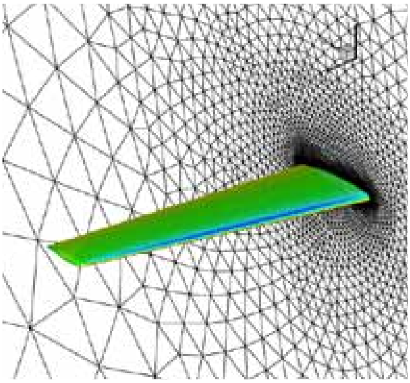
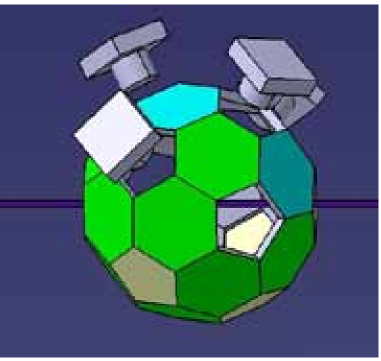
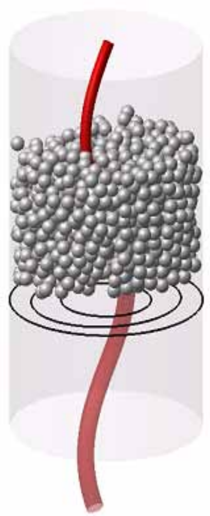
2011

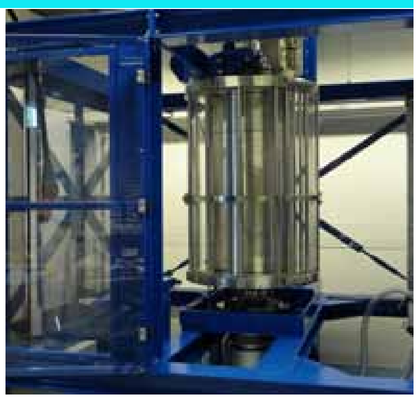


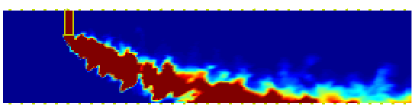


2012

Annual Report & Research Programme







J.M.Burgerscentrum

Research School for Fluid Mechanics

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

Annual Report & Research Programme 2011-2012

JM Burgerscentrum
Research School for Fluid Mechanics

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

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Preface

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

Prof.dr.ir. G Ooms
Scientific Director

It was with great sadness that we heard about the passing away of professor Charles J. Hoogendoorn on January 17, 2012. Charles Hoogendoorn was an excellent manager and inspiring leader. In meetings he was very able to convince others of his point of view. He contributed much to the strongly increased attention in The Netherlands during the last decades for research on fluid mechanics and heat transfer. He was one of the founders of the J.M. Burgerscentrum and the first scientific director of the research school. Charles Hoogendoorn was active in international organizations. He was, for instance, co-founder and president of Eurotherm. He had a genuine interest in other people. As a professor he guided many MSc students and PhD students to a successful completion of their study. We remember Charles Hoogendoorn as a great man, whose work over the years has been of importance for the J.M. Burgerscentrum.

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 (2011). 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 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 professors.

In 2011 the scientific directors of EM (the national research school for solid mechanics) and of the JMBC have jointly submitted a graduate program proposal to NWO. An earlier attempt in 2010 failed, but this time their proposal was accepted. NWO awarded 800 kEuro for the development of the program and for the sponsoring of a number of PhD projects. A Graduate Program Supervisory Board was appointed to organize the excellence MSc track ‘Fluid and Solid Mechanics’. In September 2012 this track will be started with a number of selected students that follow the special MSc program belonging to the track. A special feature of the program is the considerable freedom of the students in carrying out their study. At the end of their MSc study they write their own PhD project proposal. A jury will select the best ones, for which sponsoring is available.

The Burgersdag 2012 was held at the Eindhoven University of Technology. There was a large number (270) of participants. In his opening speech professor Wim van Saarloos (director of FOM) emphasized the special relation between FOM and the JMBC. The Burgers Lecture was held by professor Gray Worster from Cambridge University. The largest part of the day was again devoted to 12 minute presentations by PhD students during two parallel sessions. At the end of the Burgersdag the ‘Leen van Wijngaarden Prize’ was presented for the first time to dr.ir. Gerrit Elsinga from the Laboratory for Aero- & Hydrodynamics (Delft University of Technology). In the future this prize will be awarded every four years to a staff member (younger than forty years) of one of the JMBC groups for his important and unique research contribution to fluid mechanics. The participants enjoyed the Burgersdag. The JMBC received many enthusiastic reactions after the event.

The JMBC needs to be re-accredited again in 2013 by the Royal Netherlands Academy of Sciences. To that purpose the application report needs to be submitted before 31 December 2012. In the judgment of the research output the existing evaluation reports of the individual JMBC groups will play an important role. According to the recent guidelines of the Academy particular attention will be given to the educational activities of the JMBC (and its individual groups). In this respect the JMBC course program is of significance. Another point of interest is the contact between the JMBC and industries and technological institutes. Much attention will be given this year to the writing of the application report and related activities in order to achieve again re-accreditation by the Royal Netherlands Academy of Sciences.

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*

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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 twice per year with the scientific director to discuss new activities of relevance to industries and technological institutes.

Each year (also in 2011) 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 270 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, JCR Hunt, G Ooms, B Eckhardt	3.6	2.0	10.4
	BJ Boersma	5.7	2.0	12.0
Marine Technology	RHM Huijsmans, TJC van Terwisga	1.6	0.0	8.0
	C van Rhee	1.0	0.0	4.0
Applied Mathem. Analysis	C Vuik, P Wesseling, AWH Heemink	6.8	0.0	10.4
Multi-Scale Physics	HEA van den Akker, S Sundaresan, AP Siebesma, CR Kleijn, RF Mudde, RAWM Henkes, DJEM Roekaerts	4.9	5.0	20.8
Physics of Nuclear Reactors	THJJ van der Hagen (M Rohde)	2.8	2.0	1.6
DelftChemTech	M Kreutzer	2.1	0.5	4.0
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	-	-	-
TUE				
Applied Physics	AA Darhuber, F Toschi, MEH van Dongen	7.0	1.6	9.0
	GJ van Heijst, HJH Clercx, BJ Geurts	4.9	1.0	8.8
Mechanical Engineering	LPH de Goey (RJM Bastiaans),	1.7	3.0	15.2
	JJH Brouwers, JGM Kuerten	2.0	-	4.0
	AA van Steenhoven, AH Dietzel HA Zondag	2.1	1.8	10.0
Mathematics and Computer	RMM Mattheij (ten ThijeBoonkkamp) F Toschi	0.8	0.0	3.2
Science	CJ van Duijn, JJM Slot	2.3	-	1.6
Biomedical Engineering	FN van de Vosse	0.3	-	3.2
Multiphase Reactors Group	JAM Kuipers, M van Sint Annaland	2.0	1.8	10.8
Transport in permeable Media	K Kopinga, OCG Adan	2.0	-	3.2

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, A Prosperetti, JF Dijksman L van Wijngaarden, R Verzicco	9.56	0.0	22.8
	F Mugele	9.1	3.0	10.0
	RGH Lammertink	1.0	0.4	4.0
Mathematical Sciences	EWC van Groesen	0.5	-	3.0
	JJW van der Vegt, HJH Clercx, BJ Geurts	1.8	-	8.0
Mechanical Engineering	HWM Hoeijmakers, A Hirschberg	2.0	2.6	7.2
	ThH van der Meer	1.1	0.4	8.0
	S Luding	3.1	-	4.0
Water Engineering & Manag.	SJMH Hulscher	4.0	-	386
RUG				
Chemistry	HB Levinsky	3.3	-	-
Mathematics	AEP Veldman	2.3	-	5.6
UL				
Mathem. and Natural Sciences	M van Hecke	1.3	-	2.4
Mathematical Institute	B Koren	0.2	-	3.0
WUR				
Biometris	J Molenaar	0.4	-	-
Experimental Zoology Group	JL van Leeuwen	0.6	-	0.8
UU				
Physics and Astronomy	LRM Maas	0.2	-	0.8

The calculation of fte's is based on:
Professor 0,4 fte | Associated professor and assistent professor 0,5 fte | post-doc 1,0 fte | PhD-student 0,8 fte

Overview of university participants

University	Scientific staff (fte)	Support staff (fte)	PhD-students (fte)
TUD	39.1	16.5	104.4
TUE	25.1	9.2	69.0
UT	33.86	7.0	76.8
RUG	5.6	-	5.6
UL	1.5	-	5.4
WUR	1.0	-	0.8
UU	0.2	-	0.8
Total	106.36	32.7	262.8

The actual number of PhD students during 2011 was approx. 300

Industrial Board

For the first time I enjoy the privilege to write a few introductory 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 growth to the presently well recognised research school. Nevertheless, last year we noted a striking development, that is the interest of the Dutch Industry for the use of OpenFOAM. The assembled industries showed a surprising interest in the initiative. The list of industries is:

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 and FlowServe.

This inspired a dedicated initiative to promote the use of OpenFOAM at the Dutch Universities. Basically, the aimed target was to grow a community of researchers that have a proper understanding of OpenFOAM, and use this to formulate their scientific findings. 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 group found the outcome rather remarkable, that is that the application perspective of the application was found insufficient.

Looking backward, all involved in the initiative remain very supportive, and are presently formulating alternative programmes.

The descried initiative was not possible without the demonstrated interests of Dutch Industries for the knowledge developed within the Burgers Centre. We enjoy the support of our scientific director Prof. Gijs Ooms and the support of Ilse Hoekstein-Philips as continuous values in the Burgers Centre.

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.

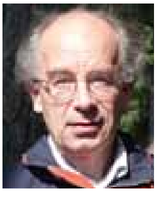
Dr. RPJ Duursma
Tatasteel
Chairman of the Industrial Advisory Board

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

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

Dr.ir. NG Deens
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 Thursday 12th May 2011 a one-day meeting was held at Deltares in Delft. The theme of that day was "Multiphase Flow and Applications in Civil Engineering".

Contactgroup "Computational Fluid Dynamics (CFD)"

The purpose of the contactgroup CFD is to give CFD-researchers and users of CFD in universities, laboratories and industries in The Netherlands and Belgium the opportunity to get to know each other and to get acquainted with each other's work. In 2011 no meeting was arranged.

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 10th time. It took place in Ede-Wageningen on October 10 and 11. 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. Rick Harwig (TU/e) on “Preparing for the energy transition” and by Prof. Dr. Ing. Hennig Bockhorn (University Karlsruhe) on “Computational combustion. Useful tools or useless toys”. Sessions were held on “Future fuels”, “Industrial research”, “Numerical modeling” and “Engines and Gas Turbines”.

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. In the past the contact group has also been involved in organizing educational and research events including a Lorentz Center workshop on “Multiscale fluid dynamics with the Lattice Boltzmann method” held in 2011.

Prof.dr. F Toschi
Eindhoven University of Technology

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

Contactgroup "Turbulence"

The objective of the contactgroup turbulence is to organize meetings between researchers of the J.M. Burgers Centre active in the field of turbulence. The purpose of these meetings is give the AIO/OIO's and other university researchers the opportunity to present their research results in an informal atmosphere and at the same time to promote a discussion on these results. The meetings also strengthen the contact between the researchers of the J.M. Burgers Centre and allows exchange of results and experience. Activities in 2009 : organisation of the Turbulence Course.

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

Dr. M Versluis
University of Twente

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 26-29 April 2010 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.

Prof.dr.ir. AA van Steenhoven
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 with a first meeting in Delft. 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. Members of the contact group organize the JMBC course "Capillarity-driven flows in microfluidics", which was first given in 2009 and repeated in 2011. The date of the next meeting of the contact group (spring 2012) will be announced shortly by email to all members of the contact group.

Burgers Program for Fluid Dynamics at the University of Maryland

Inspired by the intellectual heritage of J.M. Burgers, the mission of the Burgers Program for Fluid Dynamics at the University of Maryland 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. At the second Burgers Symposium James Wallace gave a talk commemorating the legacy of Frans T. M. Nieuwstadt. The interdisciplinary Burgers Program encompasses over 70 faculty members spread over 22 different units in the College of Computer, Mathematical and Physical Sciences, the College of Chemical and Life 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 distinguished professors from universities abroad to spend up to a year at the University of Maryland working with our faculty and their graduate students. The first Burgers Visiting Professor was Bruno Eckhardt, Professor of Theoretical Physics from Phillips Universität in Marburg, Germany. He spent the 2004-2005 academic year with us. In 2005-2006 we enjoyed the visits of two Burgers Associate Professors: Dr. Sasa Kenjeres of J. M. Burgers Center in the Netherlands and Dr. Serge Simoëns of the Ecole Centrale de Lyon in France. In May 2007 Prof. Jerry Westerweel, Director of the Laboratory for Aero and Hydrodynamics of Delft University of Technology was our Burgers Visiting Professor for three months. In the spring of 2008 Prof. Willem van de Water of the Eindhoven University of Technology visited our Program to work with Prof. Wolfgang Losert of our Physics Dept. for 2 ½ months. In addition, several graduate students from JMBC have had visits of several months at Maryland. Faculty from the University of Maryland are encouraged to spend a sabbatical at one of the Dutch Universities associated with JMBC. For instance, Kenneth Kiger, who was a speaker at the Burgersdag 2006, earlier had spent a sabbatical year with the JMBC research group in Delft.

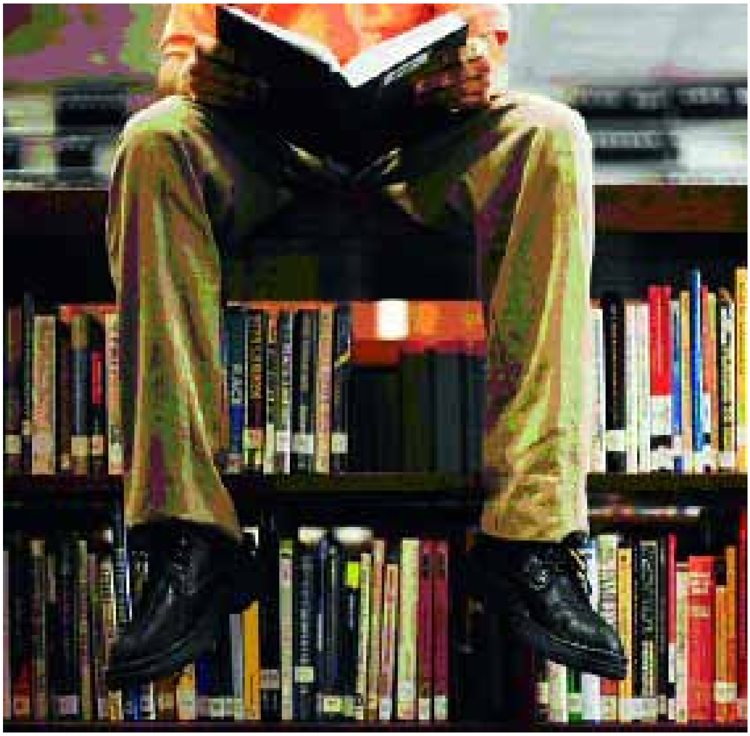
Burgers Lectureship - We have also initiated an annual Burgers Lecture which is given by a distinguished visitor who comes to the campus for several days or even weeks in November. This is always the keynote lecture at our annual Burgers Symposium, which takes place in the week before the annual Division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

Annual Graduate Student/Post-doctoral Fellow Showcase 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.

Tutorial School on Fluid Dynamics - This new initiative will be inaugurated in late May 2010, with plans to offer it every year. The subject of the first School is Turblence. The level of instructions is aimed a level beyond that of a first graduate course in the subject area. Almost 40 graduate student and post-doc participants from the U.S. and other coutries, including nine from JMBC, will attend.

Fluid Dynamics Reviews seminars - This seminar series, which has continued for over forty 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



Order-to-disorder transition in a coffee stain

H Gelderblom, ÁG Marín, D Lohse and JH Snoeijer (UT)

When a droplet containing suspended particles, such as coffee, evaporates, a ring-shaped stain is left behind on the substrate; see Fig. 1. This coffee-stain effect was first explained by Robert Deegan et al. [1]: in an evaporating drop with a pinned contact line, a capillary flow is generated to replenish the liquid that has evaporated from the drop edge. This flow drags along the particles, which are then deposited at the contact line. We have studied the dynamics of the ring stain formation in water drops with polystyrene particles [2]. As shown in Fig. 2, the remaining stains showed a remarkable structure: in the outermost layers of the stain, the particles have aggregated in a crystalline way, whereas further inwards the particle packing becomes very disordered.

To explain this peculiar particle ordering, it is crucial to understand the dynamics of the droplet evaporation. To this end, we filmed the droplets simultaneously from the sides and from below, and performed micro-PIV to measure the velocity field inside the droplets. A rush-hour of particles was observed during the last moments of the droplet's life [3]: the particle velocity increases dramatically as the droplet height decreases to zero. This temporal divergence of the velocity can be understood quantitatively from simple mass conservation. This is induces a diverging radial velocity at the of the droplet life.

The order-to-disorder transition in the remaining stain can be explained by this rush-hour behavior in the particle velocity. Particles that arrive early, when the deposition rate is still low, have time to arrange by Brownian motion and form an ordered structure. Particles that arrive during the rush hour have no time for such arrangement and form a jammed, disordered pattern. We can predict when the order-to-disorder transition will occur by comparing the particle diffusion time to the typical arrival time. A critical particle speed is obtained when these two timescales are equal: particles that arrive at a lower speed will form the ordered phase, particles with a higher speed the disordered phase.

Coffee stains with their characteristic dark rings on a desk.

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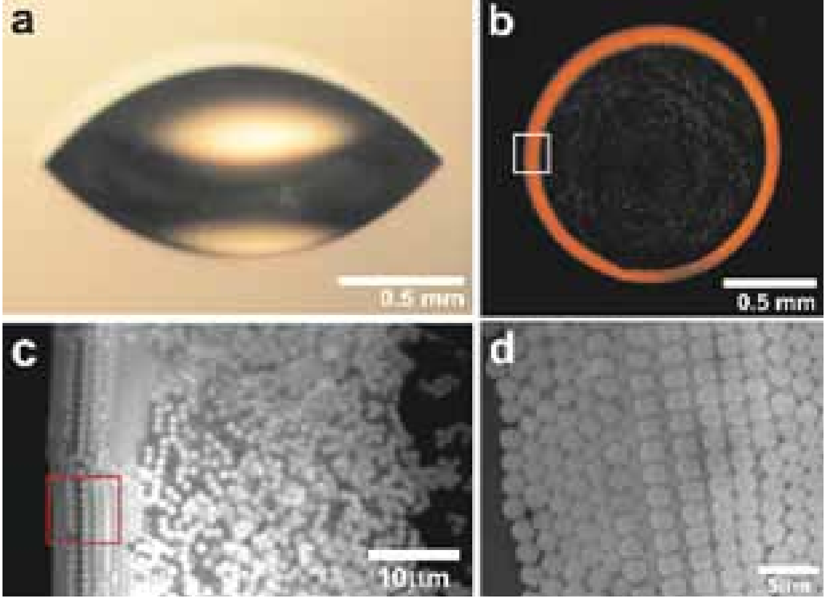


a) A water droplet containing 1-micrometer polystyrene particles on a glass slide. b) The ring-shaped stain of particles left on the substrate after the droplet has evaporated. c) The same stain 50x enlarged. Particles in the outermost layers have arranged in a crystalline way, whereas the inner layers have a disordered structure. d) The stain 2x further enlarged, to show the crystalline structure of the particles

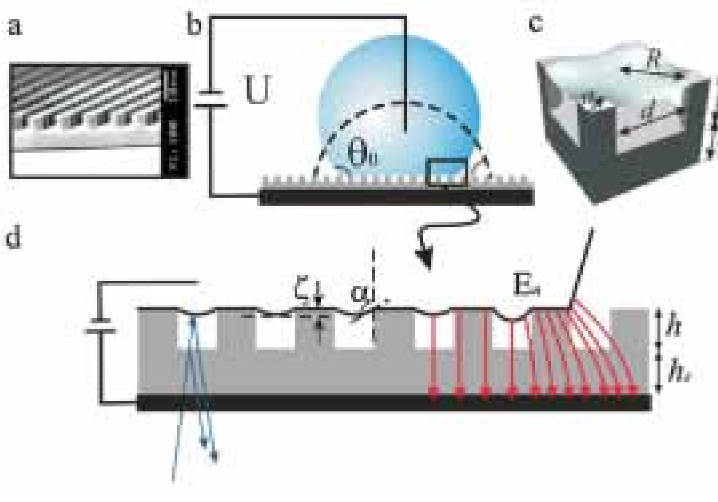
RGH Lammertink (UT, Soft matter, Fluidics and Interfaces)

The wetting characteristic of a surface by water is influenced by both the chemical and topographical composition of that surface. The topography of the surface can enhance the repellency for water, even to so-called superhydrophobic states. The superhydrophobic state is characterized by air entrapment in the cavities between the surface structures. This air entrapment results in extraordinary water repellency, low roll-off angles, and strong optical reflectivity.

