey)

Funded

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

Start of the project
1994

Information
FW Wubs
050 363 3994
f.w.wubs@rug.nl
www.math.rug.nl/~wubs

Project Aim

The repeated solution of large systems of equations in most simulation methods makes the quest for improved matrix solvers another major research area. In-house a multilevel preconditioner (MRILU) and a new multilevel preconditioner for CFD problems (HYMLS) have been developed. Application area is the modelling of flow patterns in global ocean circulation (with UU-IMAU) and the study of the behavior of flows beyond but close to the transition point (self-sustaining structures, traveling wave solutions).

Progress

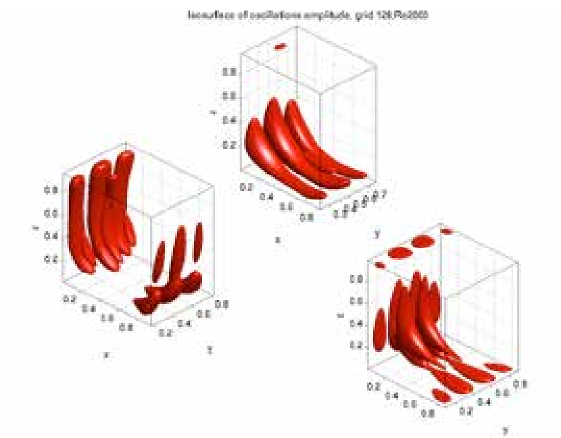
In the research on sparse-matrix solvers a first version of multilevel HYMLS has been finished. This has been coupled to eigenvalue solvers in the Trilinos package. It currently allows to perform bifurcation analysis on incompressible Navier-Stokes equations on systems up to the order of 10 million unknowns in a few hours on a cluster with 128 nodes. In the new year a cooperation starts with the German Aerospace Laboratory (DLR) on the further development of HYMLS towards massively parallel computers with applications in eigenvalue problems from fluid dynamics.

Dissertations

1. Jonas Thies, Scalable algorithms for fully implicit ocean models. Promotor: prof.dr. A.E.P. Veldman; copromotor: dr.ir. F.W. Wubs. University of Groningen, 21 January 2011,

Scientific Publications

1. F. Wubs and J. Thies. A parallel multilevel ILU solver for fully coupled Navier-Stokes equations. In: Proc. 6th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2012), Eds.: Eberhardsteiner, J.; Boehm, H.J.; Rammerstorfer, F.G., Publisher: Vienna University of Technology, Austria, ISBN: 978-3-9502481-9-7 (2 pages).



Isosurface of oscillations amplitude 128^3 grid, Re=2000, eigenvectors of velocities along centerline.

Iterative solvers for electromagnetic problems

Project Aim

The project aims at developing Krylov subspace solvers for general nonsymmetric linear systems Applications are sparse nonsymmetric problems in quantum mechanics and dense complex non-Hermitian problems in electromagnetic scattering. The work extends to the development of sparse eigensolvers for Maxwell's equations in the analysis of dielectric waveguides.

Progress

New results with stabilization techniques for Krylov subspace methods have been presented at the 2012 SIAM Conf. Appl. Linear Algebra (Valencia, Spain). Block code for multilevel Incomplete LU factorization solvers has been developed. It was presented at the IMA Conf. Numer. Linear Algebra and Optim. (Birmingham, UK). Continuing last years' activity on matrix solvers for dense linear systems in electromagnetics, new preconditioning algorithms have been developed, enabling us to solve very large scattering problems involving dense matrices with around 20 million unknowns. This work was carried out in cooperation with the School of Information and Electronics, Beijing Institute of Technology, and has been presented at the ICCAM 2012, Int. Congr. Comput. Appl. Math. (Ghent, Belgium).

Dissertations

-

Scientific Publications

1. A. Bonfiglioli, S. Campobasso, B. Carpentieri, and M. Bollhoefer. A parallel 3D unstructured implicit RANS solver for compressible and incompressible CFD simulations. Lecture Notes in Computer Science, 7204, 2012, 313--322.
2. B. Carpentieri and M. Bollhoefer. Symmetric inverse-based multilevel ILU preconditioning for solving dense complex non-hermitian systems in electromagnetics. Progress In Electromagnetics Research, PIER, 128, 2012, 55-74.
3. B. Carpentieri, Y.-F. Jing, T.-Z. Huang, W.-C. Pi, and X.-Q. Sheng. Combining the CORS and BiCORSTAB iterative methods with MLFMA and SAI preconditioning for solving large linear systems in Electromagnetics. Applied Computational Electromagnetics Society Journal, 27(2), 2012, 102-111.
4. B. Carpentieri. Trends in Electromagnetism from Fundamentals to Applications, chapter Fast Preconditioned Krylov Methods for Boundary Integral Equations in Electromagnetic Scattering. InTech, V. Barsan and R.P. Lungu Eds, 2012, 155-176.
5. B. Carpentieri. Advanced Computational Technologies, chapter Fast integral equation solvers in Computational Electromagnetics. Calin Enachescu, Florin Gheorghe Filip, Barna Iantovics (Eds.), Advanced computational technologies, Romanian Academy Publishing House, Bucharest, 2012, 235--246.
6. B. Carpentieri, M. Bollhoefer, T.-Z. Huang, Y.-F. Jing, W.-C. Pi, and X.-Q. Sheng. Preconditioned krylov subspace methods for solving high-frequency deep cavity problems in electromagnetics. In: Proc. of the ICCAM 2012, International Congress on Computational and Applied Mathematics, Ghent, Belgium, July 9-13, 2012.
7. B. Carpentieri, Y.-F. Jing, T.-Z. Huang, and Y. Duan. A stable variant of the Biconjugate A-Orthogonal Residual method for non-Hermitian linear systems. In: Proc. of the 2012 SIAM Conference on Applied Linear Algebra, Valencia, Spain, June 18-22, 2012.