Fundamental studies related to the wetting states on superhydrophobic surfaces are relevant for many scenarios. In fluid mechanics for instance, the flow along superhydrophobic walls is influenced by the wetting state via the occurrence of slip velocity near the wall. A careful design of the wetting state is required in many processes, including heterogeneous catalyzed processes and wet chemical etching processes. We have investigated the wetting state of water droplets on well-defined microstructured surfaces. The exact geometry and surface chemistry define the energetic most favorable state of a water droplet. Here, we describe two means of affecting the energy state of the droplet; by means of electrowetting and by drop evaporation.

Evaporating droplets are frequently encountered in production of (bio) arrays, inkjet printing, and coating processes. We have addressed the wetting transition during evaporation by means of a global energy argument. This argument estimates the interfacial energy of the droplet as a function of drop size. It can thereby predict for each drop size which wetting state is the most favorable. The predicted drop size at which the transition should occur is thereby easily obtained. The predicted drop size for the transition was found to match very well with the experimentally observed one.

During electrowetting experiments, the state of the drop is a result of the balance of the Maxwell stress and the Laplace pressure. For a well-defined structured substrate, it is possible to derive the critical condition corresponding to the transition between the Cassie Baxter and Wenzel state. A particularly interesting feature is, that the transition is fully reversible. By using patterned electrode substrates, local switching of the wetting state was demonstrated.



System configurations. (a) Scanning electron microscope image of Teflon coated microstructure. (b) Electrowetting setup: a voltage U is applied between a droplet and an electrode covered with a dielectric micropatterned surface. The contact area is monitored with an inverted microscope from the bottom through the superhydrophobic substrate. (c) The unit cell of microstructure. (d) Magnified sketch of the solid-liquid interaction area.

Reference

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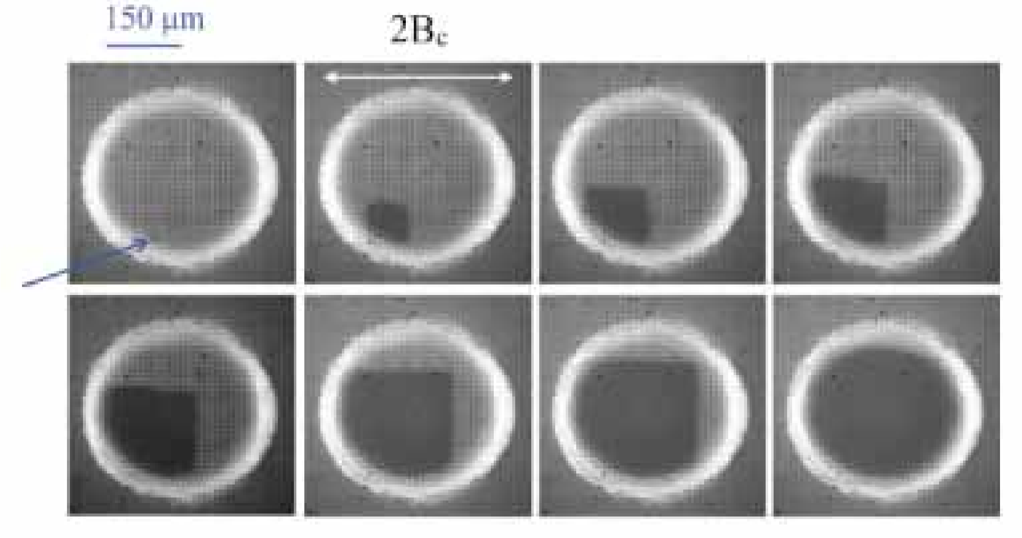
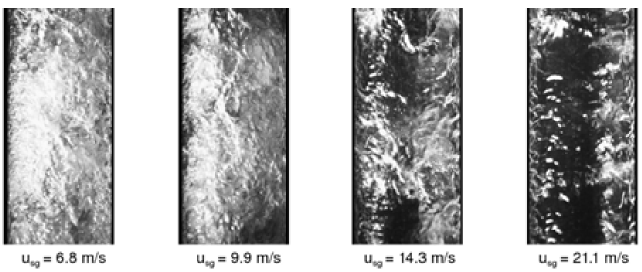
Snapshots of the bottom view reveal water infiltration dynamics at the transition from a Cassie-Baxter to a Wenzel wetting state triggered by evaporation. The dark areas indicate the water imbibition, while the air pockets present in the bright areas enclosed by a rather bright circumference marked by the droplet base.



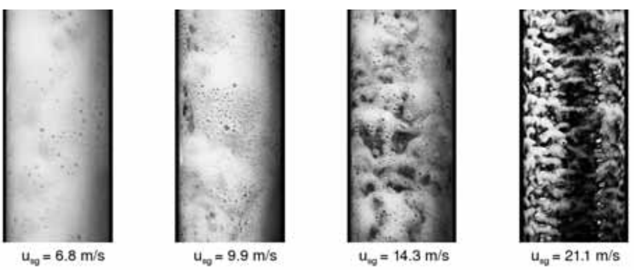
D van Nimwegen, L Portela, R Henkes (TUD)

We see an increasing interest from the oil and gas industry to better understand the multiphase flow in reservoirs, wells, pipelines, and facilities (such as separators, pumps, compressors, heat exchangers). This has led to various applied research projects carried out in the multiphase flow team in Delft that are funded by the industry (such as Shell/NAM, TNO, Petrobras, and ENI). A nice example of that type of applied research is the project on foamers for wells, funded by NAM, and carried out by PhD student Dries van Nimwegen.

When the pressure in a gas reservoir is reducing over the many years of its life time, the gas velocity in the wells is gradually reduced. Therefore at some moment the liquids coproduced with the gas (condensate and water) will no longer be dragged with the gas to the top of the well. Instead these liquids will start to fill the well and finally will kill the well. By injecting proper chemicals to reduce the surface tension, the liquid and gas will form a foam that stops the liquid loading of the well and will thus extend the field life of the reservoir. The technique is already being used by NAM in the Netherlands for an increasing number of aging wells. But sometimes, for unknown reasons, the technique fails. We have carried out experiments with water and air a 12 m high vertical flow loop with 5 cm diameter at atmospheric pressure. The figure first shows the flow visualization without foamer. The gas velocity is increased from low to high when going from left to right. For the flow in the left plot, the gas velocity is low and the liquid falls back. Now a foamer is added, and the visualization is showed in the other figure. The liquid forms a foam with the gas, and is dragged upward to the top of the loop, even at the lowest gas velocity.



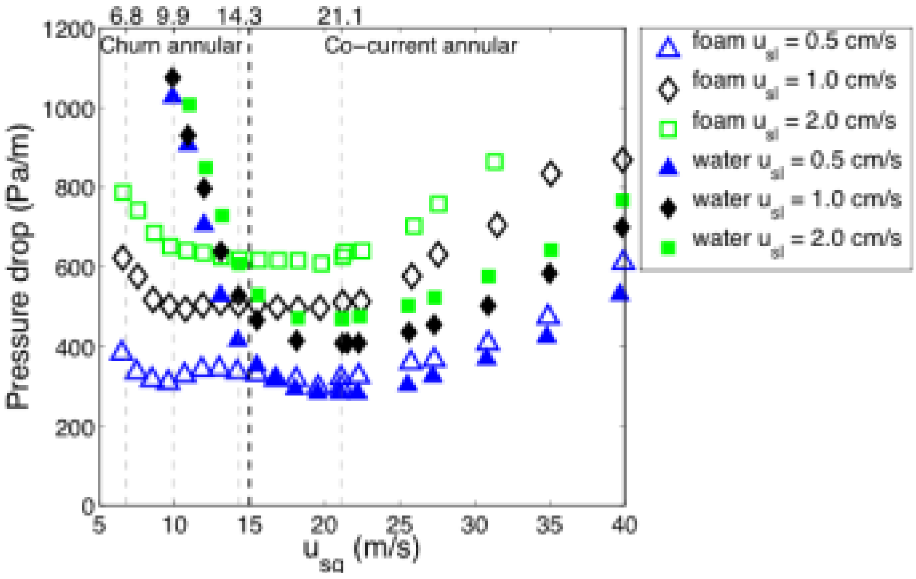
(a) Without adding surfactants



(b) With the addition of surfactants

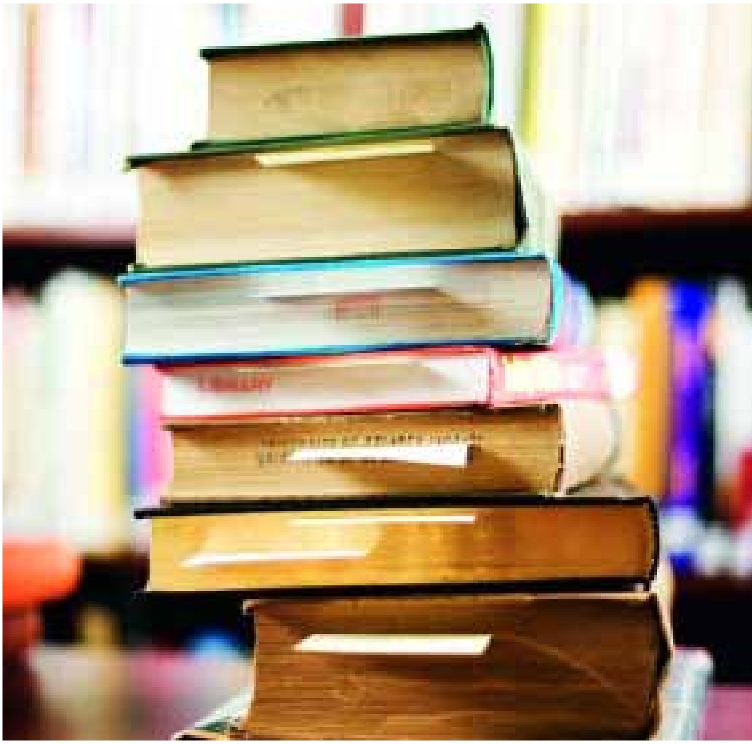
Effect of surfactants in helping to lift liquids with the gas flow

A whole range of experimental techniques is now being applied to measure the flow structure: differential pressure sensors, quick closing valves to measure the total liquid holdup, conductivity wire mesh and optical probes for the local holdup and for the velocity of the structures. See the results of the pressure drop measurements in the figure. In parallel students from Chemical Engineering carry out experiments to understand the chemical-physics of foamers, such as through measuring the dynamic surface tension and the flow in a small scale foam column. Follow-up measurements in the 360 m deep test rig of Shell in Rijswijk are also being planned. The experimental data will be used to develop models for the flow transport with foamers. This will enable to predict how much extra gas can be produced from a well when using such surfactants.



Measured pressure drop, showing that liquid loading at reduced gas flow rate is prevented by adding surfactants

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.

Focal points in the research programme

Four “focal points” have been selected from the three research themes, which receive special attention. A brief description of these “focal points” is given below.

1. Bio fluid mechanics

Most biological organisms live in a flowing medium (air or water). Nature has found solutions for fluid mechanical problems which enable fish to swim fast or cellular organisms to propel. These solutions are intriguing to understand and may lead to new solutions for technical problems. Similarly, fluid flow is essential inside the human body, where the blood is pumped around and the air is inhaled.

Deposition of aerosols in the lung, sound production by speaking, atherosclerotic plaque formation at well determined positions, gene activation at cellular levels are all more or less determined by fluid mechanic processes.

Finally, diagnostic and therapeutic techniques make use of fluid mechanic and heat transfer insights. The development of heart valves and the monitoring of temperatures inside the body during operations are examples for that.

Although most of the above mentioned problems can be solved with known physical principles, the complicated geometrical structures and the combination of phenomena (for example the transitional flow of non-Newtonian media in elastic bifurcating channels like blood vessels and airways) form an exciting new area for the development of advanced numerical and experimental techniques. Due to the geometry, three-dimensional unstructured meshes are to be used and the most efficient solvers are required to solve the flow at the relevant dimensionless parameters. Micro-PIV systems are needed to analyse the flow field in micro-vessels and fast optical techniques will enlighten the perfusion in permeable tissues.

New physical insights are needed for several areas, especially in multidisciplinary science. Some examples are given: The combination of fluid mechanics and solid mechanics is apparent in the phenomena at the focal folds where the unsteady flow separation is strongly influenced by the complex movement of the structure. Many modern uses of micro-bubble ultrasound contrast agents rely on the highly nonlinear response of the bubbles to a driving ultrasonic field and a quantitative model is lacking. The heat transfer processes in the anaestesized body are strongly determined by control mechanisms that are only globally known. Drag reduction occurs at the skin of several fish and reverse transition from turbulent to laminar flow is present in the nasal cavity and stenotic blood vessels; the relation with the wall structure is unclear.

Fluid mechanical parameters stimulate the activation of genes in cells, with striking downstream effects - unexplained. The interaction between the non Newtonian mucus layer in the airways and the oscillating airflow during cough is undescribed. The settlement and growth of settlements in aquatic ecosystems require the combination of advanced flow and mass transport models. As we have noted, research on this topic is extremely diverse and complex, because it involves a large number of different areas of expertise and advanced techniques. Therefore, this theme is an excellent area for collaboration between research groups inside and outside the fluid-mechanics community.

2. Granular matter

Granular matter exhibits many fascinating phenomena and is attractive both from a fundamental and an applied point of view. Its economic potential is enormous: it has been estimated that no less than 40 percent of the capacity of the industries that process granular matter is wasted due to problems connected to the handling of these materials.

Depending on the situation, granular matter can behave similar to a solid, a liquid, or a gas. E.g., when dry sand is poured, it acts as a fluid. The pile on which it is poured is solid-like, stabilised by forces in between the sand beeds. These forces organise themselves in tree-like networks. Finally, when dry sand is strongly shaken or fluidized through a gas stream, it behaves gas-like.

The transition from one to the other regime can be very sudden and the dynamics of such a transition is very rich. When in a gas-like or fluid-like state, the granular particles can all the locally sudden cluster. In many applications this can lead to serious problems, as whole production lines get stuck or the free available surface of some heterogenous catalysator all the sudden gets to small. So it is crucial to better understand the transition to the clustered state in order to avoid it.

The origin of the potential to cluster lies in the inelasticity of the particle-particle collision: If two particles collide, they loose kinetic energy and will thus stay closer to each other, trapping even further particles in the developing cluster.

Even without the phase transitions granular dynamics is difficult to understand. For the fluidised phase the brute-force approach is molecular dynamical simulations, based on some interaction potential between the particles. If this potential is chosen realistically (i.e., rather hard), the time step of advancing the numerical simulation can only be extremely slow, making this approach inpracticable. Better results have been obtained with either (unrealistically) soft potentials or with event driven codes. The ultimate goal must be to achieve at some continuum description, similar to the Navier-Stokes equation for fluid dynamics. Though considerable success in this direction has meanwhile been achieved, the problem is far from being solved. One of the main questions is how to pick the boundary conditions for such a continuum field.

One of the current physical questions one wants to answer is: How do average velocity profiles and velocity fluctuations look like in granular flow? On the experimental side, tomographical methods have turned out to be very successful to reveal these questions. Another intriguing problem of granular dynamics is size segregation. The most famous example presumably is the so called “Brazil nut” effect: In vibro-fluidised granular material big particles tend to “swim” to the top. Two explanations compete. The original interpretation was that the smaller particles can easier fall into gaps which the big ones are leaving when jumping up.

In this way the big particles would be pushed towards the top. The second explanation is based on convection roles and channels which would form, which are too small for the big particles to dive down again, so that they must stay on the top. Both of these interpretations are challenged by the recent discovery of an inverse Brazil nut effect which pushes big particles to the bottom.

Finally, we would like to mention the interaction of granular matter ("sand") with water, which often leads to pattern formation, e.g., the famous sand ripples on the beach. On a larger scale, this interaction is crucial (in particular for the Netherlands) for the protection of the coastline.

3. Measurement techniques

Optical diagnostics become more important for the investigation of flows. The principal differences with conventional methods, such as hot-wire anemometry, is that these optical methods can be considered as non-intrusive and that they provide data on the instantaneous spatial structure of the flow field. These optical methods can be divided into two categories: one in which the flow information is extracted from tracer particles added to the fluid (seeded flows), and one in which the fluid information is extracted from the fluid itself (spectroscopic methods).

Seeded flows

The motion of the flow can be detected by adding to the fluid very small tracer particles that are small enough to consider the method as non-intrusive. Essentially the motion is recorded by measuring the displacement of the tracers between to recordings taken with a small time delay. These methods are collectively known as particle image velocimetry, or PIV. In its most basic implementation, the fluid motion is recorded in a planar cross section of the flow, yielding between 103 and 105 velocity vectors per image, with a precision better than 1%. By using stereoscopic recording, it is possible to measure all three velocity components in a plane. This can now be considered as a standard configuration that can be applied for a broad range of applications, ranging from creeping flows to transonic flows.

The challenge in the near future is to further extend the capabilities of these methods:

- Combination of PIV methods with other (optical) diagnostics makes it possible to determine more complex flow properties. For example, the combination of PIV with measurements of the concentration field or temperature field makes it possible to directly measure scalar flux and heat flux;
- Currently under development is a PIV method that can be used for the investigation of two-phase flow, in which one fluid (viz., liquid) is seeded with tracer particles, and the second fluid (viz., bubbles, droplets, or solid particles) is observed simultaneously. Here the challenge is to obtain measurements in a flow system with very strong optical aberrations due to the second phase;
- One major challenge is to be able to measure the full three-dimensional flow field.

Within the JMBC a photogrammetric technique is developed and applied to various flow problems, and a 3D holographic recording method for PIV is under development.

Spectroscopic methods

The development of laser diagnostic techniques is essential for detailed non-intrusive studies of physical and chemical processes in reactive and non-reactive gas flows. At the University of Nijmegen various sensitive detection techniques have been developed and applied to different systems, such as laminar flames, optically accessible diesel engines and non-reactive turbulent flows. Most of these techniques are molecule specific, such as Laser Induced Fluorescence (LIF) detection, Cavity Ring Down Spectroscopy (CRDS) or Raman scattering, which allows for the determination of molecular concentrations. By the application of optical imaging techniques using CCD camera's two-dimensional density distributions can be determined with high spatial and temporal resolution.

The obtained data are used to validate numerical model calculations, which are being performed by other collaborating JMBC groups. For the study of non-reactive flows both Rayleigh and Raman scattering is applied to characterise the density distribution close to boundaries, whereas filtered Rayleigh scattering and Molecular Tagging Velocimetry (MTV) are used for nonseeding velocity measurements. Recently a new promising MTV technique has been developed at Nijmegen, Air Photolysis And Recombination Tracking (APART), which can be used also at high pressure (at least up to 40 bar) to measure velocities with very high spatial resolution. This latter technique is applied for the study of turbulence in collaboration with the groups of Nieuwstadt and Van de Water.

In the near future these laser techniques will be further improved and applied to both combustion and non-reactive flow research. At the University of Groningen LIF, CARS, infrared Cavity Ringdown Spectroscopy and spontaneous Raman scattering are being used for quantitative characterisation of the physics and chemistry of combustion processes, specifically pollutant formation and ignition processes, at atmospheric and reduced pressure.

4. Advanced Numerical Techniques

An essential tool in studying flow problems is computational fluid dynamics (CFD). CFD is a collective term for a large number of numerical techniques, often each with its own area of application. The last decades have shown a growing knowledge of the fundamental concepts of CFD, and the efficiency of numerical algorithms has progressed at a considerable pace. It is foreseen that this growth will continue for some time.

Although much emphasis is on turbulent flows at high Reynolds number and multi-phase or reacting flows (which are posing the more challenging problems from a physical point of view), insights in simpler problems may be equally useful and often even essential for constructing stable and efficient methods, to be used in more general contexts. Of the latter kind one should mention basic progress in iterative methods and in discretisation approaches. Iterative developments have shown widespread use of multigrid methods and special fast solvers for large linear systems. Combination with implicit time-integration can deal with the issue of stiffness in e.g. reacting flow.

Discretisation methods are challenged by complex geometries and moving boundaries, and by large ranges of length- and time scales. Within the JMBC both Cartesian and unstructured (adaptive) grid approaches are being pursued to deal with the geometric and topological challenges. The (structured) Cartesian grid approach is combined with local grid refinement based on defect correction. The scale resolution problem is tackled e.g. by symmetry-preserving finitevolume methods (with a benign behaviour on underresolved flow features) and by space-time discontinuous finite-element methods (offering flexible spatial and temporal grid adaptation). Also unified algorithms for low-Mach number flow are under development. Further, following a different discretisation philosophy, Lattice-Boltzmann methods are being studied, which possess potential advantages in multi-phase flow simulation. Another important tool in enabling the computations to be performed in a ‘reasonably limited’ time is parallellisation. Besides a more straightforward use of multiprocessors where the parallelism is taken care of by the compiler, a variety of domain decomposition techniques is in development. In particular within a context where different flow modelling is used in the individual subdomains, research will open up interesting applications, e.g. in turbulent flow simulation where a mixture of RaNS, LES and/or DNS modelling can be envisaged.

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

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Prof.dr.ir. G Ooms

Prof.dr.ir. B Eckhardt

The group of prof. J Westerweel in the section fluid mechanics consist of the following collaborators: prof.dr.ir. BJ Boersma, dr. R Delfos, prof.dr. JCR Hunt, prof,dr.ir. G Ooms, dr. R Lindken, dr.ir. C Poelma, and dr.ir. MJBM Pourquie. The common theme of the research in this group is turbulence and complex flows, such as multiphase flows, microfluidics and biological flows. The research is aimed at fundamental aspects of flows, but always with a clear connection to a practical application or process in industry. This research is carried out by modern experimental methods, such as particle image velocimetry, and by modern numerical methods, such as direct numerical simulation and large-eddy simulation. In most research experimental and numerical methods are combined.

The turbulence research aims at the interaction of turbulence with other processes, such as mixing and chemical reactions, dispersion of small particles, entrainment, aeroacoustics, and polymer drag reduction. A purely fundamental investigation is the transition to turbulence in a pipe flow. Multiphase flows include liquid/liquid dispersions, the interaction between particles and bubbles in a turbulent liquid , and drag reduction in bubbly flow. An example of a three-phase flow is to investigate the use of gas bubbles to capture small particles in a turbulent liquid. This fundamental investigation is related to a mixing and purification process in steel production. About half of the group is active in the area of (multiphase) microscale flows, i.e. microfluidics. This includes investigation of separation methods and (rapid) mixing in microfluidic devices. Mixing is investigated using various geometries, external forces (e.g., electroosmotic flow and acoustic forcing) and actuators. Recently a new stereoscopic micro-PIV system was developed and applied to the investigation of three-dimensional microfluidic flows. Other activities include the development of liquid/liquid microreactors for sample treatment and detection of DNA.

More recent we began to investigate microscale cardiovascular flows. The aim is to investigate the relation between differentiation and adaptation of tissues to fluid mechanical forces. This provides fundamental knowledge to understand the mechanisms of certain diseases, such as atherosclerosis. This research is carried out in close collaboration with medical groups at the universities of Leiden and Rotterdam.

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

Project Aim

The merit of using flows close to the liquid-vapor critical point as the working fluid of a closed Brayton cycle gas turbine is now widely recognized, and the development of this technology is now actively pursued. The aim of the project is the study, modeling and simulation of compressible flows occurring close to a fluid's critical point. Due to the strong variations of the thermodynamic properties in this region, particular attention will be focused on numerical aspects on solving the fully compressible Navier-Stokes equations and on turbulence modeling as common turbulence models have been introduced under the ideal gas assumption. Steady and unsteady problems of practical interest, as the case of turbomachinery components in advanced power systems, will be studied.

Progress

A fully compressible Navier-Stokes solver, developed at Stanford University has been selected for the studies aimed in this project. In order to account for the strongly nonlinear variation of the thermophysical properties of fluids close to the critical point, the CFD code was coupled with an extensive library for the computation of properties of fluids and mixture. A specialized look-up table approach and mesh generator to obtain high quality meshes for radial turbomachinery components has been developed. First simulations where performed on a radial compressor operating with supercritical CO_2 for which experimental data exits. A detailed evaluation of the CFD results was performed and compared with the available experimental data. The results of these first results will be presented at the ASME Turbo Expo in 2012 held in Copenhagen and at the ECCOMAS conference held in Vienna.

Dissertations

-

Scientific Publications

1. R. Pecnick, and P. Colonna, Accurate CFD analysis of a radial compressor operating with supercritical CO_2, Supercritical CO_2 Power Cycle Symposium, May 2011, Boulder Colorado.

Projectleaders
P Colonna, R Pecnik

Researchtheme
Complex dynamics of fluids

Participants
P Colonna, R Pecnik, E Rinaldi

Cooperations
-

Funded

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

Start of the project
2011

Information

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Flameless combustion conditions and efficiency improvement of single- and multi-burner-FLOXTM furnaces in relation to changes in fuel and oxidizer composition (flexFLOX)

Projectleaders
BJ Boersma, W de Jong,
DJEM Roekaerts

Researchtheme
Complex dynamics of fluids

Participants
G Sarras

Cooperations
MK Stollinger (TNW)

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
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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 the part of the flexFLOX project described here is to develop and validate computational models.

Progress

To study the flameless combustion of the Delft-Jet-in-Hot-Coflow (DJHC) burner a hybrid finite volume – transported Probability Density Function (PDF) method is used. It combines an underlying Reynolds stress model with the Monte Carlo simulation of velocity and scalar statistics. To reduce the computational cost, a tabulated chemistry model based on two mixture fractions and a progress variable is used. The simplified chemistry is based on the Flamelet Generated Manifold (FGM) method. Unsteady, non-premixed flamelet solutions are used to construct the manifold. The non-premixed flamelets are based on counter flow diffusion flames between the pure fuel (methane) and a certain coflow composition. The unsteady flamelet solutions are obtained with the CHEM1D code. To improve memory efficiency, the final 3D-FGM table is tabulated using the Delft Flame code. The next step to fully describe the radial variation of the measured coflow oxygen concentration and temperature is to introduce the enthalpy deficit as an additional independent variable and create a 4D-FGM table.

Dissertations

-

Scientific Publications

1. G. Sarras, M.K. Stoellinger, M.A. Etaati, and D.J.E.M. Roekaerts. Simulation of the Delft Jet-in-Hot-Coflow burner using transported PDF methods and FGM tabulated chemistry, Combura'11 Symposium, STW (Pub.), Ede, The Netherlands, 2011, 42-43.

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

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

We study the wave generation by perform the DNS of the air flow over water layer with linear shear velocity disturbed by small wave amplitude. The results, such as wave growth rate, will be compared with analytical theory.

Dissertations

-

Scientific Publications

-

Projectleaders

BJ Boersma

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Poomsawat

Cooperations

-

Funded

Faculty of Engineering
at Kamnhaeng Saen,
Kamphaeng Saen Campus
Kasetsart University
Thailand

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

Start of the project

2010

Information

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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
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Project Aim

Developing a code for modeling flow and heat transfer over evaporating droplets by means of Direct Numerical Simulation (DNS) for different Reynolds numbers, and consequently different flow regimes, taking into account the temperature distribution inside the droplets and the consequent effect on heat transfer coefficient.

Progress

Study of flow and heat transfer over spherical particles, modeling heat transfer from a spherical particle with a non-uniform surface temperature to investigate the variations of heat transfer coefficient along the surface of the particle, the results are presented in the submitted paper for CHT12. Study of heat and mass transfer from evaporating droplet in turbulent flow (abstract submitted to THMT12). Developing a code to model heat and mass transfer in turbulent flow.

Dissertations

-

Scientific Publications

-

Identification and modification of acoustic source in a turbulent flow

Project Aim

The aim of the project is to use well resolved experimental and numerical techniques to identify acoustic source in turbulent flows and develop strategies to reduce the acoustic emissions.

Progress

An wind tunnel model has been designed and build. It consist of a flat plate in which a rectangular cavity take place. The dimension of the cavity can be adjusted. The model is instrumented with eleven pressure sensor. Several measurements campaigns has been carried out in the vertical wind tunnel of the aerospace faculty at Tu Delft. Measurements consisted of planar and tomographic particle image velocimetry measurements syncronized with wall pressure fluctuation measurements and far field noise measurements have been carried out. In these measures particular attention was given to the influence of the incoming boundary layer characteristics on the sound production. For this reason measurements with both a laminar and a turbulent boundary layers have been performed. Results show how the thickness of the incoming boundary layer is an essential parameter for the generation of tonal noise. Furthermore, it is shown that the results of the high resolution planar measurements give a better acoustic prediction than the 3D tomographic measurements. The project has been finished in the fall of 2011.

Dissertations

1. Koschatzky, V., 2011, An experimental study on the aeroacoustics of wall bounded flows, Phd thesis, Delft University of Technology (promotors, B.J. Boersma & J. Westerweel).

Scientific Publications

1. Koschatzky, V., Westerweel, J., & Boersma, B.J, 2011, A study on the application of two different acoustic analogies to experimental PIV data, Phys of Fluids, 23, 065112.
2. Koschatzky, V., Moore, P.D., Westerweel, J., Scarano, F., & Boersma, B.J., 2011, High speed PIV applied to aerodynamic noise investigation, Experiments in Fluids, 50, 863-876.

Projectleaders

BJ Boersma, J Westerweel

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Poomsawat

Cooperations

-

Funded

FOM

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

Start of the project

2010

Information

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Study of droplet dynamics and turbulence modification in two-phase flows by means of DNS

Projectleaders
J Westerweel, BJ Boersma, JCR Hunt, G Ooms

Researchtheme
Complex dynamics of fluids

Participants
M Kwakkel, W-P Breugem, BJ Boersma

Cooperations
-

Funded
TUD

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

Start of the project
2008

Information
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Project Aim

The goal of this project is on understanding droplet dynamics and turbulence modification in the clustering regime St~1. Droplets whose characteristic size is significantly larger than the Kolmogorov length scale are considered, whence they can not be modeled as point droplets. Situations leading to break-up and coalescence of these droplets are of particular interest. Finally, direct numerical simulations of a turbulent channel flow with a large number of droplets will be performed.

Progress

Coalescence and break-up models have been implemented in the multiple marker Coupled Level-set and Volume-of-Fluid (CLSVOF) method. The coalescence model is based on a film drainage model, which is able to predict the drainage time. This drainage time is used to determine if and when droplets should physically coalesce. When (numerical) break-up is detected, two separate markers are created to prevent future numerical coalescence. Together with the possibility to simulate a large number of droplets, the influence of droplets on the characteristics of turbulent channel flow can now be investigated. Furthermore, coalescence and break-up will lead to a specific droplet size distribution within the turbulent channel, which is also of interest.

Dissertations

-

Scientific Publications

1. Kwakkel, M., Breugem, W.P., Boersma, B.J. (2011). An efficient multiple marker front-capturing method for two-phase flows. Submitted to Computers & Fluids.

Drag reduction in watersports

Project Aim

Friction of water is a large contributor to the total drag in water sports. Reducing this drag leads to higher velocities, which is all about in most water sports; Going faster! The friction can be reduced by changing the surface properties, due to coatings, which will influence the interaction between water and object. The project aim is to develop, characterize and testing specific coatings which will reduce this friction drag.

Progress

The Taylor-Couette testing facility of the Laboratory for Aero- & Hydrodynamics at the Delft University of Technology proved to be useful to analyze the drag reducing effect of specific surfaces and products. The data with riblets show a similar trend and a maximum of 5% drag reduction. In the future, self-developed coatings will be characterized and tested on their drag reducing effect. Micro-structured surfaces with a hydrophobic/-philic character seem promising as surface treatment to go faster!.

Dissertations

-

Scientific Publications

1. A J Greidanus, R Delfos and J Westerweel, Drag reduction by surface treatment in turbulent Taylor-Couette flow, Journal of Physics: Conference Series 318 (2011) 082016.

Projectleaders

J Westerweel, BJ Boersma
G Ooms, JCR Hunt, B Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

A Greidanus, R Delfos, J Westerweel

Cooperations

InnoSportNL, DSM, TNO, MARiN

Funded

InnoSportNL, DSM, MARiN

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

Start of the project

2008

Information

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A Supra-disciplinary approach to research and training in surface Physics for Advanced Manufacturing (S.P.A.M.)

Projectleaders
J Westerweel, BJ Boersma,
G Ooms, JCR Hunt, B Eckhardt

Researchtheme
Complex dynamics of fluids

Participants
S Tokgoz, G Elsinga, J Westerweel,
B Wieneke

Cooperations
LaVision GmbH, TU Delft, ASML

Funded
European Project

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

Start of the project
2009

Information
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Project Aim

The aim of the project is to advance the current state of the flow and temperature measurement techniques and to use the new methods for different applications. The development of advanced 3D PIV velocity and scalar measurement techniques supposed to be applied to investigate contact line hydrodynamics in immersion hoods.

Progress

In 2011 implementation of tomographic PIV to Taylor-Couette flow was performed. We investigated the actual spatial resolution of tomographic PIV by comparing turbulent dissipation rates estimated via tomographic PIV and torque measurements. Additionally, we studied the effect of flow structures to the torque values of turbulent Taylor-Couette flow and confirmed that the flow structures are strongly influenced by the rotation number. Our analyses using time-averaged mean flow showed the presence of Taylor vortices for small rotation numbers, where increasing the rotation number results in the shape deformation. We also worked on background oriented schlieren (BOS) method to investigate sub-1 Kelvin temperature gradients in a thin fluid layer. Simultaneous BOS and PIV measurements were performed to measure 2D temperature distribution and velocity field in the thin layer.

Dissertations

-

Scientific Publications

1. S. Tokgoz, G. E. Elsinga, R. Delfos, J. Westerweel: “An experimental study on the influence of the coherent structures to the torque scaling in turbulent Taylor–Couette flow”, 17th International Couette-Taylor Workshop, Leeds, July 25-27, 2011.
2. S. Tokgoz, G. E. Elsinga, R. Delfos, J. Westerweel: “Experimental investigation of torque scaling and coherent structures in turbulent Taylor–Couette flow”, J. Phys.: Conf. Ser. 318 082018.

Project Aim

The aim of this research proposal is to investigate how large gas bubbles rising through a turbulently flowing liquid-particle suspension interact with the particles of the suspension. More specifically, we will investigate how the solid particles adhere to the surfaces of the bubbles, or get entrapped in the wakes of the bubbles, both leading to an upward transport of the particles. This mechanism, called flotation, is primarily investigated by experimental methods.

Progress

Based on the measurement results from the past years, a new model is available predicting the concentration increase or decrease in the near-wake of a spherical cap as a function of a mean-flow Stokes number, the Froude number and the average turbulence level in the wake. The influence of turbophoresis was also studied, but its contribution was found to be too small to give statistically significant improvements over the predictions of the basic model. The adhesion of particles to the bubble surface was studied on air bubble trapped in a conical pipe with a counterflow. Both high-speed recordings for the encounter rates and time series of colour images of the bubbles were taken. The latter allowed the analysis of attachment rates. Although the data analysis is not done yet, air bubbles with stationary wakes show significantly higher initial attachment rates than e.g. ellipsoidal bubbles.

Dissertations

-

Scientific Publications

1. N.G.W. Warncke, R. Delfos, G. Ooms, J.Westerweel: Particle Entrainment in Spherical-Cap Wakes. J. Phys.: Conf. Ser. 318, 052025, 2011.

Projectleaders

J Westerweel, BJ Boersma, G Ooms, JCR Hunt, B Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

N Warncke, R Delfos, J Westerweel

Cooperations

-

Funded

STW, Tata Steel RT&D

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

Start of the project

2007

Information

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Projectleaders
J Westerweel, BJ Boersma,
G Ooms, JCR Hunt, 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
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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).

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 developed novel ultrasound-based particle image velocimetry methods for non-invasive in vivo blood flow measurements.

Dissertations

-

Scientific Publications

1. Egorova A.D., Van der Heiden K., Van de Pas S., Vennemann P., Poelma C., DeRuiter M.C., Goumans M.J.T.H., Gittenberger-de Groot, A.C., ten Dijke P., Poelmann R.E. and Hierck B.P.(2011) “Tgf-beta signaling is required for shear stress induced klf2 expression in embryonic endothelial cells” Developmental Dynamics 240 (7) pp.1670-1680.
2. Wielhouwer E.M., Ali S., Al-Afandi A., Blom M.T., Riekerink M.B.O., Poelma C. et al. (2011) “Zebrafish embryo development in a microfluidic flow-through system” Lab on a Chip 11 (10) pp.1815-1824.
3. A. Kloosterman, C. Poelma and J. Westerweel (2011) “Flow rate estimation in large depth-of-field micro-PIV” Exp. in Fluids 50 (6) pp.1587-1599.
4. C. Poelma, J. M. Mari, N. Foin, M.-X. Tang, R. Krams, C.G. Caro, P.D. Weinberg and J. Westerweel (2011) “3D Flow reconstruction using ultrasound PIV” Exp. in Fluids 50 (4).
5. Kloosterman A., Poelma C., Hierck B.P. and Westerweel J. (2011) “Insight into the developing vitelline network with micro-PIV measurements” EUROMECH Colloquium 521 - Biomedical Flows at Low Reynolds Numbers (ETH Zurich, 29-31 Aug 2011).
6. Poelma C., van der Mijle R., Mari J.M., Tang M.-X., Weinberg P. and Westerweel J. (2011) “Ultrasound imaging velocimetry: toward clinical application” EUROMECH Colloquium 529: Cardiovascular Fluid Mechanics: from theoretical aspects to diagnostic and therapeutic support (Cagliari, Italy; 27-29 June 2011).

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 a nanoscale. A measurement method is to be developed in order to measure the interface of a droplet at a nanoscale. The method should allow static and dynamic contact angles as well as droplet coalescence to be studied under varying conditions. Experiments will 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 (TIRFM) is developed in order to study nanoscale contact line dynamics. The developed technique is validated with non disturbing imaging by Atomic Force Microscopy (AFM). A combined TIRFM-AFM setup is operational for characterization the evanescent excitation field by total internal reflection of incident light. First results demonstrate it is possible to measure droplet-droplet coalescence at nanoscale level.

Dissertations

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Scientific Publications

1. M.J.Z. Franken, C.Poelma and J. Westerweel. Nanoscale contact line visualization based on total internal reflection fluorescence microscopy. Optics Express (in preparation).

Projectleaders

J Westerweel, BJ Boersma, G Ooms, JCR Hunt, B Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

MJZ Franken, C Poelma, J Westerweel

Cooperations

ASML, UT, TU/e

Funded

ASML

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

Start of the project

2008

Information

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PROJECTLEADERS
J Westerweel, BJ Boersma,
G Ooms, JCR Hunt, B Eckhardt

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
S Drost, J Westerweel

COOPERATIONS
Teijin Aramid B.V.

FUNDED

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

START OF THE PROJECT
2011

INFORMATION
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PROJECT AIM

Understand the dynamics of the extrusion of a bundle of lyotropic liquid crystalline polymer filaments, in order to be able to control the spatial and temporal homogeneity of this process.

PROGRESS

A literature study has been done on viscoelastic entrance flow phenomena. Furthermore, exploratory simulations of viscoelastic contraction flow have been done in OpenFOAM. On the experimental part, glass flow cells, produced by Micronit B. V., have been tested. First results look promising.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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 has been performed and the facility has been made operational. Preparations have been made to introduce seeding in the facility in order to implement planar PIV.

Dissertations

-

Scientific Publications

-

Projectleaders

J Westerweel, BJ Boersma, G Ooms, JCR Hunt, B Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

D Fiscaletti, GE Elsinga, J Westerweel

Cooperations

Universitaet der Bundeswehr Muenchen

Funded

EU

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

Start of the project

2011

Information

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PROJECTLEADERS
J Westerweel, BJ Boersma,
G Ooms, JCR Hunt, 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
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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

-

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

A new test section of the cavitation tunnel for the drag reduction study has been built. It was installed and tested. PIV was used to measure the velocity profiles in the tunnel. Measurement of the inlet velocity profile was done in order to characterize the flow entering the test section. The force balance was built in order to measure the shear force on the test plate. Preliminary force measurement shows at least 50% drag redaction by the air cavity formed underneath the test plate. Parameters study was performed to define the governing parameters for formation, maintenance and other hydrodynamic characteristics of air cavities.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS

J Westerweel, BJ Boersma, G Ooms, JCR Hunt, B Eckhardt, T van Terwisga

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

O Zverkhovskyi, M Harleman, D van Gils, T van Terwisga, J Westerweel, D Lohse, R Delfos

COOPERATIONS

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

FUNDED

STW, PPG, MARIN

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

START OF THE PROJECT

2009

INFORMATION

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Flow of a viscous compressible fluid produced in a circular tube by an impulsive point source

Projectleaders
J Westerweel, BJ Boersma,
G Ooms, JCR Hunt, B Eckhardt

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
BU Felderhof, G Ooms

Cooperations
RWTH Aachen

Funded
TUD

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

Start of the project
2010

Information
G Ooms
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Project Aim

To understand and predict the flow of a viscous compressible fluid produced in a circular tube by an impulsive point source.

Progress

The flow of a viscous compressible fluid in a circular tube generated by a sudden impulse at a point on the axis is studied on the basis of the linearized Navier-Stokes equations. A no-slip boundary condition is assumed to hold on the wall of the tube. An efficient numerical scheme has been developed for the calculation of flow velocity and pressure disturbance as function of position and time.

Dissertations

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Scientific Publications

1. B.U. Felderhof and G. Ooms, Flow of a viscous compressible fluid produced in a circular tube by an impulsive point source, J. Fluid Mech. 668 (2011) 100-112.

Numerical simulation of the spectral development of inviscid helical flows

Project Aim

To investigate in detail the delay in the spectral development of an inviscid, helical flow field by varying the number of modes in the initial flow field.