Projectleaders

B Carpentieri

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

J Liao, B Carpentieri, YF Jing (Chengdu)

Cooperations

Univ. Chengdu (China) , Bejing Inst. Techn. (China), TU Braunschweig (D)

Funded

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

Start of the project

2010

Information

B Carpentieri
050 363 3939
b.carpentieri@rug.nl

8. Y.-F. Jing, T.-Z. Huang, B. Carpentieri, and Y. Duan. Investigating the composite step biconjugate A-orthogonal residual method for non-hermitian linear systems in Electromagnetics. Applied Computational Electromagnetics Society Journal, 27(2), 2012, 112--122.
9. J. Liao, B. Carpentieri, and M. Sosonkina. VBARMS: A variable block variant of the algebraic multilevel solver for general linear systems. In: Proc. of the 3rd IMA Conference on Numerical Linear Algebra and Optimisation, Birmingham, UK, September 10-12, 2012.

Aerodynamic optimization of wind turbine blades

Project Aim

The project focuses on the aerodynamic optimization of turbine blades. The simulation approach builds on viscous-inviscid boundary-layer interaction. The numerical coupling between boundary layer and inviscid outer flow is similar to that used in our bio-medical project.

Progress

In the wind energy project (with ECN), aimed at aerodynamic design of wind turbine blades, an analysis has been made of the mathematical character of the (interacting) boundary-layer equations and its consequences for their numerical solution. Focus has been on unsteady two-dimensional flow, and steady three-dimensional flow. The quasi-simultaneous coupling algorithm has been analyzed, and investigated with geometrically simple model problems (troughs and dents) featuring separated flow. The PhD manuscript was finished in December.

Dissertations

-

Scientific Publications

1. H.A. Bijleveld and A.E.P. Veldman. Quasi-simultaneous interaction method for solving boundary layer flows in primary and characteristic variables. In: A. Andrade-Campos, N. Lopes, R.A.F. Vaklente, H. Varum (eds.) Young Investigators Conference YIC2012, Aveiro (Portugal) 21-27 April 2012.
2. H.A. Bijleveld and A.E.P. Veldman. Solving 2D unsteady turbulent boundary layer flows with a quasi-simultaneous interaction method. In: J. Peinke (ed.) Proc. „Wind energy and the impact on turbulence on the conversion process“, Euromech Colloquium 528, Oldenburg, 22-24 Feb. 2012.
3. H.A. Bijleveld and A.E.P. Veldman, Quasi-simultaneous interaction method for solving 2D boundary layer flows over plates and airfoils. In: Seenith Sivasundaram (ed.) AIP Conf. Proc. 1493, pp. 149-156; doi:http://dx.doi.org/10.1063/1.4765483 (8 pages) ISBN: 978-0-7354-1105-0.
4. H.A. Bijleveld and A.E.P. Veldman, A fast and accurate method to predict 2D and 3D aerodynamic boundary layer flows. In: The Science of Making Torque from Wind, Oldenburg, 9-11 October 2012 (8 pages).
5. P. Eecen, H.A. Bijleveld, B. Sanderse, Wind energy research development of advanced design tools. Europhysics News EPN 43(2) 18-21 (DOI:10.1051/epn/2012203) (2012).

Projectleaders

AEP Veldman

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

HA Bijleveld, AEP Veldman

Cooperations

ECN

Funded

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

Start of the project

2008

Information

AEP Veldman
050 363 8988
a.e.p.veldman@rug.nl
www.math.rug.nl/~veldman

Granular and disordered media

Prof.dr.ir. ML van Hecke

The Granular and Disordered Media Group of Martin van Hecke investigates the slow flow and jamming of granulates, foams and macro emulsions. We focus on the interplay between mesoscopic organization and macroscopic flow features, and we combine video imaging with rheological measurements. We work closely together with the theory group of Vincenzo Vitelli. Topics we are currently woring on include the flow and yielding of agitated granular media, sound in sand and the fluctuating flow of foam.

Project Aim

-

Progress

-

Dissertations

-

Scientific Publications

-

.

Projectleaders

ML van Hecke

Researchtheme

Complex structures of fluids

Participants

EL Woldhuis

Cooperations

-

Funded

FOM

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

Start of the project

2008

Information

ML van Hecke
071 527 5482
mvhecke@gmail.com

Non affine foam flows

Projectleaders
ML van Hecke

Researchtheme
Complex structures of fluids

Participants
AON Siemens

Cooperations
-

Funded

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

Start of the project
2009

Information
ML van Hecke
071 527 5482
mvhecke@gmail.com

Project Aim
-

Progress
-

Dissertations
-

Scientific Publications
1. M van Hecke: Running on Cornflour. Nature, 487, 174 (2012).