Progress

We have studied numerically the time development of the energy spectrum of inviscid, incompressible, helical flows. It is well-known that helicity delays the development of turbulence. We have studied this phenomenon in more detail by investigating the influence of the number of modes in the initial flow field on the spectral development. We studied the cases with one, two, three or twenty-four modes with and without helicity in the initial flow field. It is found that the delay in the spectral development due to helicity is strongly dependent on the number of initial modes. The delay increases with decreasing number of modes. For the case of one initial mode with maximum helicity no development of the energy spectrum occurs. However, for the case of twenty-four initial modes with maximum helicity, energy transfer between the modes takes place without much delay when compared to the case of twenty-four initial modes without helicity.

Dissertations

-

Scientific Publications

1. G. Ooms, B.J. Boersma and M.J.B.M. Pourquie, Numerical simulation of the spectral development of inviscid helical flows, Eur. J. Mech. B/Fluids 30 (2011) 428-436.

Projectleaders

J Westerweel, BJ Boersma, G Ooms, JCR Hunt, B Eckhardt

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

G Ooms, BJ Boersma, MJBM Pourquie

Cooperations

-

Funded

TUD

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

Start of the project

2010

Information

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Vortex cavitation on ship propellers

Projectleaders
J Westerweel, BJ Boersma,
G Ooms, JCR Hunt, B Eckhardt,
T van Terwisga

Researchtheme
Complex dynamics of fluids

Participants
PC Pennings, TJC van Terwisga,
J Westerweel, 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	-
TNO	-
GTI	-
EU	-
Scholarships	100 %

Start of the project
2011

Information
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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 preparations have started to extend the visual access of the present test section from 0.6 m to 1.9 m. During the construction of the new test section exploratory experiments are carried out to study vortex cavitation in a circulating pipe flow using a swirl element from the research of Dirkzwager [1996].

Dissertations

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Scientific Publications

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Investigation of complex flow patterns in a moving immersion lens droplet : Contact line control during wetting & dewetting

Project Aim

This project aims to visualize and investigate the complex flow patterns that occur in a confined Couette flow that resembles a moving droplet of an immersion lens geometry, and to understand how this interacts with the dynamics of the moving contact line. We will make use of the newly developed stereoscopic micro particle image velocimetry (μ-PIV), as well as numerical simulations to gain a better understanding of the various flow patterns that occur at intermediate flow Reynolds numbers. The results should lead to strategies that can achieve flow control and to optimized design of a moving immersion lens.

Progress

We have performed full 3D-3C velocity measurements for the liquid immersion drop by means of 3D-PTV and tomographic PIV. From these results, we observed the internal flow pattern of the immersion drop. In particular, we presented a self-similar flow pattern near the droplet corner structure. This is a similar result with the sliding down drop on an inclined substrate. Furthermore, to perform theoretical analysis for the given problem, we considered a scaling argument and then we obtained the modified lubrication model including an inertial effect. This could provide the interface equation for the partially de-wetting flow at intermediate Reynolds number (i.e. the rear part of the immersion drop). Furthermore, the model presented two main results. First, a corner opening angle is a function of the dynamic receding contact angle and the capillary number. Second, we obtained the analytical solution for velocity profiles. The analytical and experimental results are in a good agreement. Furthermore, we presented a simplified numerical model for the bulk region of the immersion drop. To evaluate the numerical model, we compare the result with the measuremental result. The streamline pattern of two results is more or less identical. Furthermore, we compared the velocity profile of two results at the receding part of the immersion drop and then we showed a good agreement. To improve the immersion lithography mahcine, it is important to properly design the immersion hood. This is highly related to the design of the inlet and outlet. We exepct that the simplified numerical model is effective method to test the design of the immersion hood. This approach could suggest some idea to improve the design of the immersion hood device.

Dissertations

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Scientific Publications

1. Kim H; Große S; Elsinga GE; Westerweel J (2011) “Full 3D-3C velocity measurement inside a liquid immersion droplet,” EXP FLUIDS Vol. 51(2), 395-405.
2. Kim H; Kwak HS; Westerweel J (2011) “Assessment of mixing applications on the EOF with thermal effects,” COLLOID SURFACE A, Vol. 376, pp. 53-58.
3. Kim H; Poelma C; Westerweel J (2011) “Investigation of partially dewetting flow at Re ~ O (100) and Ca ~ O (0.01),” 64th Annual Meeting of the APS Division of Fluid Dynamics, Baltimore, USA.
4. Kim H; Poelma C; Westerweel J (2011) “Study on moving contact line at Re ~ O(100),” Gordon Research Conference 2011, USA.

Projectleaders
J Westerweel, BJ Boersma, G Ooms, JCR Hunt, B Eckhardt

Researchtheme
Complex dynamics of fluids

Participants
H Kim, GE Elsinga, C Poelma, J Westerweel

Cooperations
ASML, UT, TU/e

Funded
FOM

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

Start of the project
2008

Information

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Impact of boiling liquid on fluid-vapour-wall interaction in LNG transfer systems

Projectleaders
J Westerweel, BJ Boersma,
G Ooms, JCR Hunt, B Eckhardt

Researchtheme
Complex dynamics of fluids

Participants
M Schenker, R Delfos,
J Westerweel, A Twerda

Cooperations
-

Funded
Agentschap NL

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

Start of the project
2011

Information
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Project Aim

To investigate and understand the significant flow-mechanisms ocurring in a cryogenic flow through a corrugated hose. The large increase in pressure-drop in such flows is not understood yet, and we aim to be able to predict the pressure-drop and determine why. This might help optimize the transport-hose geometry.

Progress

A preliminary experiment exploring the possibilities of the available set-up has been performed. A second experiment was performed obtaining reproducable curves describing the pressure drop with and without the occurrence of cavitation around a single obstruction in a straight pipe. An m-file is written, based on the bernouilli equations and empirical formulas to predict the system behaviour. A literature-search has been performed, looking for theoretical and experimental methods that might apply to the current research.

Dissertations

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Scientific Publications

-

Development and application of volumetric velocity measurement techniques

Project Aim

We employ volumetric velocimetry measuring techniques, primarily Tomo-PIV, in the investigation of turbulent and instationary flows. By forming and testing hypotheses in classical turbulent shear flows, we strive not to bring empty success for better modeling of such flows in applications, rather we want to provide a certain value for the scientific community, creating new possibilities for research. To get new insights, we study somewhat new or forgotten features of same old flows with new methods.

Progress

We tested experimentally several hypotheses regarding the intermittent region of turbulent jet and boundary layer flows. At considered Reynolds number range, experimental data indicates: existance of a shear layer of the order of few precent of the flow width at the boundary between turbulent and non-turbulent (T/NT) fluid motion; jumps in axial velocity averaged relative to the T/NT boundary. These findings support an alternative model for the fluid entrainment mechanism due to the small-scale nibbling process contrary to the conventional large-scale engulfment. More importantly, we recognize this tendency of turbulence to form distinct separate inertial and viscous regions inside turbulent shear flows in both developed and transitional stages.

Dissertations

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Scientific Publications

1. Semin N.V., Golub V.V., Elsinga G. and Westerweel J. Laminar superlayer in a turbulent boundary layer. Technical Physics Letters, Vol. 37, No. 12, pp. 1154-1157, 2011, (http://dx.doi.org/10.1134/S1063785011120285).
2. Semin N.V., Elsinga G. and Westerweel J. Detection of the laminar superlayer from TPIV measurements in a turbulent jet. Seventh International Symposium on Turbulence and Shear Flows Phenomena. July 28 - 31, 2011, Ottawa, Canada. (http://www.tsfp7.org/papers/2A4P.pdf).

Projectleaders

J Westerweel, BJ Boersma,
G Ooms, JCR Hunt, B Eckhardt

Researchtheme

Complex dynamics of fluids

Participants

Ny Semin, GE Elsinga,
J Westerweel, JCR Hunt

Cooperations

prof.dr. JCR Hunt

Funded

FOM

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

Start of the project

2008

Information

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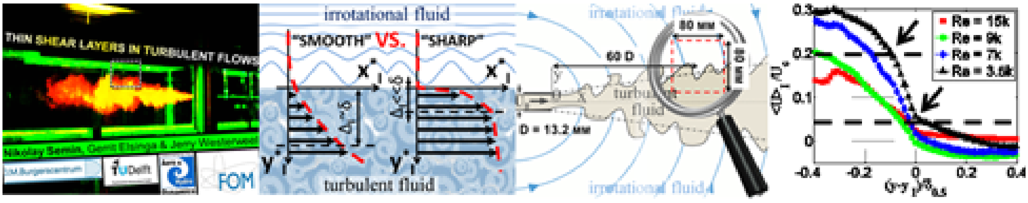

(a) research (b) question (c) method (d) result

(a) In the intermittent region, several basic questions can be posed. For instance, (left (b)) whether the velocity profile changes "smoothly" across the T/NT boundary on the scale of the flow width or (right (b)) the transition is "sharp"? (c) To answer this and other questions, we set up a careful experiment, zooming in at the fluctuating boundary of a turbulent jet flow. (d) In the non-turbulent region (y − yI > 0), the mean axial velocity component is nearly constant. At the T/NT boundary (y − yI = 0), there is a jump in the slope. Inside the turbulent region near (y − yI < −0.05 δ0.5), there is another change in the slope of the ‹U›I profile. Inside the turbulent region (y − yI < −0.05 δ0.5), the slop is decreasing further. This suggests that on average there is a shear layer at the boundary between the turbulent and irrotational regions.

Flow induced by beating artificial cilia

Projectleaders
J Westerweel, BJ Boersma,
G Ooms, JCR Hunt, B Eckhardt

Researchtheme
Complex dynamics of fluids

Participants
J Hussong, J Westerweel

Cooperations
Eindhoven University of Technology; University of Groningen, Zernike Institute for Advanced Materials; University of Freiburg-IMTEK, Department of Microsystems Engineering; Philips Research Laboratories, Materials Technology

Funded
Philips Research

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

Start of the project
2006

Information
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Project Aim

The main objective of the project is to explore and develop a novel and revolutionary technology for manipulation of fluids on a microscopic scale. The technology is inspired by a fluid manipulation mechanism found in nature, namely that of cilia propulsion. In this case, flow is induced by the concerted beating of individual microscopic hairs, the cilia, that cover the surface of a micro-channel. A test set-up is assembled at the TU Delft to quantitatively characterize the cilia motion and the flow induced by the artificial cilia.

Progress

The fluid transport produced by rectangular shaped, magnetically actuated artificial cilia was determined by means of phase-locked Micro Particle Image Velocimetry measurements in a closed flow volume. The achieved velocities are one order of magnitude higher than in previous studies (Shields2010, Vilfan2009), reaching values that are comparable with other microfluidic transport mechanisms such as electro-osmotic pumping. An analysis of the measured flow data was performed indicating that the present system is capable of achieving volume flow rates of approximately 14 micro l/min when no back pressure is built up in the micro channel. This corresponds to an effective pressure gradient of approximately 6 Pa/m. Time resolved measurements were performed, showing that the flow field reverses two times during one actuation cycle inducing instantaneous velocities of up to 2 mm/s. The project was successfully completed in 2011.

Dissertations

1. J. Hussong (2011). Flow induced by beating artificial cilia: An experimental and numerical study. PhD thesis.

Scientific Publications

1. J. Hussong, W.-P. Breugem, and J. Westerweel (2011). A continuum model for flow induced by metachronal coordination between beating cilia. J. Fluid. Mech., doi:10.1017/jfm.2011.282.
2. J. Hussong, N. Schorr, J. Belardi, O.Prucker, J. Ruehe, and J. Westerweel (2011). Experimental investigation of the flow induced by artificial cilia. Lab Chip, 11(12): 2017-2022.
3. S.N. Khaderi, c.B. Craus, J. Hussong, N. Schorr, J. Belardi, J. Westerweel, O. Prucker, J. Ruehe, J.M.J. Den Toonder, and P.R. Onck (2011). Magnetically-actuated artificial cilia for microfluidic propulsion. Lab Chip, 11(12): 2002-2010.

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

Bubble concentration profiles are measured in low Reynolds number, fully developed, horizontal, turbulent channel flow with shadowgraphy. They are compared to profiles obtained by numerical simulations of channel flow with langrangian point bubbles. In both cases the shape of the bubble distributions depends on a balance between buoyancy and turbulent dispersion, which can be expressed with a Rouse number. Simultaneous PIV and bubble shadowgraphy measurements enable the measurement of fluid statistics around the bubble locations. Bubbles are located in fluid regions with a downward velocity that compensates for the bubble rise velocity. Bubble drag reduction is studied in low Reynolds number channel flow with electrolysis bubbles. No drag reduction is observed at void fractions of 0.02%, which contradicts the suggested high drag reduction efficiency of small electrolysis bubbles.

Dissertations

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Scientific Publications

1. Harleman M, Delfos R, van Terwisga, T, Westerweel J, Micro-bubble drag reduction and dispersion studied by simultaneous PIV and shadowgraphy measurements, AMT'11 conference, Newcastle April 4-6, 2011.
2. Harleman M, Delfos R, van Terwisga, T, Westerweel J, Dispersion of bubbles in fully developed channel flow, ETC13 conference, Warsaw September 12-15, 2011.

Projectleaders

J Westerweel, BJ Boersma, G Ooms, JCR Hunt, B Eckhardt, TJC van Terwisga,

Researchtheme

Complex dynamics of fluids

Participants

O Sverkhovskyi, D van Gils, M Harleman, TJC van Terwisga, J Westerweel, D Lohse

Cooperations

TUD, UT, PPG Industries, MARIN

Funded

STW, PPG, MARIN

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

Start of the project

2007

Information

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DROP : Break-up and coalescence of droplets in turbulent flow

Projectleaders
J Westerweel, BJ Boersma,
G Ooms, JCR Hunt, B Eckhardt

Researchtheme
Complex dynamics of fluids

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

Cooperations
-

Funded
FOM

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

Start of the project
2009

Information
G Oldenziel
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Project Aim

The aim of the project is to investigate the influence turbulence has on the coalescence of colliding droplets.

Progress

Measurements on liquid film thickness for a droplet at a two-fluid interface were completed. An instability which leads to a quicker coalescence than expected in commonly used models was found. The results were reported in an article which is accepted for publication in Physics of Fluids. An experimental facility to generate turbulence was built, a so called 'French washing machine'. In 2012 coalescence of droplets will be investigated in this facility.

Dissertations

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Scientific Publications

1. Oldenziel, G. and Delfos, R. and Westerweel, J. "Measurements of liquid film thickness for a droplet at a two-fluid interface" Phys. Fluids 24 (2012) 022106.

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.

Active motion control of fast ships

Project Aim

The aim of the PhD project is to develop an active motion control system for fast planing monhulls. The heave, pitch and roll motions of the ship need to be controlled simultaneously using active flaps or interceptors located at the stern of the vessel. The positions of these control devices are determined by an anticipating controller 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 improve the seakeeping behaviour of the vessel.

Progress

A computational program that is able to calculate the heave and pitch motions of a fast ship in waves will be extended include roll motion predictions. The pressure distribution on the hull at a certain heeling angle is calculated using empirical embedded data to ensure a (very) short CPU time. The database containing the pressure distributions of a large number of 2-dimensional hull shaped sections entering the water in asymmetrical conditions has been constructed. The various pressure distributions were calculated using a Boundary Element Method (BEM) program. An experimental study to the dynamic forces of the fast oscillating control surfaces will be carried out in the towing tank of the Delft University of Technology. The design and preparations for the model tests have been completed and the experiments will commence shortly.

Dissertations

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Scientific Publications

1. A.A.K. Rijkens, J.A. Keuning and R.H.M. Huijsmans. A computational tool for the design of ride control systems for fast planing vessels. International Shipbuilding Progress. Volume: 58. Number: 4. Year: 2011

Projectleaders

RHM Huijsmans, JA Keuning

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

AAK 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

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

Projectleaders
AEP Veldman, RHM Huijsmans.

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
B Duz (TUD), HJL van der Heiden (RUG), P van der Plas (RUG), R 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
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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

Several turbulence models have been implemented and combined with various near wall approaches. Local grid refinement has been implemented in three dimensions. Parallelization of the program is finalized. Generating and absorbing boundary condition (GABC) has been implemented in three dimensions and tested. In the most recent release of the program, GABC is at the disposal of the users.

Dissertations

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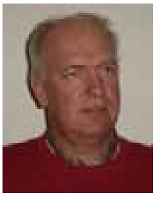
Scientific Publications

1. Duz, B., Huijsmans, R.H.M., Wellens, P. R., Borsboom, M.J.A. and Veldman, A. E. P., "Towards a general purpose open boundary condition for wave simulations", Proceedings of the 30th Conference on Ocean, Offshore and Arctic Engineering OMAE 2011-49979, Rotterdam, The Netherlands.
2. Duz, B., Huijsmans, R.H.M., Veldman, A.E.P., Borsboom, M.J.A. and Wellens, P.R., "An absorbing boundary condition for regular and irregular wave simulations", Proceedings of the 4th International Conference on Computational Methods in Marine Engineering MARINE 2011, Lisbon, Portugal.
3. Veldman, A.E.P., Luppes, R., Bunnik, T., Huijsmans, R.H.M., Duz, B., Iwanowski, B., Wemmenhove, R., Borsboom, M.J.A., Wellens, P.R., van der Heiden, H.J.L., van der Plas, P., "Extreme wave impact on offshore platforms and coastal constructions", Proceedings of the 30th Conference on Ocean, Offshore and Arctic Engineering OMAE 2011-49488, Rotterdam, The Netherlands.
4. Luppes, R., Duz, B., van der Heiden, H.J.L., van der Plas, P. and Veldman, A.E.P., "Numerical simulation of extreme wave impact on offshore platforms and coastal constructions", Proceedings of the 4th International Conference on Computational Methods in Marine Engineering MARINE 2011, Lisbon, Portugal.

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.

Fluid structure interaction in piston diaphragm pumps

Project Aim

Development of an experimentally validated numerical fluid structure interaction (FSI) model for the prediction of, operating condition induced, diaphragm deformation and strains in piston diaphragm pumps.

Progress

- Basic literature study in general CFD and FSI
- Programming of explicit 2D Navier-Stokes solver using multigrid method for Poisson equation
- Implementation of immersed boundary method for flexible immersed structures
- Implementation of immersed boundary method for ridgid immmersed structures
- Design, erection and commissioning of diaphragm deformation test rig.

Dissertations

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Scientific Publications

1. Rijswick, R.van, Kuenen.J.,Wilmsen, A.,Sloesen,.J. GLORES, the gateway to piston diaphragm pumps for high volume applications, Proceedings of the 18th International conference on Hydrotransport, Rio de Janeiro, Brazil, 22-24 September, 2010

.

Projectleaders

C van Rhee, JP van Leeuwen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

C van Rhee, A Talmon, JP van Leeuwen, RJA van Rijswick

Cooperations

-

Funded

WEIR Minerals Netherlands b.v

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

Start of the project

2010

Information

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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, C van Rhee

Cooperations
IHC Merwede BV, MTI Holland BV

Funded
IHC Merwede BV

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

Start of the project
2011

Information
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Project Aim

The goal of this project is to obtain design rules and numerical design tools for vertical hydraulic transport processes, in order to assess flow assurance of the vertical hydraulic transport process during deep sea mining.

Progress

Development of 1D numerical model for transport process of solids through a riser. Initiation of fluidization experiments to get insight in behavior of spherical and unspherical particles with 1/15 < d/D < 1/3 in vertical upward water flows.

Dissertations

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Scientific Publications

1. Wijk, J.M. van; Rhee, C. van; Talmon, A.M.;Vercruijsse, P.M. and Lucieer, P.A. (2011) An experimental and numerical study of vertical hydraulic transport for deep sea mining applications. CEDA Dredging Days 2011 Rotterdam

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 followingh 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.

Dissertations

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Scientific Publications

1. Goeree, J.C. “Numerical simulation of sedimentation using the mixture model”, proceedings CEDA Dredging Days November 2011.

Projectleaders

C van Rhee

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

J Goeree, 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, Agentschap NL, IHCMerwede BV

Funded

IHC Merwede BV, Agentschap NL

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

Start of the project

2010

Information

C van Rhee, J Goeree
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Numerical modeling of dredge plumes

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
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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

- Numerical improvement on the CFD code: implemented a novel wiggle free low dissipation advection scheme.
- Numerical benchmarks: Plume in crossflow, jet in coflow, jet in crossflow, backward facing step, flow past cube.
- Real scale measurements at dredging project on and near Trailing Suction Hopper Dredger.

Dissertations

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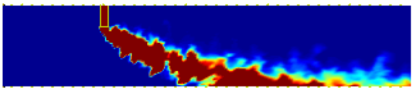
Scientific Publications

-



Example of a simulation of a dredge plume below

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

In 2011 the projects focus was on multi-dimensional pointwise error estimates for the filtered solution and the computational efficiency of the filter. On the theoretical side, we showed that the position-dependent post-processor enhances the accuracy in the entire spatial domain from order k+1 in the L2-norm to order min{2k+1,2k+2-d/2} in the L^∞-norm, when piecewise polynomials of at most degree k are used. Further, we have extended the applicability of the filter to structured triangular meshes. For the computational aspects, we have done an investigation into the efficiency of parallelizing the code for the filter as well as GPU computing.

Dissertations

-

Scientific Publications

-

Projectleaders

JK Ryan

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

P van Slingerland, 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

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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
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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

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SCIENTIFIC PUBLICATIONS

1. J. van de Koppel and R. Gupta and C. Vuik. Scaling-up spatially-explicit ecological models using graphics processors. Ecological Modelling, 222, pp. 3011-3019, 2011.
2. H. Knibbe and C.W. Oosterlee and C. Vuik. GPU implementation of a Helmholtz Krylov solver preconditioned by a shifted Laplace multigrid method Journal of Computational and Applied Mathematics, 236, pp. 281-293, 2011.
3. D. den Ouden and F.J. Vermolen and L. Zhao and C. Vuik and J. Sietsma Mathematical Modelling of NbC Particle Nucleation and Growth in an HSLA Steel under Elastic Deformation. Solid State Phenomena, 172-174, pp. 893-898, 2011.

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.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. P. van Slingerland and J. Ryan and C. Vuik. Position-Dependent Smoothness-Increasing Accuracy-Conserving (SIAC) Filtering for Improving Discontinuous Galerkin Solutions. SIAM Journal on Scientific Computing, 33, pp. 802-825, 2011.
2. M. ur Rehman and T. Geenen and C. Vuik and G. Segal and S.P. MacLachlan On iterative methods for the incompressible Stokes problem. Int. J. Num. Meth. in Fluids, 65, pp. 1180-1200, 2011.

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

FUNDED

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

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

START OF THE PROJECT

1992

INFORMATION

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Projectleaders
C Vuik, FJ Vermolen
Researchtheme
Complex dynamics of fluids
Participants
D Ibrahim, FJ Vermolen, C Vuik
Cooperations
TUD, TNO Science and Industry
Funded
NUFFIC

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

Start of the project
2007
Information
FJ Vermolen
015 278 7298.
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Project Aim

Develop numerical methods for industrial flow problems.

Progress

A new method to solve multi-phase fluid flow problems is developed. Dynamic modeling of thermal processes with phase transition by means of the density-enthalpy phase diagram for spatially homogeneous systems. Until now, preliminary results for two spatial dimensions have been obtained. This method eliminates the requirement of different sets of equations for various phases and necessitates fewer assumptions. For spatial domain discretization, we use finite elements. Recently it appears that the required time slep is very small. This motivates our research to develop time integration methods which allow large time steps.

Dissertations

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Scientific Publications

1. W.K. van Wijngaarden and F.J. Vermolen and G.A.M. van Meurs and C. Vuik Modelling Biogrout: A New Ground Improvement Method Based on Microbial-Induced Carbonate Precipitation. Transport in Porous Media, 87, pp. 397-420, 2011.

Development of an immersed boundary method implemented on cluster and grid computers, application to the swimming of fish

Project Aim

Development of numerical methods for grid computing application to simulation of swimming of fish.

Progress

The project started at the end of 2006. Two implementations of the preconditioned Conjugate Gradient method for solving large sparse linear systems of equations on a (local) heterogeneous computing grid were studied, using GridSolve as grid middleware. This was applied to a 3D bubbly flow problem. Then we experimented with using an asynchronous parallel iterative algorithm as a preconditioner with promising results, again using GridSolve. This approach/technique was then implemented in the CRAC middleware, which allows for direct communication between the processes. Experiments using the CRAC implementation were conducted on the DAS-3 supercomputer, which is a cluster of five geographically separated clusters. Initial tests with asynchronous deflation techniques were also conducted, with promising results.

Dissertations

1. Collignon, TP (2011, april 01). Efficient iterative solution of large linear systems on heterogeneous computing systems. TUD Technische Universiteit Delft (146 pag.) (Delft: TU Delft). Prom./coprom.: Prof.dr.ir. C Vuik & Dr.ir. MB van Gijzen.

Scientific Publications

-

Projectleaders

C Vuik

Researchtheme

Complex dynamics of fluids

Participants

TP Collignon, MB van Gijzen

Cooperations

B Koren, (L&R, CWI), Yunus Hassen (CWI)

Funded

TU (DCSE)

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

Start of the project

2006

Information

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Efficient solvers for advection diffusion reaction equations

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
Funded
SenterNovem, NLR, Nuffic

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

Start of the project
2001
Information
C Vuik
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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

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Scientific Publications

1. H. Knibbe and C.W. Oosterlee and C. Vuik. GPU implementation of a Helmholtz Krylov solver preconditioned by a shifted Laplace multigrid method Journal of Computational and Applied Mathematics, 236, pp. 281-293, 2011.
2. E. van ‘t Wout and H. van der Ven and D.R. van der Heul and C. Vuik The accuracy of temporal basis functions used in the TDIE method 2011 IEEE International Symposium on Antennas and Propagation July 3-8, 2011, Spokane. Editors: J.L. Young and S.L. Broschat and J.B. Schneider Institute of Electrical and Electronics Engineers, Piscataway, 2011, pp. 2708-2711, ISBN 978-1-4244-9562-7.

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 focus of the initial phase of the project is on extension of the two-dimensional Mass Conserving Level Set method from Cartesian grids to general triangular grids. The Mass Conserving Level Set method that has been developed in this group combines the properties of accurate mass conservation of the Volume Of Fluid method, and accurate interface definition of the level-set method.

DISSERTATIONS

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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

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Modeling healing of epidermal wounds and bone fracture

Projectleaders
FJ Vermolen, S van der Zwaag
Researchtheme
Complex dynamics of fluids
Participants
FJ Vermolen, PA Prokharau
Cooperations
Old Dominion University, Norfolk, USA; Centro de Investigacion Biomedica en Red en Bioingenieria, Zaragoza, Spain
Funded
DCMAT, Senternovem (NWO)

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

Start of the project
2003
Information
FJ Vermolen
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Project Aim

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Progress

A publication about modeling wound healing including wound closure, wound angiogenesis and wound contraction has been accepted in to Mathematical Biology (Vermolen & Javierre). Furthermore, a paper about a stability analysis of a model for intraosseous bone ingrowth into an implant has appeared (Prokharau & Vermolen) in Mathematical Biology. A model on the gradual differentiation of mesemchymal stem cells has been developed with incorporation of a moving ossification front. Paper submitted to Journal of Theoretical Biology. Furthermore, a paper on a semi-stochastic cell-based model for migrating cell colonies on substrates has been appeared. The model incorporates cell division, biased random walk and cell death. A mathematical model for cell deformation has been derived. The model is based on Green's Functions and contact mechanics is modeled through an uncoupled system of ordinary differential equations. Finally, a Cahn-Hilliard model has been constructed for the simulation of adipogenesis in adipocytes (fat cells). The model is used to compute the evolution of lipid droplet formation in cytoplasm. A paper (Vermolen & Gefen) has appeared.

Dissertations

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Scientific Publications

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PROJECT AIM

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PROGRESS

A paper on the actual healing of a crack in concrete has been accepted. The model contains two different types of moving boundaries. The solution strategy is based on the level set method. Currently, a diffusion-reaction model has been derived for self-healing of asphalt.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. S.V.Zemskov, F.J.Vermolen & H.M.Jonkers. Two analytical models for the probability characteristics of a crack hitting encapsulated particles: Application to self-healing materials, Computational Materials Science, 50 (12), 3323-3333, 2011.

PROJECTLEADERS

FJ Vermolen

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

FJ Vermolen, SV Zemskov

COOPERATIONS

Corusgroup (Aluminium),
Department of Materials Science and Engineering

FUNDED

DCMAT

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

START OF THE PROJECT

2003

INFORMATION

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PROJECTLEADERS
FJ Vermolen

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
FJ Vermolen, L Zhao, D den Ouden, J Sietsma

COOPERATIONS
Corusgroup (Aluminium), Department of Materials Science and Engineering

FUNDED
DCMAT

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

START OF THE PROJECT
2003

INFORMATION
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PROJECT AIM

-

PROGRESS

A Lifschits-Slyozov-Wagner model for the statistical distribution of the secondary phase particle size has been extended for multi-phase alloys. A paper (den Ouden, Vermolen, Zhao, Sietsma & Vuik) has appeared in Journal of Computational Materials Science. Furthermore, a finite-element based formulation of the level-set method has been described where all kinds of geometry are dealt with.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. Ouden, D den, Vermolen, FJ, Zhao, L, Vuik, C & Sietsma, J Modelling of particle nucleation and growth in binary alloys under elastic deformation: An application to a Cu-0.95 wt%Co alloy. Computational Materials Science, 50(8), 2397-2410.

PROJECT AIM

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PROGRESS

A paper (Maizumkar, Bruining, Vermolen) has appeared in the Journal of the Society of Petroleum Engineers. The paper deals with a model for stress enhanced diffusion in porous media. Further, a paper (van Wijngaarden, Vermolen, Vuik, van Meurs) on modeling bacterial fortification of soils was has appeared in Transport in Porous Media. A model for the bacterial adhesion in porous media has been developed. A paper has been accepted on this topic.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Wijngaarden, WK van, Vermolen, FJ, Meurs, GAM van & Vuik, C (2011). Modelling biogrout: a new ground improvement method based on microbial-induced carbonate precipitation. Transport in Porous Media, 87(2), 397-420.
2. Du, DX, Zitha, PLJ & Vermolen, FJ (2011). Numerical analysis of foam motion in porous media using a new stochastic bubble population model. Transport in Porous Media, 86(2), 461-474.

PROJECTLEADERS

FJ Vermolen, C Vuik

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

F Vermolen, C Vuik, J Bruining, PLJ Zitha, WH van Wijngaarden

COOPERATIONS

-

FUNDED

TUD/ Applied Earth Sciences, TUE

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

START OF THE PROJECT

2000

INFORMATION

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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
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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

Most generally applicable multi-phase flow models are described by non-conservative, (conditionally) hyperbolic systems of equations. As a baseline a multiple pressure model has been chosen and a start is made with the formulation of exact solutions for the Riemann problem for this system of equations, which is, contrary to the conservative case, no trivial matter.

Dissertations

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Scientific Publications

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Project Aim

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

Progress

The focus of the initial phase of the project is on extension of the Mass Conserving Level Set method from Cartesian to cylindrical coordinates, to allow the analysis of pipe flow in realistic geometries. The Mass Conserving Level Set method that has been developed in this group combines the properties of accurate mass conservation of the Volume Of Fluid method, and accurate interface definition of the level-set method, while retaining the efficiency of the latter approach.

Dissertations

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Scientific Publications

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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
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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

1. S.M. Xu, Power Grid Simulation with GPU-Accelerated Iterative Solvers and preconditioners, TU Delft, 26 August 2011.

Scientific Publications

1. S.M. Xu, W. Xue, H.X. Lin (2011), Performance Modeling and Optimization of Sparse Matrix-Vector Multiplication on NVIDIA CUDA Platform. The Journal of Supercomputing, 2011, 10.1007/s11227-011-0626-0, pages 1-12.
2. Ke Wang, Wei Xue, Hai Xiang Lin (2011), Shiming Xu, Weimin Zheng, Updating preconditioner for iterative method in time domain simulation of power systems, Journal Sci China Techn. Sci., Vol. 54, No.4, 2011, pp. 1024-1034.
3. S.M. Xu, W. Xue, K. Wang, H.X. Lin (2011), Generating Approximate Inverse Preconditioners for Sparse Matrices using CUDA and GPGPU, Journal of Algorithms and Computational Technology, Vol.5, No.3, 2011, pp. 475-500.

Projectleaders
AW Heemink

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

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PROJECTLEADERS
AW Heemink
RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
R Hanea, UM Altaf, MP Kaleta, 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
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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 reservoir models in corporation with TNO and Shell. New PhD projects around the theme "Smart Wells" in corporation with the faculty CiTG, MIT and Shell have started. In these PhD project 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. M.U. Altaf, Model reduced variational data assimilation for shallow water flow models, 2011.
2. M.P. Kaleta, Model reduced gradient-based history matching, 2011

SCIENTIFIC PUBLICATIONS

1. Simultaneous perturbation stochastic approximation for tidal models
Altaf Muhammad Umer; Heemink Arnold W.; Verlaan Martin; et al.
OCEAN DYNAMICS, Volume: 61, Issue: 8, Pages: 1093-1105, AUG 2011.
2. Model-reduced gradient-based history matching. Kaleta Malgorzata P.; Hanea Remus G.; Heemink Arnold W.; et al. COMPUTATIONAL GEOSCIENCES, Volume: 15, Issue: 1, Pages: 135-153, JAN 2011.

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. On top of that a advection-like front tracking algorithm has been developed for application in an area not directly related to fluid mechanics.

Dissertations

-

Scientific Publications

1. Vollebregt, E.A.H. and Wilders, P, FASTSIM2: a second-order accurate rolling contact algorithm, Computational Mechanics, vol. 47, pp.

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

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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, MC ter Brake, A Chernetsky, OV Pischans'kyy, SH Sandilo

Cooperations
-

Funded

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

Start of the project
2003

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Project Aim

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

Progress

In 2011 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.C. ter Brake, Tidal Embayments, modeling and understanding their morphodynamics, TU-Delft, 15 March 2011, promotor: A.W. Heemink; co-promotor: H.M. Schuttelaars.

Scientific Publications

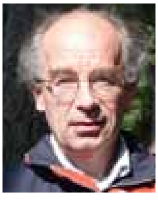
1. On the stability properties of a damped oscillator with a periodically time-varying mass, W.T. van Horssen, O.V. Pischanskyy. Journal of Sound and Vibration 330 (13), pp. 3257-3269.
2. Generalized Langevin equation with a three parameter Mittag-Leffler noise, T. Sandev, Z. Tomovski, J.L.A. Dubbeldam. Physica A: Statistical Mechanics and its Applications 390 (21-22), pp. 3627-3636.
3. Fractional Brownian motion approach to polymer translocation: The governing equation of motion, J.L.A. Dubbeldam, V.G. Rostiashvili, A. Milchev, T.A. Vilgis. Physical Review E-Statistical, Nonlinear and Soft Matter Physics 83 (1), art. No. 011802.
4. Transverse structure of tidal and residual flow and sediment concentration in estuaries: Sensitivity to tidal forcing and water depth, K.M.H. Huijts, H.E. de Swart, G.P. Schramkowski, H.M. Schuttelaars. Ocean Dynamics 61 (8), pp. 1067-1091.
5. Channel and shoal development in a short tidal embayment: An idealized model study, M.C. ter Brake, H.M. Schuttelaars. Journal of Fluid Mechanics 677, pp. 503-529.
6. Drivers of residual estuarine circulation in tidally energetic estuaries: Straight and irrotational channels with parabolic cross section, H. Burchard, R.D. het Land, E. Schulz, H.M. Schuttelaars. Journal of Physical Oceanography 41 (3), pp. 548-570.
7. Influence of topography on tide propagation and amplification in semi-enclosed basins, P.C. Roos, H.M. Schuttelaars. Ocean Dynamics 61 (1), pp. 21-38.
8. Editorship, international book: The complexity of Dynamical Systems a multidisciplinary perspective, Wiley VCH Publishers, 2011, J.L.A. Dubbeldam.
9. Chapter in The complexity of Dynamical Systems a multidisciplinary perspective: Translocation dynamics and Randomness; J.L.A. Dubbeldam.

Multi-Scale Physics

Prof.dr.ir. HEA van den Akker

Prof.dr.ir. CR Kleijn

Prof.dr.ir. RAWM Henkes



Prof.dr.DJEM Roekaerts

Prof.dr.AP Siebesma

Prof.dr. RF Mudde

Prof.dr.H Jonker

Prof.dr.S Sundaresan

The Department of Multi-Scale Physics (MSP) is dealing with Industrial and Environmental Processes. MSP aims at a better understanding, a better description and - especially in industry - a better control of these processes. MSP wishes to contribute in this way to more sustainable industrial processes and a more sustainable earth.

The research interests at MSP are organized around five themes. These themes are intended to focus and communicate the research activities of the Department and are in no way indicative of a further subdivision. People in the department may move from one theme to another from time to time, depending on developments in interests. The themes and the contact persons for each theme are:

Clouds, Climate and Air Quality (prof. Harm Jonker)
Computational Reactor Engineering (prof. Harry van den Akker, head of department))
Reactive Flows & Explosions (prof. Dirk Roekaerts)
Thermal & Materials Processes (prof. Chris Kleijn)
Multi-Phase Flows (prof. Robert Mudde)

We consider flow and transport phenomena over a wide range of time and length scales in their mutual dependence. E.g. we study the interaction of molecular transport of heat and mass, chemical reactions, turbulent eddies, bubbles, drops and particles, and flow and convective transport at the scale of the vessel or at a long range. To do so we exploit a wide variety of advanced computational and experimental tools.

The type of industrial processes we have expertise about comprises plants of any commercial scale in which liquids, gases and solids are processed and manufactured. Our expertise relates to the fluid flow aspects and the heat and mass transport phenomena vital to such processes.

Operations such as mixing and separation processes, combustion, heating and cooling, coating, deposition and precipitation processes, absorption and adsorption, and chemical processes are among our themes of research and teaching. Examples of such plants and processes are abundantly present in the process industries (chemicals, food, pharmaceuticals), but also in the oil and gas industry and in the energy sector (biomass, nuclear, solar). A special topic of interest, associated with the public domain as well as with industrial processes, concerns safety and the risks of explosions.

Many environmental processes have much in common with industrial processes as the same flow and transport phenomena and concepts are at the basis of both. In particular we are dealing with are the life cycle of clouds and the dispersion of pollutants in the environment (air quality).

Clouds play a crucial role in climate and the response of clouds in a changing climate is one of the most pressing unknowns. Therefore we do fundamental research on cloud dynamics and cloud microphysics to improve parameterizations in weather and climate models, using detailed numerical simulation, laboratory experiments, analysis of aircraft, and satellite observations.

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. The code has been extensively validated against test cases from literature as well as experimental welding trials conducted at 3ME-TUD. We extended the model to simulate arc welding (GTAW) processes, which differ from laser welding through additional Lorentz forces. Results obtained so far demonstrate the strong influence of surfactants on the welding process and indicate the importance of surface tension differences as a main driving force for most welding setups.

Dissertations

-

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
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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
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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

Free surface modeling inside the water model of a continuous caster was performed using the Volume of Fluid (VOF) method. Good agreement with cold flow water experiments has been found with respect to the dominant frequencies in the surface oscillations, which can be found in two different regimes. The first regime contains the Eigenmodes of the tank, which are solely dependent on geometric properties of the tank and are apparent at the free surface. The second regime contains large scale, anti-symmetric oscillations, which are induced by the jets emerging from the submerged nozzle. Furthermore, it has been shown that approximating the steel-air interface as a no-slip rigid surface, as is common practice in the modeling of continuous casters, can result in severe errors in the predicted flow features, such as location, size and time scale of dominant recirculation zones. Preliminary work was performed on a solver that solves both the time-dependent free surface flow and the dynamic equations describing the influence of the magnetic field on the flow (by solving an additional equation for the electric potential).

Dissertations

-

Scientific Publications

-

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

We have studied heat and mass transfer to single layers of thin parallel wires, and to single layers of small particles, as a function of open frontal area fraction, Reynolds, Prandtl and Schmidt numbers. We have deduced heat and mass transfer correlations for 0.1<Re<100, and 0.7<Pr/Sc<10, and we have evaluated the asymptotic behaviour for small and large Re. We have also studied the impact of non-regular arrangements of the wires or particles on heat and mass transfer, which was found to reduce heat and mass transfer by up to 30% at intermediate Re, whereas no influence was found for small and large Re. We have studied mass transfer to protective clothing modeled as 3 single layers (2 non-active textile layers and 1 active carbon particle layer) as a function of Reynolds, Prandtl and Schmidt numbers, particle to textile diameter ratio and mutual distance between layers. Results showed that mass transfer is marginally influenced by the textile layer structures.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS

CR Kleijn

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

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
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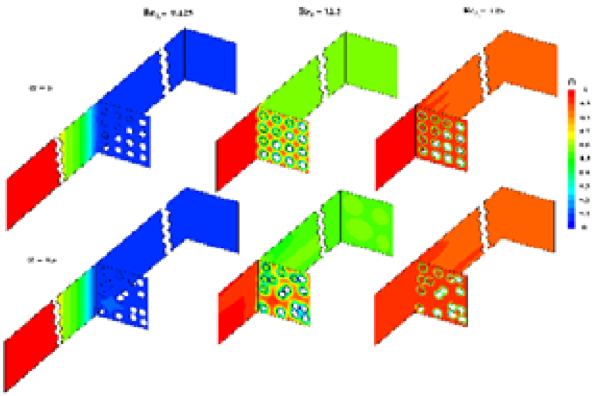
Flow and heat transfer around a disordered layer of parallel spheres at Sc=0.7 and an open frontal area fraction 0.8.



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
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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, requires 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

Applied numerical code OpenFoam was validated by comparing numerical simulations and published experimental data on the formation of bubbles and droplets in T-junction.