Turbulent glasses : predicting flows of grains and foams from an energy cascade

Project Aim

Understand complex flow of foams and grains.

Progress

Work on 3/4 projects, none very close to publication.

Dissertations

-

Scientific Publications

1. S. Dagois-Bohy, B.P. Tighe, J. Simon, S. Henkes and M. van Hecke: Soft Sphere Packings at Finite Pressure but Unstable to Shear. Phys. Rev. Lett. 109, 095703 (2012).
2. K. Nichol and M. van Hecke: Flow Induced Fluctuations Create a Granular Fluid: Effective Viscosity and Fluctuations. Phys. Rev. E, 85, 061309 (2012).
3. S. Slotterback, M. Mailman, K. Ronaszegi, M. van Hecke, M. Girvan, W. Losert: Onset of Irreversibility in Cyclic Shear of Granular Packings. Phys. Rev. E, 85, 021309 (2012).
4. S. Dagois-Bohy, S. Courrech du Pont, S. Douady, Singing-Sand Avalanches without Dunes - Geophys. Res. Lett. vol. 39, L20310, 5 , 2012.
5. Eureka! Jaargang 10, nummer 38 oktober 2012 Faseovergangen in stromend zand Geert Wortel en Martin van Hecke pag 10 t/m 13.

Projectleaders

ML van Hecke

Researchtheme

Complex structures of fluids

Participants

G Wortel, S Dagois-Bohy

Cooperations

-

Funded

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

Start of the project

2010

Information

ML Van Hecke
071 527 5482
mvhecke@gmail.com

From granular fluids to granular glasses

Projectleaders
M van Hecke
Researchtheme
Complex structures of fluids
Participants
S Dagois-Bohy, G Wortel
Cooperations
-
Funded

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

Start of the project
2010
Information
ML Van Hecke
071 527 5482
mvhecke@gmail.com

Project Aim

The aim of this project is to use simulation to probe the properties of jammed systems that are flowing. We think these systems differ substantially from static jammed systems since the mechanism of energy dissipation plays an important role in the rheological behaviour.

Progress

We have made progress by testing a number of ingredients and assumptions of the scaling model we have developed. In addition we have broadened our scope to look at the normal stress as well as the shear stress. We have become more and more convinced that the mechanism of energy dissipation determines the rheology.

Dissertations

-

Scientific Publications

1. S. Dagois-Bohy, B.P. Tighe, J. Simon, S. Henkes and M. van Hecke: Soft Sphere Packings at Finite Pressure but Unstable to Shear. Phys. Rev. Lett. 109, 095703 (2012).
2. S. Dagois-Bohy, S. Courrech du Pont, S. Douady, Singing-Sand Avalanches without Dunes - Geophys. Res. Lett. vol. 39, L20310, 5 , 2012.

VICI

Project Aim

-

Progress

-

Dissertations

-

Scientific Publications

1. Merlijn van Deen: Gekke druppels. Eureka! jg 10 nr 37, juli 2012.

Projectleaders

ML van Hecke

Researchtheme

Complex structures of fluids

Participants

MS van Deen

Cooperations

-

Funded

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

Start of the project

2012

Information

ML Van Hecke
071 527 5482
mvhecke@gmail.com

Experimental Zoology Group

Prof.dr.ir. JL van Leeuwen

The current main theme of the Experimental Zoology Group is the biomechanics and development of the locomotion and feeding system in fish and other vertebrates (such as amphibians, reptiles and horses), in an evolutionary perspective and in relation to animal welfare. Mechanisms of development, growth and adaptation are studied at several levels of structural organisation, from molecules to ecosystem. This integrates several research lines such as (1) architectural organisation and remodelling of muscle and skeletons in larval and juvenile fish, (2) biofluid dynamics of swimming in larval fish and flight in birds, (3) effects of training on growth of the muscular and skeletal system, signified by for instance molecular expression patterns, and (4) structural development and function of the equilibrium system. We have also an evolutionary mechanics line of research that relates form and function at the organismal level to the actual niches and adaptive radiation in the natural enviroment.

The following research lines are carried out

1. Biomechanics of development in teleost fish
2. Biofluid dynamics of swimming and flight
3. Evolutionary mechanics of live bearing fish
4. Biomechanics of tongues and tentacles
5. Biophysics of sensory systems
6. Biofluid dynamics of filter feeding in invertebrates

Mechanisms of manoeuvrability through undulatory fin propulsion

Project Aim

Undulating fin propulsion as used by seahorses and sepia (nearly rigid-bodied animals) offers many advantages: from stable, low speed swimming, hovering at certain depths to an unsurpassed maneuvrability. However, the mechanisms of thrust production and manoeuvring through undulating fins attached to a rigid body are largely unknown. The aim at a fundamental biological (biofluiddynamics) level is to unravel the mechanisms between fin and body kinematics on the aforementioned animals and their locomotory behaviour. Later on, PIV will be used to analyse the fluid-dynamics of undulatory fin propulsion. The knowledge gained from locomotion and fluid-dynamic experiments with the animals will serve as a guideline for the design of a multifunctional, highly manoeuvrable bio-inspired underwater sensor platform. This underwater robot will be optimized with respect to efficiency and manoeuvrability, both by free swimming experiments and hydrodynamic modelling.

Progress

Biological research

This project started August 2010. So far, much effort was put in the development of an experimental set up, including:

- Installation of aquaria for holding seahorses, pipefish and sepia.
- Design of the first locomotion experiment: high-speed video setup for the analysis of fin and body kinematics of start and stop maneuvers, and steady forward swimming (seahorses).
- Initiation of several graduation projects on seahorse and sepia locomotory behaviour and training (essential for the design of relevant locomotion experiments).
- Design of drag measurements on seahorses and sepia.
- Implementation and further development of Lighthill-Blake model (analytical model for thrust production by undulatory swimming).

Technical research

An undulatory fin is being designed to enable efficiency measurements and free swimming tests, including start and stop maneuvres and steady forward swimming. The results of this experiment will lead to information on the robot stability, available and optimal kinematic variable space, maneuverability and input for the integrative control model of the robot (the latter is developed at TU Delft).

Dissertations

-

Scientific Publications

-

Projectleaders
JL van Leeuwen

Researchtheme
Complex dynamics of fluids

Participants
S Henrion

Cooperations
T Vercruyssen, Biomechanical Engineering, TU Delft

Funded
Delphi Consortium and WU

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

Start of the project
2010

Information
S Henrion
06 389 89 546
Sebastian.henrion@wur.nl
www.ezo.wur.nl/UK/Staff/Henrion

PROJECTLEADERS
JL van Leeuwen, D Lentink

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
D Lentink, JL van Leeuwen

COOPERATIONS
Prof. Dr. M.H. Dickinson (Caltech)
Prof.dr.ir. G.J.H. van Heijst (TUE)
Prof.dr. U.K. Müller (Fresno)
Prof.dr. H. Liu (Chiba)

FUNDED
NWO and WU

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

START OF THE PROJECT
start PhD project: 2004 (diss. 2008)
start NWO ALW: 2007

INFORMATION
JL van Leeuwen
0317 482 267
johan.vanleeuwen@wur.nl
www.ezo.wur.nl/UK

PROJECT AIM

We study vortex dynamic strategies of swimming and flying. In particular, we determine whether animals tune their locomotory kinematics to exploit the dynamics of vortices to maximize performance and to simplify control. We explore to what extent such strategies are adopted by zebrafish larvae and fruit flies, that propel themselves in a similar Reynolds regime. We aim to unravel whether fish and insects exploit common vortex dynamic mechanisms.

PROGRESS

In 2012, David Lentink moved to Stanford University where he started his own laboratory. He continues as guest researcher within the Experimental Zoology group. We continued to work on development of swimming in zebrafish larvae, both on the development of the musculoskeletal system that drives the wimming motions and the computational fluid dynamics of larval swimming (colloboration with Chiba University, Tokyo). We showed that swim training in larval fish changes the order in which skeletal elements appear during development. A 'free-swimming' CFD model was finished that accepts body shape deformations as input. The model predicts the resulting flow field, including the mechanical stresses on the body of the fish and the forward motion of the fish. We also finished a study on the structure and function of the median finfold in larvae of teleost fishes.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Boogaart, J.G.M. van den; Muller, M.; Osse, J.W.M. (2012). Structure and function of the median finfold in larval teleosts. Journal of Experimental Biology 215 . - p. 2359 - 2368.
2. Fiaz, A.W.; Leon-Kloosterziel, K.M.; Gort, G.; Schulte-Merker, S.; Leeuwen, J.L. van; Kranenbarg, S. (2012). Swim-Training Changes the Spatio-Temporal Dynamics of Skeletogenesis in Zebrafish Larvae (Danio rerio). PLoS One 7 (4). Artikelnr e34072.
3. Li, G.; Müller, U.K.; Leeuwen, J.L. van; Liu, H. (2012). Body dynamics and hydrodynamics of swimming larvae: a computational study. Journal of Experimental Zoology 215 . - p. 4015 - 4033.

Institute for Marine and Atmospheric research Utrecht (IMAU)

Prof.dr. LRM Maas

Research in this theme focuses on the interactions between the water motion, sediment transport and bottom changes in coastal seas and estuaries. Both sandy and mud-dominated coastal systems are investigated. The following approaches are used to gain more understanding of hydrodynamic and morphodynamic processes: collection and analysis of field observations, simulations with complex numerical models and interpretation of these results, development and analysis of idealized mathematical models.

Project Aim

To unravel the role of intermediate-scale internal waves, existing due to the anisotropy of geophysical media, in the energy transfer from large, global scales, to small, dissipative scales. To identify the importance of hydrodynamic conditions on the sediment distribution in the coastal zone.