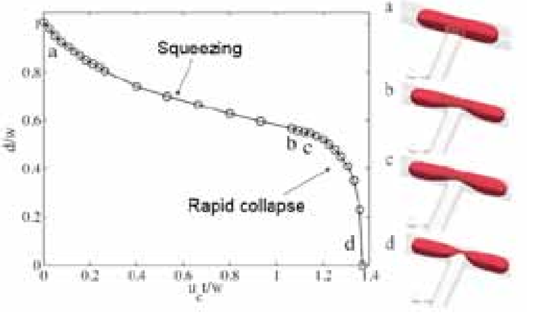
The dynamics of the breakup of bubbles and droplets in microfluidic T-junction was studied through 3-D numerical simulations. The general mechanism of breakup and pinch-off was investigated.

Dissertations

-

Scientific Publications

1. "How does a confined droplet break?", Duong A. Hoang, Volkert Van Steijn, Luis M. Portela, Michiel T. Kreutzer and Chris R. Kleijn, AIChE Annual Meeting 2011, Minneapolis, USA.
2. "Droplet breakup in confined microchannel", Duong A. Hoang, Volkert Van Steijn, Luis M. Portela, Michiel T. Kreutzer and Chris R. Kleijn, NPS11, Arnhem.
3. "Numerical study on droplet breakup in a microfluidic T-junction", Duong A. Hoang, Volkert Van Steijn, Luis M. Portela, Michiel T. Kreutzer and Chris R. Kleijn, ISTP22-82, 22nd International Symposium on Transport Phenomena, Delft.



The evolution of droplet interface during breakup

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 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). Our experimental results show that an increase in heterogeneity of the substrate increases the pinning force between the substrate and the liquid droplet. Additionally we find that even droplets smaller than the capillary length are flattened by gravity and this needs to be accounted for in the calculations of the pinning force.

Dissertations

-

Scientific Publications

-

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

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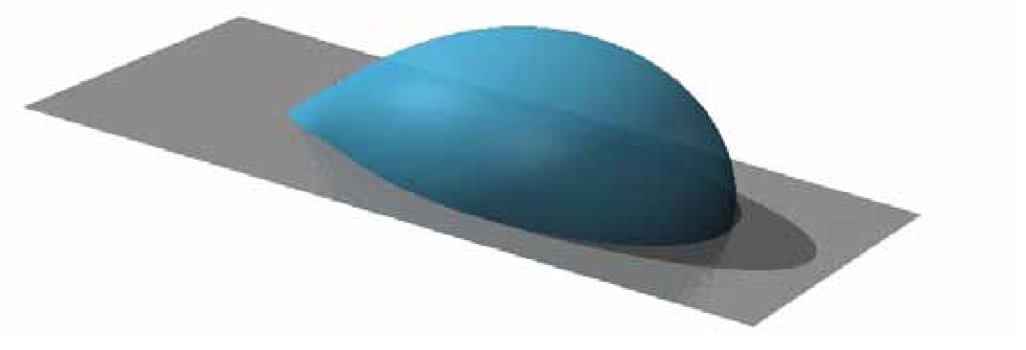

Model experiments on improved continuous steel casting through electromagnetic flow control

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
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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 experimental model of a continuous casting mould in a thin slab caster was built, using water as a working fluid. In this experiment, free surface dynamics are recorded using a high speed camera. For specific combinations of inlet velocity and nozzle depth, large scale, low frequency oscillations are seen at the free surface. The oscillating pattern at the left side of the mould is out of phase with the oscillation on the right side. For better insight, preliminary PIV measurements based on the movement of tiny soap bubbles have been performed. It is seen that a complex pattern of growing and shrinking vortices is present in the sub-surface region which causes the free surface oscillations. At the moment we are building a dedicated PIV setup to draw firm conclusions about the influence of sub-surface fluid behavior on the free surface dynamics, and we are extending our experiments to different aspect ratio moulds and to non-isothermal flows.

Dissertations

-

Scientific Publications

-

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 at our 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 (point, line, area concentration sources).

Progress

Several extensions of standard two-equation eddy-viscosity turbulence models have been investigated, which are expected to eliminate some well-known deficiencies of the standard models relevant for accurate predictions of environmental flows. These include effects of surface roughness through generalized wall functions, a redefined TKE production, a time-scale limiter and a hybrid RANS/LES approach. Another novelty is an efficient representation of blocked flow regions for mimicking built objects. The accuracy and robustness of these models in a structured non-orthogonal Navier-Stokes solver have been investigated. 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)..

Dissertations

-

Scientific Publications

1. Kenjeres, S. and Busking T. (2011), “Capturing Transients in Turbulent Flows Over Complex Heterogeneous Urban Areas at Laboratory Scales”, Proceedings of the the XXIII International JUMV Automotive Conference, Science and Motor Vehicles with Exhibition, April 19-21, Belgrade, Serbia, Invited Paper NMV11AutoSim03, pp.1-13.

Projectleaders

S Kenjeres, CR Kleijn

Researchtheme

Complex dynamics of fluids

Participants

S Kenjeres, CR Kleijn

Cooperations

-

Funded

TU Delft, KNAW

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

Start of the project

2006

Information

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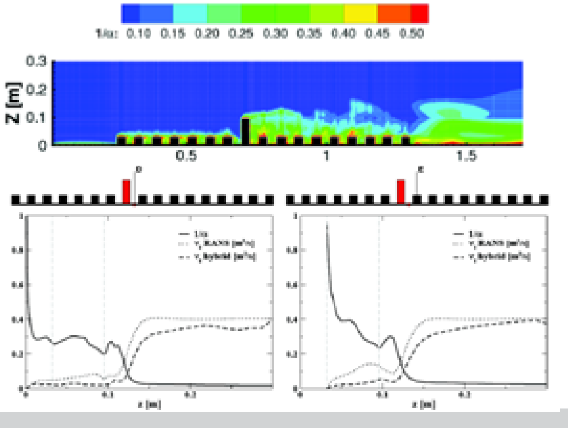

Top- contours of the inverse ”hybrid seamless parameter” in the central vertical plane of the urban-area configuration at an arbitrary time instant of a hybrid RANS/LES simulation. Bottom- the instantaneous vertical profiles of the turbulent viscosity (from RANS and hybrid RANS/LES method) and of the parameter at two characteristic locations in the central vertical plane.

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

Projectleaders
S Kenjeres, CR Kleijn

Researchtheme
Complex dynamics of fluids

Participants
S Kenjeres, R Von Rohr, C Wagner, S Kuhn

Cooperations
R Von Rohr, ETH Zurich

Funded
ETH Zurich, TU Delft, ERCOFTAC, HPC-Europa

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

Start of the project
2006

Information
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Project Aim

This is a joint project between Dept. of Multi Scale Physics at the TU Delft and the Laboratory for Transport Processes and Reactions of Prof. 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

Measurements of turbulent forced and mixed convection flow and heat transfer over two-dimensional sinusoidal heated walls for 20<Re<30000 and 0<Ri<5000 have been performed at ETH Zurich. The first sets of numerical simulations have been performed at TU Delft – including a newly developed 4-equation elliptic relaxation RANS model and LES with dynamical Smagorinsky model. Comparison between experiments and results of RANS and LES (first and second-order statistics as well as local and integral distributions of Nusselt numbers and wall-friction coefficients) for Re=5600 demonstrated an excellent mutual agreement, as well as with spectral DNS results from literature. Dynamical LES have been performed for mixed convection situations at Re=20 – 2000, and the role of the coherent structures in wall heat transfer has been analyzed.

Dissertations

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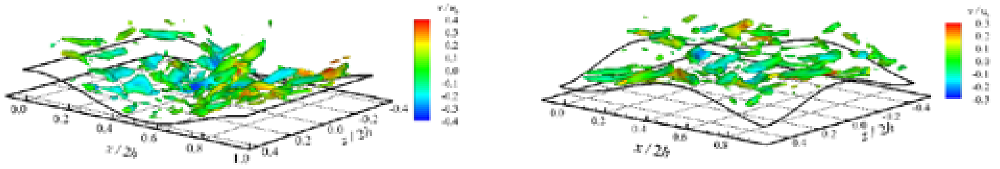
Scientific Publications

1. Wagner C., Kenjeres S., Rudolf von Rohr P. (2011), "Dynamic large-eddy simulations of momentum and wall heat transfer in forced convection over wavy surfaces", Journal of Turbulence, Vol.12, No.7, pp.1-27 (doi: 10.1080/14685248.2010.547496).



Coherent structures in an instantaneous velocity field for a forced convection case over 2D (-left) and 3D (-right) wavy wall extracted by lambda_2 criteria colored by the vertical velocity component – results from a dynamic LES, Wagner, Kenjeres and von Rohr (2011).

Numerical simulations and experiments of electromagnetically driven turbulent flows

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

Targeting accurate predictions of heat transfer at very high Ra numbers, the performance of T-RANS with a low-Re 3-equation sub-scale model and hybrid seamless RANS/LES have been compared to well-resolved LES in the $10^7 < Ra < 10^9$ range. Whilst the application of conventional coarse grid LES resulted in 50% under-prediction of Nusselt at $Ra=10^9$, the T-RANS results showed excellent agreement for heat transfer with both well-resolved LES ($10^7 < Ra < 10^9$) and experiments ($10^6 < Ra < 10^{16}$). In order to sensitize the T-RANS approach to high-frequency instabilities, different ways of hybrid seamless RANS/LES merging have been investigated. It is demonstrated that the new hybrid approach is capable of capturing a significantly larger portion of the fine-structure spectrum than possible with T-RANS, whilst also returning accurate predictions of heat transfer and turbulence statistics. In addition to T-RANS approach, a magnetically extended SGS model in LES framework has been applied in an intermediate range of Ra numbers (up to $Ra=10^{10}$). In addition to thermal buoyancy driven flows, we also performed DNS studies of flow around magnetic obstacles in transitional flow regimes.

Dissertations

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Scientific Publications

1. Kenjeres S., ten Cate S., Voesenek C. J. (2011), “Vortical Structures and Turbulent Bursts Behind Magnetic Obstacles in Transitional Flow Regimes”, International Journal of Heat and Fluid Flow, Vol.32, pp.510-528 (DOI: 10.1016/j.ijheatfluidflow.2011.02.011).
2. Kenjeres S. (2011), “Electromagnetically driven dwarf tornados in turbulent convection”, Physics of Fluids 23, 015103, pp.1-10 (doi: 10.1063/1.3541817).
3. Kenjeres S. (2011), “Turbulence anisotropy and coherent structures in electromagnetically generated vortex patterns”, Proceedings of the 13th European Turbulence Conference, ETC-13, 12-15 September 2011, Warsaw, Poland, pp.1-9, Journal of Physics: Conference Series 318 (2011), 072030.
4. Kenjeres S. (2011), “Transient Vortex Bursts Behind Magnetic Obstacles”, 4th International Symposium Bifurcations and Instabilities in Fluid Dynamics, Universitat Politecnica de Catalunya, 18-21 July, 2011, Barcelona, pp.1-2.

Projectleaders
S Kenjeres, CR Kleijn

Researchtheme
Complex dynamics of fluids

Participants
S Kenjeres, CR Kleijn

Cooperations
CWI, KNMI

Funded
KNAW, TU Delft

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

Start of the project
2006

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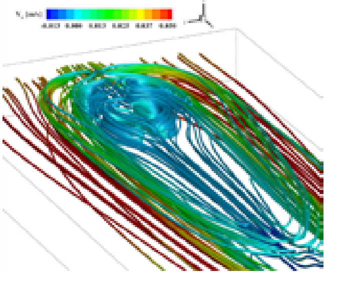

Magnetically generated vortex shedding: flow of electrically conductive working fluid subjected to locally imposed magnetic field (magnetic obstacle) in transitional flow regimes (Re=900, N=10, where Re-is Reynolds number based on half-channel height, N-magnetic interactive number), Kenjeres, ten Cate and Voesenek (2011).

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

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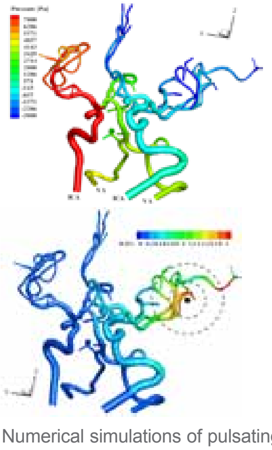

Numerical simulations of pulsating blood flow and magnetic drug targeting in the brain vascular system: The wall-shear-stress (WSS)(-left) and magnetic field (-right) distributions in a real patient brain vascular geometry, Kenjeres and Righolt (2011).

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. In these regions the drug is slowly released from the magnetic carriers. Consequently, relatively small amounts of a drug magnetically targeted to the localized disease site can replace large amounts of the freely circulating drug. At the same time, drug concentrations at the targeted site will be significantly higher compared to the ones delivered by standard (systemic) delivery methods. 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 relevant hydrodynamic and electro-magnetic properties of human blood were taken from the literature. The model is then validated for different test cases ranging from a simple cylindrical geometry to real-life right-coronary arteries in humans. The time-dependency of the wall-shear-stress for different stenosis growth rates and the effects of the imposed strong non-uniform magnetic fields on the blood flow pattern are presented and analyzed. It is concluded that an imposed non-uniform magnetic field can create significant changes in the secondary flow patterns, thus making it possible to use this technique for optimisations of targeted drug delivery.

Dissertations

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Scientific Publications

1. Cohen Stuart, D. C., Kleijn, C. R., and Kenjeres S. (2011), "An efficient and robust method for Lagrangian magnetic particle tracking in fluid flow simulations on unstructured grids", Computer and Fluids, Vol.40 (1), pp.188-194, (doi: 10.1016/j.compfluid.2010.09.001).
2. Kenjeres S. and Righolt B. (2011), "Simulations of Magnetic Capturing Efficiency of Drug Carriers in the Brain Vascular System", Proceedings of the 7th International Symposium on Turbulence and Shear Flow Phenomena, TSFP-7, July 28-31, 2011, Ottawa, Canada, pp.1-6.

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

Experiments have been carried out in a low elbow of a gas/liquid flow pipeline, with inclinations of 1.7° and 2.1°, and a diameter of 50.8 mm. Zero net liquid flow was achieved with various amounts of liquid in the dip, and data for the gas velocity, holdup, and pressure gradient were recorded at the critical point, i.e. the gas velocity that sweeps out the liquid pool from the pipe. It was found that the hanging liquid layer is very sensitive to the gas velocity i.e. that achieving the balance of shear forces and gravity in order to keep the layer suspended requires a very fine control over the gas velocity. Modeling of the zero net liquid flow was done with a steady-state stratified two-phase flow model. It was found that, at the conditions of interest, the model gives multiple solutions. We were interested in the case where there were two solutions, one has zero holdup and the second one has the critical holdup value. The model qualitatively confirmed the behaviour of the liquid layer close to critical gas velocity, which means that the solution with a finite holdup is replaced by zero holdup, when the gas velocity is increased to its critical value. Progress was made with designing and building a two phase PIV experiment for pipe flow with a pool of liquid. First measurements were taken, and based on these modifications in the set-up were made. Furthermore some CFD simulations with the Fluent tool were carried out.

Dissertations

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Scientific Publications

1. Singh, R. Menon, R.A.W.M. Henkes, Comparison of CFD tools for multiphase flow applications, Proc. 8th International Conference on CFD in Oil & Gas, Metallurgical and Process Industries, Trondheim Norway, 21-23 June 2011, Paper CFD11-149, 2011.
2. J.E. Seim, V.L. Van Beusekom, R.A.W.M. Henkes, O.J. Nydal, Experiments and modeling for the control of riser instabilities with gas lift, Proc.15th Int. Conf. on Multiphase Prod. Technology, pp. 19-31, 2011.
3. M. Ramdin, R.A.W.M. Henkes, CFD for multiphase transport in pipelines, Proc. 30th Int. Conf. on Ocean, Offshore and Arctic Engineering, Paper OMAE2011-49514, 2011.

Projectleaders
RAWM Henkes, MT Tummers

Researchtheme
Complex dynamics of fluids

Participants
M Birvalski

Cooperations
Shell

Funded
Shell

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

Start of the project
2010

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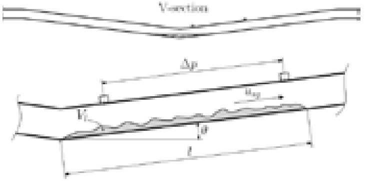

V-section with hanging liquid film

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
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Project Aim

This project is a combined experimental/modeling study on the performance of foamers for deliquification of gas wells as used in the gas and oil industry. The reduction of the reservoir pressure for maturing fields will cause that gas wells will start to accumulate liquid (water, condensate). The use of proper foamer chemicals will mix the liquid and gas into a foam, which decreases the hydrostatic head in the well and re-establishes the flow. The study includes flow experiments using a 12 m, 5 cm diameter facility.

Progress

A literature review was carried out to select molecular phenomena that lead to the foam formation. Most of phenomena can be accounted for by the dynamic surface tension (DST). DST is an amalgam of different time dependent phenomena such as (1) surfactant diffusion to surface, (2) reorientation of molecules, (3) adsorption and (4) micellar dynamics. Small scale experiments were carried out in a foaming column, and the steady and dynamic surface tension of different foamers was measured. The pressure measurements in the larger flow loop were automated. Various experimental techniques were tested: conductivity wire mesh, optical probe, and quick closing valves. These enable to measure the local foam structures during flow, as well as the total liquid holdup in the pipe. A dedicated piston setup has been developed, to further investigate foam coming from the main setup. This enables to perform rheological experiments for the foam.

Dissertations

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Scientific Publications

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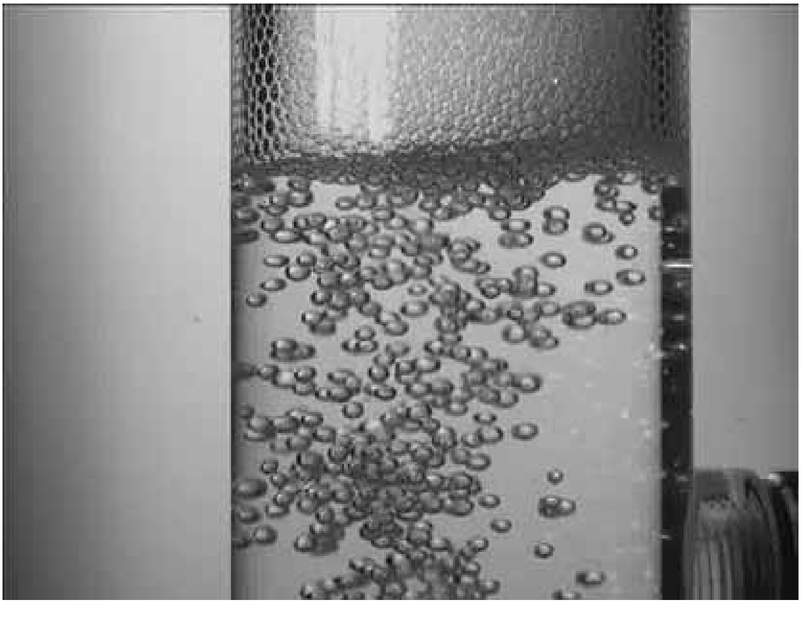

Foam generation

Long liquid slugs in stratified gas/liquid flow in horizontal pipes

Project Aim

The aim of the project is to study the properties and behavior of long liquid slugs, which can occur in horizontal tubes, when operating in the stratified flow regime at relatively high liquid levels. The project includes measurements in a 2” tube with a total length of 137 m using dedicated measurement equipment to detect the growth and structure of the long liquid slugs. Furthermore, the dynamic modeling of these two-phase flow phenomena will be undertaken.

Progress

The last research results were obtained in 2010. In year 2011 some final results were published (see the first reference below). This marks the end of this STW project.

Dissertations

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Scientific Publications

1. U. Kadri, R.A.W.M. Henkes, R.F. Mudde, R.V.A. Oliemans, Effect of gas pulsation on long slugs in horizontal gas–liquid pipe flow, Int. J. Multiphase Flow 37, pp. 1120-1128, 2011.
2. R. Oliemans, Oil-water liquid flow rate determined from measured pressure drop and water hold-up in horizontal pipes, J. of the Braz. Soc. of Mech. Sci. & Eng. 33, pp. 259-264, 2011.

Projectleaders
RVA Oliemans, RF Mudde, RAWM Henkes

Researchtheme
Complex structures of fluids

Participants
U Kadri

Cooperations
Shell, TNO, DSM

Funded
STW

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

Start of the project
2003

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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

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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 turns 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

Since the recent start of this project, a multi-topic literature review has been carried out. That includes the chemical properties of asphaltenes, the thermodynamic models proposed that describe asphaltene phase separation and on the work that has been conducted so far by others on the deposition of asphaltenes under flow conditions. Based on the results of the literature study a structured research plan is defined. This will include numerical simulations in which the path and growth of particles is tracked using a turbulent liquid flow carrier in a pipe configuration.