Progress

-

Dissertations

-

Scientific Publications

1. da Silva, JCB, JM Magalhães, T Gerkema, and LRM Maas. 2012, Internal solitary waves in the Red Sea: An unfolding mystery. Oceanography 25(2): 96–107.
2. Boisson, J, C Lamriben, LRM Maas, P-P Cortet, and F Moisy, Inertial waves and modes excited by the libration of a rotating cube. Phys. Fluids 24, 076602 doi: 10.1063/1.4731802.
3. Maas, LRM and J Hazewinkel, Golfaantrekkers in anisotrope media. Nederlands Tijdschrift voor Natuurkunde, 10, 408-411.
4. Groeskamp, S and LRM Maas, Ship-borne contour integration for flux determination. Journal of Sea Research 74, 26–34.
5. B King, M Stone, HP Zang, T Gerkema, M Marder, RB Scott & HL Swinney, 2012 Buoyancy frequency profiles and internal semidiurnal tide turning depths in the oceans. J. Geophys. Res. 117, C04008, doi:10.1029/2011JC007681.
6. MJ Mercier, M Mathur, L Gostiaux, T. Gerkema, J.M. Magalhães, J.C.B. da Silva & T. Dauxois (2012): Soliton generation by internal tidal beams impinging on a pycnocline: laboratory experiments. J. Fluid Mech., 704, 37-60, doi:10.1017/jfm.2012.191.
7. T Gerkema & L Gostiaux (2012): A brief history of the Coriolis force. European Physics News, 43/2, 14-17, doi:10.1051/epn/2012202.
8. Gerkema, T. and H. van Haren, 2012. Absence of internal tidal beams due to non-uniform stratification. J. Sea Res., 74, 2-7.

Projectleaders

LRM Maas, T Gerkema

Researchtheme

Complex dynamics of fluids

Participants

Anna Rabitti, Carola van der Hout, Meinard Tiessen, Matias Duran Matute

Cooperations

NWO

Funded

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

Start of the project

2009

Information

L Maas
0222 369419
maas@nioz.nl
www.nioz.nl/maas

Dynamical Oceanography at IMAU

Prof.dr.ir. HA Dijkstra

In my group, we study the role of the ocean circulation in the variability of the climate system and the processes controlling the large-scale ocean circulation.

Focus of work in on the path changes of ocean western boundary currents (such as the Gulf Stream in the Atlantic, the Kuroshio in the Pacific and the Agulhas 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 understand these phenomena and our favorite framework to analyse the complex behavior of ocean flows is that provided by stochastic dynamical systems theory.

PREDICTABILITY OF KUROSHIO CURRENT PATH TRANSITIONS

Project Aim

Our objectives are (i) to develop a unifying theory of the Kuroshio path variability, (ii) to assess the decadal time scale predictability of these path transitions, (iii) to determine the effects of the large-scale barotropic instabilities, meso-scale eddies and wind-stress variations on this predictability and (iv) to study of impact of different observational data on the prediction skill of the models used.

Progress

Much progress has been obtained in solving the stochastic partial differential equations for the single layer problem (Sapsis and Dijkstra, 2013) by using a Dynamical Orthogonal Field formulation. These solution methods are now used in a multi-layer model set-up to investigate the interaction of the baroclinic eddies and the barotropic instabilities and to formulate a stochastic representation of these eddies.

Dissertations

-

Scientific Publications

1. Chylek, P., C. K. Folland, L.M. Frankcombe, H. A. Dijkstra , G. Lesins and M.K. Dubey. Greenland ice core evidence for spatial and temporal variability of the Atlantic Multidecadal Oscillation. Geophysical Research Letters, 39, L09705, doi:10.1029/2012GL051241, (2012).
2. T. Sapsis and H. A. Dijkstra. Interaction of additive noise and nonlinear dynamics in the double-gyre wind-driven ocean circulation., J. Phys. Oceanography, 43, 366-381 (2013).

Projectleaders

HA Dijkstra

Researchtheme

Complex dynamics of fluids

Participants

L Frankcombe, J Viebahn

Cooperations

Dr. Fred Wubs (RUG), Dr. T. Sapsis (Courant Institute, NY, USA)

Funded

NWO-EW (COMPLEXITY)

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

Start of the project

2011

Information

HA Dijkstra
H.A.Dijkstra@uu.nl

WHO & WHERE

TUD | 015 278 9111

Mechanical Engineering - Mekelweg 2 - 2628 CD Delft

♦	Prof.dr.ir. J Westerweel	015 278 6887	j.westerweel@tudelft.nl
	Prof.dr. DJEM Roekaerts	015 278 2470	d.j.e.m.roekaerts@tudelft.nl
	Prof.dr.ir. RAWM Henkes	015 278 1323	r.a.w.m.henkes@tudelft.nl
	Prof.dr. JCR Hunt	015 278 2904	jcrh@cpom.ucl.ac.uk
	Prof.dr.ir. G Ooms	015 278 1176	g.ooms@tudelft.nl
	Prof.dr.ir. B Eckhardt	015 278 2904	bruno.eckhardt@physik.uni-marburg.de
♦	Prof.dr.ir. BJ Boersma	015 278 7979	b.j.boersma@tudelft.nl

Maritime Engineering - Mekelweg 2 - 2628 CD Delft

♦	Prof.dr.ir. RHM Huijsmans	015 278 2889	r.h.m.huijsmans@tudelft.nl
	Prof.dr.ir. TJC van Terwisga	015 278 6860	t.v.terwisga@tudelft.nl
♦	Prof.dr.ir. C van Rhee	015 278 3973	c.vanrhee@tudelft.nl

Applied Mathematics - Mekelweg 4 - 2628 CD Delft

♦	Prof.dr.ir. C Vuik	015 278 5530	c.vuik@tudelft.nl
	Prof.dr.ir. P Wesseling	015 278 3631	p.wesseling@tudelft.nl
♦	Prof.dr.ir. AW Heemink	015 278 5813	a.w.heemink@tudelft.nl

Chemical Engineering - Julianalaan 136 - 2628 BW Delft

♦	Prof.dr.ir. CR Kleijn	015 278 2835	c.r.kleijn@tudelft.nl
	Prof.dr. RF Mudde	015 278 2834	r.f.mudde@tudelft.nl
	Prof.dr.ir. HEA van den Akker	015 278 5000	h.e.a.vandenakker@tudelft.nl
	Prof.dr.ir. S Sundaresan	015 278 5000	sundar@princeton.edu
♦	Prof.dr.ir. MT Kreutzer	015 278 9084	m.t.kreutzer@tudelft.nl

Radiation Science and Technology - Mekelweg 15 - 2629 JB Delft

♦	Prof.dr.ir. THJJ van der Hagen/Rohde	015 278 2105	t.h.j.j.vanderhagen@tudelft.nl

Aerospace Engineering - Kluyverweg 2 - 2600 GB Delft

♦	Prof.dr.ir. H Bijl	015 278 5373	h.bijl@tudelft.nl
	Prof.dr.ir. F Scarano	015 278 9111	f.scarano@tudelft.nl
	Prof.dr.ir. PG Bakker	015 278 5907	p.g.bakker@tudelft.nl

Civil Engineering and Geosciences - Stevinweg 1 - 2628 CN Delft

♦	Prof.dr.ir. GS Stelling	015 278 5426	g.s.stelling@tudelft.nl
	Prof.dr.ir. WSJ Uijttewaal	015 278 1371	w.s.j.uijttewaal@tudelft.nl
♦	Prof.dr. HJJ Jonker	015 278 6157	h.j.j.jonker@tudelft.nl
	Prof.dr. AP Siebesma	015 278 4720	a.p.siebesma@tudelft.nl

TUE | 040 247 9111 | PO Box 513 - 5600 MB Eindhoven

Applied Physics

♦	Prof.dr.ir. AA Darhuber	040 247 4499	a.a.darhuber@tue.nl
	Prof.dr.ir. MEH van Dongen	040 247 3194	m.e.h.v.dongen@tue.nl
♦	Prof.dr. HJH Clercx	040 247 2680	h.j.h.clercx@tue.nl
	Prof.dr.ir. GJF van Heijst	040 247 2722	g.j.f.v.heijst@tue.nl
	Prof.dr.ir. F Toschi	040 247 3911	f.toschi@tue.nl
	Prof.dr.ir. BJ Geurts	040 247 4285	b.j.geurts@tue.nl
♦	Prof.dr.ir. K Kopinga	040 247 4303	k.kopinga@tue.nl
	Prof.dr.ir. OCG Adan	040 247 3398	o.c.g.adan@tue.nl

Mechanical Engineering

♦	Prof.dr. LPH de Goey/Bastiaans	040 247 2938	l.p.h.d.goey@tue.nl
	Prof.dr. B Johansson	040 247 9111	-
♦	Prof.dr.ir. JJH Brouwers	040 247 5397	j.j.h.brouwers@tue.nl
	Prof.dr.ir. Golombok	040 247 9111	-
♦	Prof.dr.ir. DMJ Smeulders	040 247 2140	d.m.j.smeulders@tue.nl
	Prof.dr.ir. AA van Steenhoven	040 247 2140	a.a.v.steenhoven@tue.nl
	Prof.dr. AH Dietzel	040 247 9111	-
	Prof.dr. HA Zondag	040 247 9111	-
♦	Prof.dr.ir. EH van Brummelen	040 247 5470	e.h.v.brummelen@tue.nl

Biomedical Engineering

♦	Prof.dr.ir. FN van de Vosse	040 247 4218	f.n.v.d.vosse@tue.nl

Mathematics and Computer Science

♦	Prof.dr.ir. B Koren	040 247 2080	-
	Prof.dr.ir. F Toschi	040 247 3911	f.toschi@tue.nl
♦	Prof.dr.ir. CJ van Duijn	040 247 2855	c.j.v.duijn@tue.nl
	Prof.dr. JJM Slot	040 247 2184	j.j.m.slot@tue.nl

Chemical Engineering and Chemistry

♦	Prof.dr.ir. JAM Kuipers	040 247 4158	j.a.m.kuipers@tue.nl
	Prof.dr.ir. M van Sint Annaland	040 247 2241	m.v.sintannaland@tue.nl

UT | 053 489 9111 | PO Box 217 - 7500 AE Enschede

Applied Physics

♦	Prof.dr. WJ Briels	053 489 2947	w.j.briels@utwente.nl
♦	Prof.dr. D Lohse	053 489 8076	d.lohse@utwente.nl
	Prof.dr.ir. D van de Meer	053 489 9111	-
	Prof.dr. A Prosperetti	053 489 9111	prosperetti@jhu.edu
	Prof.dr.ir. JF Dijksman	06 2334 1331	j.f.dijksman@ziggo.nl
	Prof.dr.ir. L van Wijngaarden	053 489 3086	l.vanwijngaarden@tnw.utwente.nl
	Prof.dr. R Verzicco	053 489 2470	r.verzicco@utwente.nl
♦	Prof.dr. F Mugele	053 489 3094	f.mugele@utwente.nl