Dissertations

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Scientific Publications

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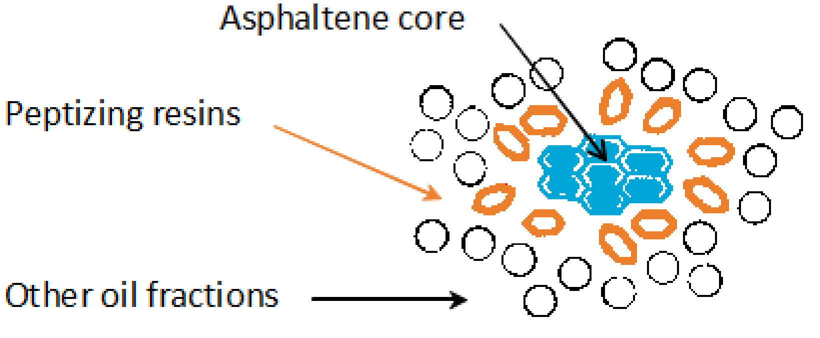
Asphaltene structure



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

Project Aim

This DSTI 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

During 2011, the main focus has been on the methods to obtain useful experimental data from the large scale test rig. This rig has been further optimized, but problems with the used liquids hampered progress. The main results are the identification of the wiremesh sensor and endoscope with high speed cameras as useful techniques which will be fully used in 2012 to increase understanding of swirling flow.

Dissertations

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Scientific Publications

1. Inline oil-water separation in swirling flow, proc 8th Int. Conf. CFD in Oil & Gas, Metallurgical and Process Indus-tries, Trondheim, June 2011, J.J. Slot, L.J.A.M. van Campen, H.W.M. Hoeijmakers, R.F. Mudde.
2. Swirling flow for oil/water separation, posters for 2011 FOM meeting and the NPS-11 meeting, L.J.A.M. van Campen, J.J. Slot, R.F. Mudde and H.W.M. Hoeijmakers.
3. An axial cyclone for oil/water separation, paper, poster and presentation for the 12th Int. Conf. Multiphase Flow in Industrial Plants, L.J.A.M. van Campen, J.J. Slot, R.F. Mudde and H.W.M. Hoeijmakers.

Projectleaders

RF Mudde

Researchtheme

Complex dynamics of fluids

Participants

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

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PROJECTLEADERS
RF Mudde, HEA van den Akker
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
F Mousazadeh, RF Mudde,
HEA van den Akker
COOPERATIONS
ECE Ouwerkerk, B Witkamp
FUNDED
Shell Global Solutions

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

START OF THE PROJECT
2009
INFORMATION
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PROJECT AIM

The objective of this project is to develop a fluid mechanical model of the formation of hot spots in a three-phase trickle bed reactor. We use an Eulerian multiphase modeling to solve numerically the three-phase flow, the chemical reactions and thermodynamics.

PROGRESS

The project started with literature review. After literature review we started running simulations. First, we performed CFD simulations for two-phase flow (gas phase and stationary solid particles) reactor with reaction. The reaction is in the gas phase between Ethylene and Oxygen which produces Ethylene Oxide. We used an Euler-Euler method to solve the mass, momentum and energy conservation equation for each phase separately. Then we performed CFD simulations for three phase trickle flow reactor taking the reaction between gas and liquid phase into account. The results provide flow field inside the reactor as well as the temperature profile in axial and radial direction. Special attention is given to the radial heat and mass transfer that is a consequence of the lateral mixing induced by the solid particles.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

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Thin oil rims

Project Aim

The optimization of the production of a oil field depends on the ability to control the wells. Water and gas coning, i.e. the flow of water from a pool below the oil or gas from the gas cap, can severely limit the production. Especially in thin oil rims, where horizontal (‘snake’) wells and multi-laterals are applied, coning makes operation and production delicate, as coning can occur at any of the many inflow points. Moreover, counter-intuitive well response and the long time constant involved in the operation of oil wells may easily lead to improper control actions that trigger gas coning. Hence, action by operators to increase the production may lead to unstable behavior and will turn the initial increase finally into a dramatic decrease of oil production and possibly to a loss of reservoir pressure. On the other hand, a proper management of the gas production can, via gas lift, enhance the oil production rate and assure a proper recovery of the oil the entire field. Similarly water coning will not only reduce oil production, but may also lead to almost irreversible water break-through.

Progress

The project has started in the second half of 2008. First a literature study is conducted. Next, a 1D fluid flow model is developed that deals with multiphase flows and can accommodate various intake points in the pipe line. The code can simulate transient mulitphase flows, with an intermittent character. Experiments were conducted in the severe slugging flow loop at Shell Technology Centre Amsterdam, for a downward pipeline-vertical riser system. Experiments were also conducted for horizontal and hilly-terrain pipelines. Analytical models were developed to predict the severe slugging envelop for a downward pipeline-riser configuration. Shell’s in-house multiphase flow simulator, Compas, is used and modified with recently ublished slip correlations to more robustly predict the severe slugging phenomena. The commercial multiphase flow simulator OLGA, is used for comparison purpose. Also, to model severe slugging in a real oil well and especialy, its interaction with a reservoir, a coupled OLGA-steady state near well model is used.

Dissertations

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Scientific Publications

-

Projectleaders
RF Mudde

Researchtheme
Complex dynamics of fluids

Participants
R Malekzadeh, RF Mudde

Cooperations
ISAPP: Shell, TNO

Funded
Shell/TNO

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

Start of the project
2008

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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, A De, MK Stollinger

Cooperations
W de Jong, ES Cho, G Sarras (3mE)

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

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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 PhD Thesis by Oldenhof has been written and will be published in 2012. An extensive experimental database enabling detailed model validation is available. Modeling of the DJHC using a transported probability density function (PDF) allows to study the turbulence-chemistry interaction in more detail. To reduce the computational cost, the chemistry was simplified by a Flamelet Generated Manifold (FGM) method . Combining FGM and PDF methods provides an accurate and efficient numerical method to study turbulent flames. Simulation of the DJHC flame using PDF-FGM have been performed. And the initial results are encouraging. Further improvement of the results will be achieved by accounting for temperature fluctuations in the coflow.

Dissertations

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Scientific Publications

1. De, A, Oldenhof, E, Sathiah, P, Roekaerts, D. Numerical Simulation of Delft-Jet-in-Hot-Coflow (DJHC) Flames Using the Eddy Dissipation Concept Model for Turbulence-Chemistry Interaction. Flow, turbulence and combustion, 87 (4) (2011) 537-567. DOI: 10.1007/s10494-011-9337-0.
2. Oldenhof, E, Tummers, MJ, van Veen, EH, Roekaerts, DJEM. Role of entrainment in the stabilisation of jet-in-hot-coflow flames. Combustion and Flame, 158 (8) 2011, 1553-1563. DOI: 10.1016/j.combustflame.2010.12.018.
3. Etaati, MA, Roekaerts, DJEM, Sarras, G, and Stollinger, MK. Modeling of the Delft jet-in-hot-coflow burner as a non-adiabatic three stream problem. In Proceedings European combustion meeting, T. Griffiths (Ed.), Cardiff, UK, 2011, paper 293, 1-6.
4. Oldenhof, E, Tummers, MJ, Veen, EH van, and Roekaerts, DJEM. High speed measurements in the Delft jet in hot coflow burner. In Proceedings of highly resolved experimental and numerical diagnostics for turbulent combustion, CORIA, Universite Rouen, France, 2011, 7 pages.

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 hat 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. A hybrid PDF-RANS method which is based on a Monte Carlo solution of the PDF has been developed at TUD in past projects. 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. The agreement between simulation result and measurements is very good in the one bar flame, and reasonable in the three bar flame. The three bar flame produces much higher soot concentrations and therefore the radiative heat loss is stronger. The influence of radiative heat loss on the chemical composition has been neglected in the simulations and this explains the less satisfactory simulation results of the high pressure flame. To further improve the simulation results, the effect of radiative heat loss will be included in the chemistry model as a next step.

Dissertations

-

Scientific Publications

-

Projectleaders

DJEM Roekaerts

Researchtheme

Complex dynamics of fluids

Participants

MK Stoellinger

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

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Flameless combustion conditions and efficiency improvement of single- and multi-burner-FLOXTM furnaces in relation to changes in fuel and oxidizer composition (flexFLOX)

Projectleaders
DJEM Roekaerts, MJ Tummers
Researchtheme
Complex dynamics of fluids
Participants
LD Arteaga Mendez, MA Etaati
Cooperations
W de Jong (3mE, TU Delft), WS-Prozesstechnik, Stuttgart Numeca Int., Belgium, TNO glass group
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
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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 the part of the flexFLOX project described here is to study experimentally and validate computational models as well as to develop numerical methods (tabulation chemistry method).

Progress

The effect of hydrogen addition to natural gas turbulent flames was studied in the Delft Jet in Hot Coflow Burner. A study of the flame sensitivity (flame length, liftoff height and stability limits) to the flow conditions was conducted. Time resolved PIV and flame luminiscente meassurements were performed for four selected cases. The studies are currently being extended to the case with mixtures of carbon dioxide and natural gas as fuel, representing a model mixture for biogas. A Single Burner Furnace is being constructed. It contains a recuperative burner and cooling tubes and is equipped with quartz windows enabling laser diagnostic experiments. In this way the properties of flameless combustion of similar fuel mixtures as studied in the jet-in-hot-coflow burner can be studied, but now in the presence of interactions with walls and cooling tubes. Progress on modeling is reported in the contribution by G. Sarras (3mE).

Dissertations

-

Scientific Publications

1. Etaati, MA, Roekaerts, DJEM, Sarras, G, and Stollinger, MK. Modeling of the Delft jet-in-hot-coflow burner as a non-adiabatic three stream problem. In Proceedings European combustion meeting, T. Griffiths (Ed.), Cardiff, UK, 2011, paper 293, 1-6.

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

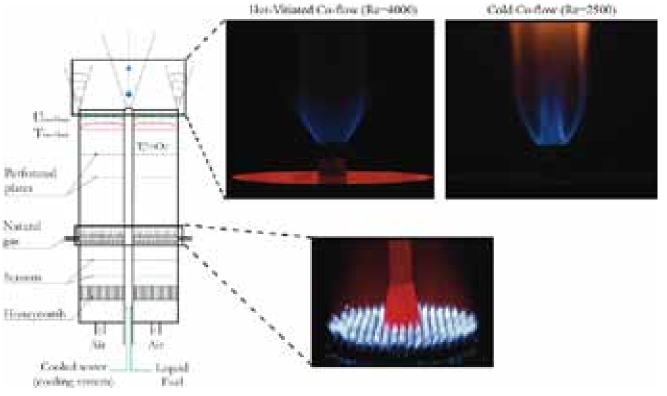
Test rig was completed and co-flow “combustion roar” eliminated from the experiments by slightly lifting the pipe from the burner-holder surface. With the implemented water cooling system, liquid fuel pre-evaporation is absent and it is possible to create hot-vitiated conditions down to 6.5% oxygen volume fraction in the co-flow. A test-matrix of isothermal, evaporating and reacting sprays under cold and hot-vitiated conditions was already defined. Laser doppler anemometry (LDA) was implemented to characterize the co-flow turbulent properties and spray structure under several conditions. High kinematic viscosities due to the hot conditions leads to laminarization of the co-flow and more complex numerical simulations are needed. Autocorrelation function was measured in hot-vitiated conditions and turbulent characteristics attested. Last, sprays do not exhibit any recirculation phenomena and are slightly axisymmetric near the nozzle, especially for high injection pressures. Phase doppler anemometry (PDA) was implemented to obtain the droplet spectrum in the spray domain. In order to obtain a fully characterization of both phases, gas and liquid, the PDA system will be implemented along with the LDA.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Rusli, N.B., Kenjeres, S., Yassin, A.Y.M., Hong, A.K.B. and Amin, N. (2010). Three-dimensional numerical simulations of blood flow behaviour in stenotic and aneurysmal arteries. In O Matveichuk & PJ Rosen Esquivel (Eds.), Proceedings of the 1st Regional Conference on Applied and Engineering Mathematics, pp. 197-202, Malaysia.



PROJECTLEADERS

MJ Tummers, DJEM Roekaerts

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

HRC Rodrigues, MJ Tummers, DJEM Roekaerts

COOPERATIONS

TH van der Meer (U Twente)
S Zhu (U Twente)

FUNDED

Technology Foundation STW (CCC program)

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

START OF THE PROJECT

2010

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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
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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 submitted to the Journal of Atmospheric Sciences. More recent work looks into the influence of the mean state of the free troposphere (the layer between 2 and 10 kilometers) on deep convection. We run an ensemble of 90 high-resolution simulations, and consider both the humidity of the environment and the stratification. Differences of more than a factor 2 in cloud top height are observed, even though the surface forcing is the same in all simulations. It appears that the differences are mainly due to the loss (detrainment) of air from the cloud updraft. The differences can be described in terms of a non-dimensional parameter which describes which mixtures of cloudy and environmental air are positively buoyant, the so-called critical mixing ratio. This parameter is used to formulate simple models that describe the transport of moisture and heat due to the presence of clouds.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

A laboratory experiment to study the effect of turbulence on droplet growth and size distributions in clouds

Project Aim

The aim of the project is to increase the understanding of cloud microphysics, in particular the effect of turbulence on droplet growth and coalescence in convective clouds which affect both the optical properties of clouds and the warm rain formation. Issues like preferential concentration, turbulence enhanced settling velocities and turbulence enhanced collision coalescence will be addressed. Phase Doppler Anemometry (PDA) is to be used for measuring droplet velocities and droplet size distributions simultaneously. Particle Image Velocimetry is to be used to measure instantaneous veocity distribution of droplets.

Progress

The experimental set up has been designed and implemented to produce droplets and to study the behavior in a turbulent environment. During the last year several measurements have been taken to simulate the process of droplet evaporation and collision and coalescence upto the radius of 100 micron in laboratory set up. A number of observations related to effects of different saturation conditions and the distance between the airbrush atomiser and the measuring volume on formation of droplets have been recorded. The Phase Doppler Anemometry (PDA) has been used to measure the axial and vertical velocities of droplets and their diameters. In addition, measurements were done using a Particle Image Velocimetry (PIV) system producing spatial information of the turbulent flow velocities combined with droplet distributions. Multi-fractal analysis is performed of droplet images. The post processing of the velocity data is carried out to find the strain rate — droplet concentration correlation.

Dissertations

-

Scientific Publications

-

Projectleaders
HJJ Jonker, M Tummers

Researchtheme
Complex dynamics of fluids

Participants
T Chatterjee, HJJ Jonker,
M Tummers, RF Mudde, L Portela

Cooperations
Prof.Dr.J.Hunt (J.M.Burgers Center for Fluid Mechanics & University College London), Dr. W.Grabowski (NCAR, Boulder,Colorado,U.S.A)

Funded

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

Start of the project
2007

Information
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High resolution regional climate modeling of convection and precipitation over the Netherlands

Projectleaders
AP Siebesma, SR de Roode, HJJ Jonker

Researchtheme
Complex dynamics of fluids

Participants
R Mendez-Gomez, E Jones, J Van der Dussen, SJ Böing, SR de Roode, HJJ Jonker, AP Siebesma

Cooperations
KNMI, WUR

Funded
Kennis voor Klimaat

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

Start of the project
2010

Information
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Project Aim

Operations at the Amsterdam airport Schiphol are very sensitive to critical weather conditions, like fog, low level clouds, heavy rainfall and strong winds, and sudden changes in these conditions. Changes in our future climate will have its impact on the variability of the weather at Schiphol Airport and on the frequency and intensity at which extreme events will occur. The objective of this project is to evaluate and to improve the capability of a new high resolution weather forecast model HARMONIE to represent and resolve mesoscale systems over the Netherlands such as: isolated convective cells, cold-air outbreaks, squall lines and the precipitation associated with these systems.

Progress

Two series of simulations of the exceptionally rainy period of August 2006 month have been performed. HARMONIE is operated in two different modes: a hindcast mode and a climate mode. In the hindcast mode, consecutive models are started each day at 12 UTC from the ECMWF analysis. Each model integration is 36-h long and the period from 12h to 36h is used for the evaluation. The hindcast mode enforces the simulated atmospheric circulation to stay close to the observed circulation which facilitates a comparison with observations on a daily level. The hindcast results are therefore indicative for what we can expect from HARMONIE when used as an operational weather forecast model. The total amount of precipitation of the HARMONIE hindcast (191 mm) is very close to the observations (195 mm). The HARMONIE climate run (224 mm) overestimates the observational amount. Both HARMONIE runs do not reproduce the observed contrast between the coastal and the inland precipitation but rather simulate a rather flat spatial distribution. To better understand why the spatial distribution and the amount of monthly precipitation from HARMONIE climate run differs from the observations the hydrological budget will be analysed. In particular, surface evaporation and the effect of soil moisture will be investigated.

Dissertations

-

Scientific Publications

-

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

Simulation results for the proposed large eddy simulation model intercomparison case have been submitted by all participating groups.An extra advection scheme was implemented in the Dutch LES model, in order to improve the simulations for this case and other intercomparison cases. All submitted model results have been compared with the observations on which this case was based, in an article that is in its finishing stages at the moment. Several sensitivity studies have been performed, to shed light on the sometimes large differences among the model results and between models and observations. Results from many different Single Column versions of climate models from participating groups, have also been submitted. The LES data is now being analysed in order to better understand the results from the SCMs and to find the weak points in these models.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS

SR de Roode, HJJ Jonker, AP Siebesma

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

J van der Dussen, SJ Böing, E Jones, 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

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Droplet-turbulence dynamics under heterogeneous conditions

Projectleaders
HJJ Jonker, L Portela, RF Mudde

Researchtheme
Complex dynamics of fluids

Participants
V Perrin, HJJ Jonker, L Portela, RF Mudde

Cooperations
-

Funded
FOM

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

Start of the project
2010

Information
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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

A parallelized Lagrangian particle tracking module has been added to an existing mixing layer DNS code, together with a collision routine able to compute collision statistics. Different mixing layer and forcing mechanisms have been investigated to obtain a statistically steady state mixing layer. The flow field has been modified to isotropic turbulence for validation purposes. Spectra and turbulent quantities of the isotropic flow field are in agreement with literature values. The gravitational kernel and the tracer particles kernel are in agreement with the theoretical value. The full particle/collision module is being extensively tested and validated with values from the literature.

Dissertations

-

Scientific Publications

-

Predictive Large-Eddy-Simulations: Improving cloud and precipitation forecasting

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. Currently, the LES has been running in forecasting test-mode for nearly 6 months, and we are now analyzing the resulting data.

Dissertations

-

Scientific Publications

-

Projectleaders
HJJ Jonker, AP Siebesma

Researchtheme
Complex dynamics of fluids

Participants
J Schalkwijk, HJJ Jonker, AP Siebesma, RAJ Neggers

Cooperations
KNMI

Funded
TUD, KNMI

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

Start of the project
2010

Information
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Projectleaders
HJJ Jonker, S Kenjeres,
SR de Roode

Researchtheme
Complex dynamics of fluids

Participants
P 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
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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

The cities of Arnhem, Amsterdam and Rotterdam are now involved in this project, each with a neighborhood with specific requests. A detailed analysis has been made of these areas and first simulations for wind and temperature are performed. The first steps towards a surface energy balance are made, with a shadow casting algorithm implemented in the simulation code. Locations of shadow on ground and buildings are now associated with a fixed temperature.

Dissertations

-

Scientific Publications

-

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

A first purely stochastic model based on LES data has been constructed. The model works fine for the steady shallow cumulus case BOMEX. This model has also been succesfully tested for the shallow cumulus case ARM in which a diurnal cycle is included. At this moment the model only works for these 2 specific cases, because it has been designed with the help of LES data based on these cases. Of course, the model should perform under more general circumstances. To achieve this, we will use an existing deterministic parameterization scheme and try to combine it with our stochastic scheme. The first paper called "Stochastic convection parameterization estimated from high-resolution model data" has been submitted to the journal Theoretical and Computational Fluid Dynamics. We are still investigating the possibilities of combing existing determinsitic parameterizations with our stochastic scheme.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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
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Physics of Nuclear Reactors

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.

Experimental and numerical investigation of cross flow in a rod bundle geometry

Project Aim

To develop a deep understanding of the inter sub-channel cross flow in a vertical rod bundle geometry. The project aim is motivated by the existance of the cross flow in the core of light water nuclear reactors and its effect on the local power production and the heat transfer from the fuel rods to the coolant due to different feedback mechanisms. During the project the existance and origin of the large scale vortices near the channel gap interface and their role towards the cross flow mixing will be investigated.

Progress

In the past year, the focus has been on the identification of coherent structures in a realistic bundle geometry as one can find in nuclear reactors. Moreover, cross-flow mixing (i.e. radial mixing) and the modeling have been studied. In order to be able to measure the velocities inside the bundle geometry with LDA, a Refractive Index Matching (RIM) technique was used. For this technique, Fluorinated Ethylene Propylene (FEP) was used as tube material. It had been shown that FEP could be effectively used as a solid RIM material with water at ambient conditions. Experiments on the radial mixing of a passive scalar induced by crossflow showed that the mechanisms responsible for the inter-channel mixing strongly depend on the gap hydraulic diameter. If present, the coherent structures were found to impart a significant contribution towards crossflow mixing for all channel Reynolds numbers. The defense of this PhD project took place on June 23, 2011.

Dissertations

1. Single-Phase Crossflow Mixing In A Vertical Tube Bundle Geometry: An experimental study (PhD thesis).

Scientific Publications

1. Mahmood, A., M. Rohde, et al. (2011). An experimental study on the identification of flow patterns responsible for crossflow in a vertical tube bundle geometry. NURETH-14, Toronto, Canada.