Chemical Engineering

♦	Prof.dr.ir. RGH Lammertink	053 489 2063	r.g.h.lammertink@utwente.nl

Mathematical Sciences

♦	Prof.dr.ir. EWC van Groesen	053 489 3413	e.w.c.vangroesen@utwente.nl
♦	Prof.dr.ir. JWW van der Vegt	053 489 5628	j.j.w.vandervegt@utwente.nl
♦	Prof.dr.ir. BJ Geurts	053 489 4125	b.j.geurts@utwente.nl
	Prof.dr. JGM Kuerten	053 489 3408	j.g.m.kuerten@utwente.nl
	Prof.dr. HJH Clercx	053 489 3408	h.j.h.clercx@utwente.nl

Mechanical Engineering

♦	Prof.dr.ir. HWM Hoeijmakers	053 489 4838	h.w.m.hoeijmakers@utwente.nl
	Prof.dr.ir. A Hirschberg	040 247 2163	a.hirschberg@tue.nl
♦	Prof.dr.ir. ThH van der Meer	053 489 2562	t.h.vandermeer@utwente.nl
♦	Prof.dr. S Luding	053 489 4212	s.luding@ctw.utwente.nl

Water Engineering and Management

♦	Prof.dr. SJMH Hulscher	053 489 4256	s.j.m.h.hulscher@utwente.nl

RUG | 050 363 9111 | PO Box 800 - 9700 AV Groningen

Mathematics

♦	Prof.dr. AEP Veldman	050 363 3988	veldman@math.rug.nl

UL | 071 527 5505 | PO Box 9506 - 2300 RA Leiden

Mathematics and Natural Sciences

♦	Prof.dr. M van Hecke	071 527 5482	mvhecke@lorentz.leidenuniv.nl

WUR | 0317 477 477 | PO Box 9101 - 6701 BH Wageningen

Experimental Zoology

♦	Prof.dr.ir. JL van Leeuwen	0317 482267	johan.vanleeuwen@wur.nl

UU | 030 253 9111 | PO Box 80125 - 3508 TC Utrecht

Physics and Astronomy

♦	Prof.dr. LRM Maas	0222 369 419	maas@nioz.nl
♦	Prof.dr.ir. HA Dijkstra	030 253 5441	h.a.dijkstra@uu.nl

Board of Directors

Prof.dr.ir. G Lodewijks (TUD, Chairman)	015 278 9111	g.lodewijks@tudelft.nl
Ir. AJ Dalhuijsen (VSL)	015 269 1500	adalhuijsen@vsl.nl
Prof.dr.ir. CR Kleijn (TUD)	015 278 2835	c.r.kleijn@tudelft.nl
Prof.dr.ir. JJW van der Vegt (UT)	053 489 5628	j.j.w.vandervegt@utwente.nl
Prof.dr.ir. GMW Kroesen (TUE)	040 247 4357	g.m.w.kroesen@tue.nl

Management Team

Prof.dr.ir. GJ van Heijst (TUE)	040 247 2722	g.j.f.v.heijst@tue.nl
Prof.dr. D Lohse (UT)	053 489 8076	d.lohse@utwente.nl
Prof.dr.ir. J Westerweel (TUD)	015 278 6887	j.westerweel@tudelft.nl

Industrial Board

Dr.ir. J Baltussen (AKZO-Nobel)	026 366 1479	joop.baltussen@akzonobel-chemicals.com
Ir. A van Berkel (TNO Science & Industry)	055 549 3759	arij.vanberkel@tno.nl
Ir. AJ Dalhuijsen (VSL)	015 269 1500	adalhuijsen@vsl.nl
Prof.dr.ir. J den Toonder (Philips)	040 274 3306	jaap.den.toonder@philips.com
Dr. RPJ Duursma (Tatasteel)	0251 492 363	rene.duursma@tatasteel.com
Ir. A van Garrel (ECN)	0224 564170	vangarrel@ecn.nl
Ir. J Gonzalez del Amo (ESA/ESTEC)	071 565 4781	jose.gonzalez.del.amo@esa.int
Ir. G Hommersom (Dow Benelux)	0115 67 4102	ghommersom@dow.com
Dr.ir. J Janssen (Unilever)	010 460 6324	jo.janssen@unilever.com
Dr.ir. M Veenman (DSM)	046 476 1240	maurice.veenman@dsm.com
Ir. JJ Meerman (Teijin Aramid)	088 268 9367	hans.meerman@teijinaramid.com
Prof.dr.ir. AE Mynett (WL)	015 285 8580	a.mynett@unesco-ihe.org
Dr. B Oskam (NLR)	020 511 3357	oskam@nlr.nl
Dr.ir. HJ Prins (Marin)	0317 493 405	h.j.prins@marin.nl
Ir. H Reinten (Oce)	077 359 4061	hans.reinten@oce.com
Ir. M Riepen (ASML)	040 268 3000	michel.riepen@asml.nl
Ir. G Saccoccia (ESA/ESTEC)	071 565 4781	giorgio.saccoccia@esa.int
Ir. P Veenstra (Shell)	020 630 3384	peter.veenstra@shell.com
Ir. Veraar (TNO Defence and Safety)	015 284 3395	ronald.veraar@tno.nl
Dr.ir. FC Visser (Flowserve)	076 502 8311	fvisser@flowserve.com
Ir. H Vos (TNO Science & Industry)	015 269 2311	hugo.vos@tno.nl
Dr.ir. B Vreman (AKZO-Nobel)	026 366 9440	bert.vreman@akzonobel.com
Dr. J Longo (ESA/ESTEC)	071 565 6662	jose.longo@esa.int
Dr.ir. J van 't Westeinde (Deltares)	015 278 3210	jos.vantwesteinde@deltares.nl
Ir. M Roest (VORTECH)	015 285 0127	mark.roest@vortech.nl

PhD Students Contact Group

TUD

AJ Greidanus	015 278 9111	a.j.greidanus@tudelft.nl
M Olivero	015 278 9479	m.olivero@tudelft.nl
JSB van Zwieten	015 278 9111	j.s.b.vanzwieten@tudelft.nl
PB Smit	015 278 9111	p.b.smit@tudelft.nl
X Yang	015 278 9111	xiaogang.yang@tudelft.nl
D Violato	015 278 5902	d.violato@tudelft.nl

TUE

HM Slagter	040 247 3685	h.m.slagter@tue.nl
RPC Zegers	040 247 5689	r.p.c.zegers@tue.nl
CWJ Berendsen	040 247 9111	c.w.j.berendsen@tue.nl

UT

B Bera	053 489 9111	b.bera@utwente.nl
H Gelderblom	053 489 9111	h.gelderblom@tnw.utwente.nl
HJJ Staat	053 489 9111	h.j.j.staat@utwente.nl
W Kranenburg	053 489 2959	w.m.kranenburg@ctw.utwente.nl
BJ Konijn	053 489 9111	b.j.konijn@utwente.nl
AA Verbeek	053 489 2507	a.a.verbeek@utwente.nl

RUG

HJL van der Heiden	050 363 3970	h.j.l.van.der.heiden@rug.nl

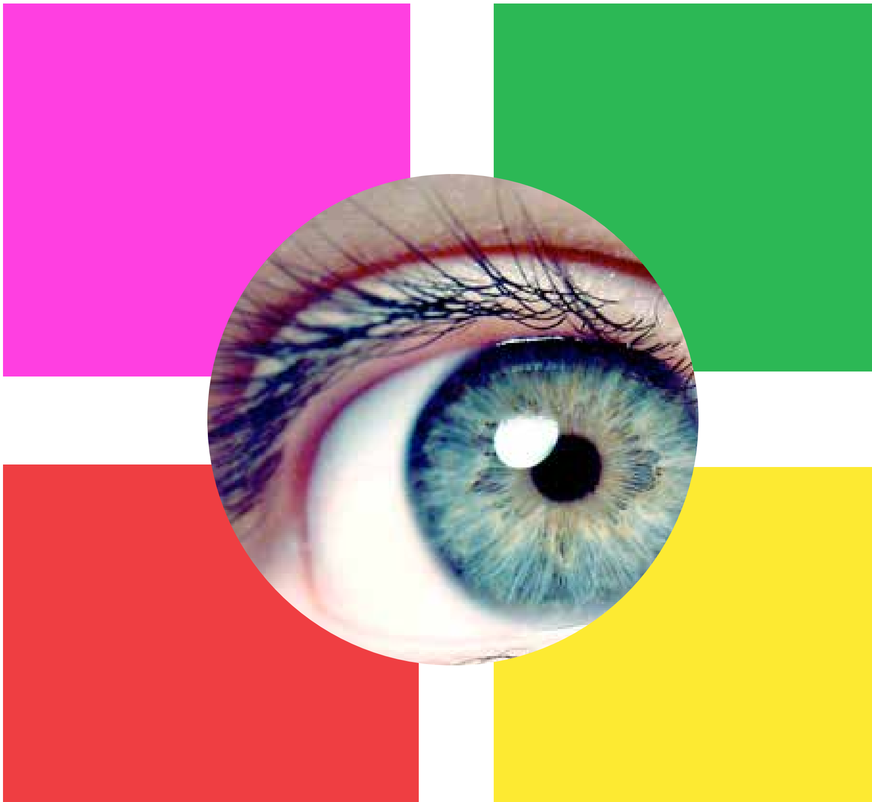
JM Burgerscentrum (the Netherlands)

Prof.dr.ir. G Ooms, scientific director	015 278 1176	g.ooms@tudelft.nl
I Hoekstein-Philips, secretariat	015 278 3216	jmburgerscentrum@tudelft.nl

Mekelweg 2
2628 CD Delft

Burgers Program Maryland

James M Wallace, Professor, Dept. of Mechanical Engineering
www.eng.umd.edu/~wallace
Gemstone Program Director
www.gemstone.umd.edu/
Chair, Burgers Program for Fluid Dynamics
www.burgers.umd.edu/
T 301 314 6695
F 301 314 8469
E wallace@eng.umd.edu



JMBC Annual Report & Research Programme
2012-2013