Projectleaders

M Rohde, T van der Hagen, RF Mudde

Researchtheme

Complex structures of fluids

Participants

A Mahmood, M Rohde, T van der Hagen, RF Mudde, L Portela

Cooperations

PNR/RID (TU Delft), Multi-Scale Physics (TU Delft), NFI Limited (Japan)

Funded

HEC/NUFFIC, TU Delft

University	45 %
FOM	-
STW	-
NWO Other	-
Industry	10 %
TNO	-
GTI	-
EU	-
Scholarships	45 %

Start of the project

2006

Information

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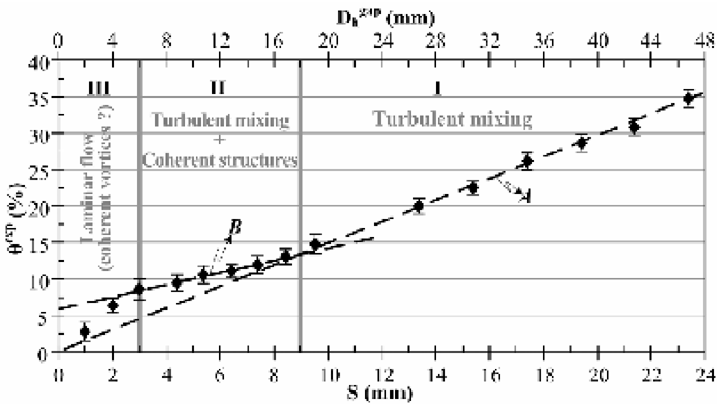

Inter-channel mixing as a function of various gap spacing, for constant Rech = 10,000. For comparison purposes, the gap hydraulic diameter is shown on a secondary x-axis. The dashed line represents a linear fit to the data points.

The natural circulation driven supercritical water nuclear reactor: a fundamental stability study

Projectleaders
M Rohde

Researchtheme
Complex structures of fluids

Participants
C T'Joen

Cooperations
University of Pisa

Funded
NWO (Veni Scheme)

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

Start of the project
2007

Information
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Project Aim

One of GEN-IV reactor concepts is the so-called supercritical water reactor (SCWR), in which supercritical water is used to cool the nuclear core. This would result in a higher thermal efficiency. An important topic that needs to be studied is the reactor stability. In this project the possibility of cooling the SCWR by natural circulation is considered. This enhances the inherent safety of the reactor, since perturbations in the flow are weakened by the density response in the core (negative feedback). A consequence, however, is that the physics become more complicated. Hence, studying (and guaranteeing) stability of such a system will become a great challenge.

Progress

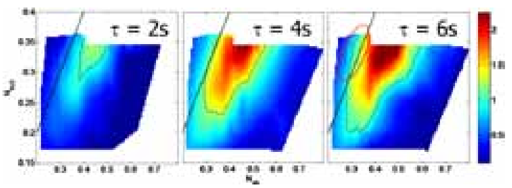
An experimental facility 'DeLight' was designed and constructed at the Delft University of Technology. This facility is a scaled version of the European concept of the SCWR, named the HPLWR and can operate in both natural and forced circulation mode. To lower the pressure and temperatures a scaling fluid was used, Freon R-23. To mimick a nuclear reactor, artificial neutronic feedback was used. It was shown that when operating in natural circulation, there are no thermo-hydraulic instabilities. However, the neutronic feedback can induce instabilities. These are then quantified by the 'decay ratio' of the measured signals. By varying the inlet temperature and power of a system, stability maps can be drawn which visualise the system behaviour at different operational conditions. By varying the fuel time constant τ it was shown that at higher fuel time constants the system becomes increasingly unstable, as shown in the figure below.

Dissertations

-

Scientific Publications

1. T'Joen, C. G. A. and M. Rohde (2011). Experimental study on the stability of a natural circulation driven super-critical water cooled reactor. 22nd international symposium on transport phenomena, Delft, The Netherlands.
2. T'Joen, C. G. A., F. Kam, et al. (2011). Stability research on a natural circulation driven SCWR. NURETH-14, Vancouver, Canada.
3. T'Joen, C. and M. Rohde (2011). Experimental study on natural circulation driven HPLWR. ISSCWR-5, Vancouver, Canada.
4. T'Joen, C. and M. Rohde (2011). Stability research on the natural circulation driven HPLWR. ISSCWR-5, Vancouver, Canada .
5. T'joen, C., L. Gilli, et al. (2011). "Sensitivity analysis of numerically determined linear stability boundaries of a supercritical heated channel." Nuclear Engineering and Design 241(9): 3879-3889.
6. Rohde, M., C. P. Marcel, et al. (2011). "Downscaling a supercritical water loop for experimental studies on system stability." International Journal of Heat and Mass Transfer 54(1-3): 65-74.



Heat transport and mixing in supercritical flows (as part of the THINS project : Thermal-Hydraulics in Innovative Nuclear Systems)

Project Aim

The aim of this research project is to investigate the turbulent heat transport in a supercritical fluid near a heated wall. The DeLight facility (located at the section of Physics of Nuclear Reactors) consists of an annular pipe flow with a heated core, and it is designed to perform experiments under normal conditions as well as near the onset of heat transfer deterioration. The study of the change of transport coefficients at this point is the main objective of this part of the project. Secondly, the mixing of supercritical jets and its influence on the opposing wall (thermal fatigue) will be studied. The fluid used for this study is the Freon R23 (CHF3) to reduce pressure and temperatures.

Progress

Challenges in this project are of experimental nature: the thermal boundary layer is roughly ten times smaller than the momentum boundary layer due to the high Prandtl number. Moreover, as the density of the fluid changes drastically near the critical point, the laser beams might bend in a complex manner. Nevertheless, numerical estimations of the beam path show that these experiments and the required accuracy are within reach. The experimental facility is close to completion, and LDA measurements will be started early 2012. The supercritical jet experiment is still in the design stage; the layout for the vessel containing the plenum with the three jets is currently completed and validated.

Dissertations

-

Scientific Publications

1. Roelofs, F., M. Rohde, et al. (2011). European developments in single phase turbulence for innovative reactors. NURETH-14, Toronto, Canada.
2. Peeters, J. W. R., C. G. A. T'Joen, et al. (2011). Investigation of the thermal boundary layer development length in supercritical water flows in an annulus at laminar flow conditions. 22nd international symposium on transport phenomena, Delft, The Netherlands.

Projectleaders

M Rohde

Researchtheme

Complex dynamics of fluids

Participants

N Warncke, C T'Joen

Cooperations

KIT, CEA, SCK-CEN, ENEA, NRG, PSI, HZDR, KTH, U Pisa, U Modena, U Bologna, Ansaldo, CD-adapco, IJS, ICL, ASCOMP, IRSN, GRS, CRS4, UCL, TUM, LUT, TEES

Funded

EU

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

Start of the project

2010

Information

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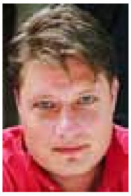
Optically accessible test section with central heating rod (left) and the entire annulus required to fully develop the flow before the Freon enters the test section (right)

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.

Project Aim

The aim of the project is to synthesize monodisperse core-shell nanoparticles with pre-defined properties, understand factors influencing the morphology, as well as getting insights into the coating process of nanoparticles in liquid and gas phase.

Progress

Progress in fabrication of microfluidic devices with well-established mixing, injection, cooling rate, multiple temperature zones as well as in situ UV-Vis spectroscopic measurements has been made. A lot of time was spent on accurate determination of the mixing time inside droplets based on fluorescence images taken by high-speed camera. Furthermore, gold-silver core-shell nanoparticles were synthetized in microfluidic devices with a tunable thickness of silver shell. First preliminary results were obtained on in situ growth study of gold nanoparticles from which we can deduce kinetics of the growth.

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 (Ministry of Economic Affairs)

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

Start of the project

2009

Information

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Microfluidic screening of novel solvents for CO_2 capture

Projectleaders
MT Kreutzer, A Bardow,
PJ Hamersma

Researchtheme
Complex dynamics of fluids

Participants
S Lefortier

Cooperations
Decarbit project

Funded
European Community's Seventh Framework Programme

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

Start of the project
2008

Information
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Project Aim

The aim of the project is to develop a microfluidic screening method to determine solubility and diffusivity of CO2 in solvents.

Progress

We developed and improved a microfluidic screening method to simultaneously determine solubility and diffusion of CO_2 in solvents. From the absorption of the bubbles in the microfluidic setup, corrected for the expansion due to the pressure gradient, we can obtain information about solubility, diffusion coefficient and mass transfer characterization. For validation purposes, solvents with known characteristics such as Depeg (Selexol), NMP, Potassium Carbonate, 1-octanol, water and the ionic liquid [bmim][Tf2N] were analyzed. The results obtained show a good agreement with literature values. A relation between the mass transfer coefficient in the present setup and diffusion coefficient was found. The new method was easily extended to investigate a ternary mixture of physical solvents, thereby establishing the possibility of rapid screening of complex fluid mixtures.

Dissertations

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Scientific Publications

1. Lefortier, SGR, Hamersma, PJ, Bardow, A & Kreutzer, MT (). Rapid microfluidic screening of solubility and mass transfer in CO2 solvents. In s.n. (Ed.), 2011 AIChE annual meeting conference proceedings (pp. 1-1). Minneapolis, US: s.n.

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

-

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
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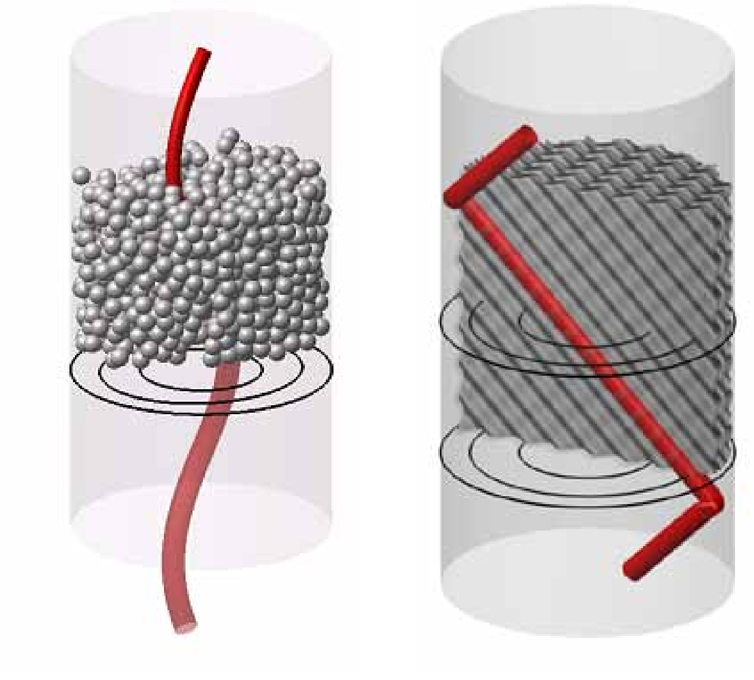

In a randomly packed bed (left), there is no convective transport of gas and liquid in radial direction, leading to a poor cooling of gas and liquid. The structured packings we use (right) have diagonal channels, forcing an efficient heat exchange of the gas and liquid with the wall.

Projectleaders
RF Mudde, PJ Hamersma, JR van Ommen

Researchtheme
Complex dynamics

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
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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 probe and X-ray 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. In the systems with the St<<1, an increase in the solids volume fraction: changes the dominant force: surface tension to inertia; makes the bubbles more oblong.

Dissertations

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Scientific Publications

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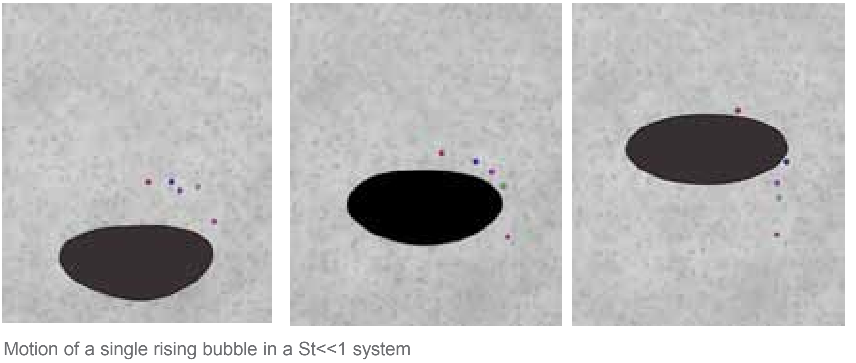

Motion of a single rising bubble in a St<<1 system

PROJECT AIM

Our goal is to study the evaluate the local rate of photon absorption by the photocatalytic particles in multiphase photoreactors, with solid and gas-phase particles interacting with photons. Since a photoreaction is only triggered in the presence of photons, the gradient in the rate of photon absorption results in a gradient in the photoreaction rate in the photoreactor, even in ideally-mixed reactors. Hence, our study is of importance for photocatalytic kinetic studies at lab scales and also for photoreactor design. Eventually we aim to quantify the local amount of photon absorption and incorporate it into the hydrodynamics of the photoreactor to predict the maximum achievable photonic efficiency.

PROGRESS

The propagation of light in a liquid-solid slurry containing TiO2 particles, using simplified flux models as well as a Monte Carlo simulation was investigated. Based on such analysis, and including the effect of mixing and diffusion, we have proposed guidelines for the design of two-phase photocatalytic batch reactors that help to predict the intrinsic photoreaction rate by separating the photoreactor properties from the photocatalyst properties. Also, the effect of diffusion limitations in a flow reactor at laminar regime was investigated. We have further studied the scattering of light by bubbles in liquid based on Snell and Fresnel's laws of reflection and refraction. The outcome of this study was implemented in a Monte Carlo approach to evaluate the absorption of light by TiO2 particles in a three-phase slurry bubble column where both bubbles and TiO2 particles interact with the light.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

-

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

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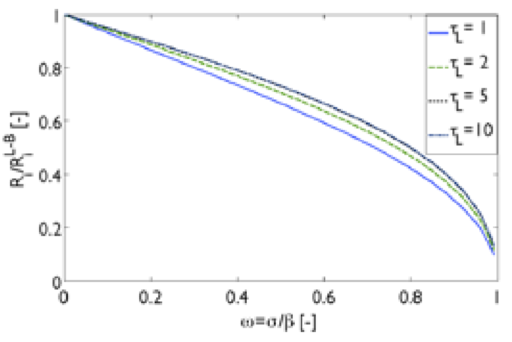
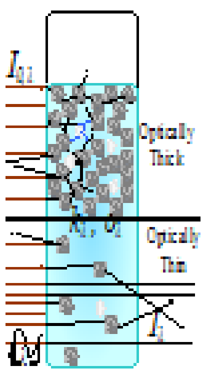
Deviation of photoreaction rate (Ri, including the effect of scattering by photocatalyst) from that of Lambert-Beer (RiL-B , neglecting the scattering) vs. photocatalyst scattering albedo (ω), at different optical thicknesses(τL)





Absorption and scattering of light by particles in a multiphase photoreactor

Ultrathin coating of fine particles using atomic and molecular layer deposition

Projectleaders
JR van Ommen, GMH Meesters

Researchtheme
Complex structures of fluids

Participants
D Valdesueiro

Cooperations
DSM and several other partners within the Marie Curie Program PowTech

Funded
EU - Marie Curie, DSM

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

Start of the project
2011

Information
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Project Aim

The goal of the project is the production of core-shell micron-sized particles, by using a novel technique called Atomic Layer Deposition or Molecular Layer Deposition. 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 of degradation by the environment, for example via oxidation or dissolution. The second one is to activate the surface of the particles by depositing valuable materials, such as catalytic material.

Progress

The progress during the first seven months of the project has been mainly of learning the basic knowledge to approach the project. At this moment, the experimentation is about to begin, firstly by improving the process of fluidization of the fine particles, and once an optimum method for fluidizing is achieved, we will coat particles for different applications.

Dissertations

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Scientific Publications

-

Project Aim

The goal of the project is to develop new strategies of signal analysis for fluidized beds to characterize (changes in) the hydrodyanmics. This can, for example, be used for on-line monitoring of fluidized bed drying and granulation. Due to the implementation of the Process Analytical Technology initiative in the pharmaceutical industry, there is an increasing interest to apply on-line monitoring tools for process control. In spite of the amount of the existing techniques developed to monitor the beds, there are only a few techniques available to do monitor granule properties on-line.

Progress

During 2011 we applied several techniques of signal analysis to the pressure fluctuation signal obtained in fluidized bed dryers and granulators. Some of them had already been used before –attractor comparison method and analysis of the dominant frequency of the signal– and others have been developed in this project: standard deviation of a narrow frequency band. We concluded that the granules size as well as the final drying point could be monitored with the techniques proposed. Moreover, we published a review paper of signal analysis of fluidized bed pressure fluctuations, and explored possible multifractal behaviour of these signals.

Dissertations

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Scientific Publications

1. Lilian de Martín, Kaspar van den Dries, J. Ruud van Ommen. Comparison of three different methodologies of pressure signal processing to monitor fluidized-bed dryers/granulators. Chemical Engineering Journal 172 (2011) 487– 499.
2. Van Ommen, J.R., Sasic, S., Van der Schaaf, J., Gheorghiu, S., Johnsson, F., Coppens, M.O., 2011. Time-series analysis of pressure fluctuations in gas-solid fluidized beds - A review. International Journal of Multiphase Flow 37, 403-428.
3. Ghasemi, F., Ruud van Ommen, J., Sahimi, M., 2011. Analysis of pressure fluctuations in fluidized beds. I. Similarities with turbulent flow. Chemical Engineering Science 66, 2627-2636.

Projectleaders

JR van Ommen

Researchtheme

Complex dynamics of fluids

Participants

L de Martín, K van den Dries, M-O Coppens, S Sasic, M Sahimi and others

Cooperations

-

Funded

TUD

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

Start of the project

2010

Information

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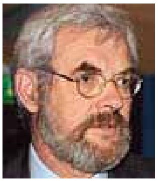
Aerodynamics

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.

Advanced image analysis techniques for particle image velocimetry and PIV uncertainty estimators

Project Aim

Study of digital algorithms to increase the reliability and the velocity measurement dynamic range. The work is based on the exploitation of time-sequences of 2D recordings or 3D reconstructions from tomographic PIV. Specific dat analysis techniques are investigated to obtain a-posteriori error estimates from PIV experiments.

Progress

In 2010 the Pyramid Correlation algorithm has been introduced, which makes use of multiple image pairswith varying time-separation. The method exhibits an increased robustness in comparison to single-pair correlation and measurement noise is decreased both in numerical simulations as well as in rel experiments. In 2011 the problem of measurement gaps is dealt with by introducing Navier-Stokes solutions in relatively large spatial gaps of data. A Pattern Tracking method is investigated since mid 2011 to extend the velocity dynamic range of time-resolved PIV. The method is based on a time-accurate image-sequence deformation to achieve high-order accuracy of the fluid parcel trajectory and of the motion of the surrounding parcels.

Dissertations

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Scientific Publications

1. Sciacchitano A, Scarano F, Pyramid correlation for time-resolved PIV, PIV11, Kobe, JP.
2. Scarano F, Sciacchitano A, Robust elimination of light reflections in PIV, PIV11, Kobe, JP.

Projectleaders

F Scarano

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

A Sciacchitano, K Lynch

Cooperations

LaVision GmbH

Funded

LaVision GmbH

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

Start of the project

2008

Information

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PROJECTLEADERS
H Bijl, AH van Zuijlen

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
TP Scholcz

COOPERATIONS
University of Bristol, INRIA, CSIR, DLR, IRIAS, University of Liverpool, Politecnico di Milano, NUMECA, Optimad Engineering, Airbus-UK, EADS-MS and IITP and UCT

FUNDED

EU (FP7)	
University	-
FOM	-
STW	-
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	100 %
Scholarships	-

START OF THE PROJECT
2010

INFORMATION
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PROJECT AIM

TUD is focusing on high fidelity computations and increasing their computational speed by using reduced order models to speed up the convergence of the solution, especially for fluid structure interaction computations. For this algorithms have to be developed to take into account the information from a reduced order model in the full order model computation (and possibly vice versa: correct (or increase the accuracy of) the reduced order model using results from the full order model).

PROGRESS

1) A literature survey is performed to numerical methods that incorporate information of reduced order models in order to speed up the computation.

2) A technique from multi-fidelity optimization, called space-mapping, is applied to 1-D academic fluid-structure interaction problem. Space mapping allows to accelerate the partitioned fluid-structure algorithm using information of a reduced order model. The results will be presented at the conference “Coupled problems 2011”, Kos Island, Greece, 20-22 june 2011

3) The Aggressive Space Mapping algorithm is applied to a 2-D academic fluid-structure interaction problem. The numerical performance of the method is assessed for various levels of coupling strength and time step sizes. The results will be presented in a peer-reviewed scientific journal.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. T. Scholcz, A. van Zuijlen and H. Bijl. A multi-model incremental adaptive strategy to accelerate partitioned fluid-structure algorithms using space-mapping. IV International Conference on Computational Methods for Coupled Problems in Science and Engineering. 2011.

FLOVIST: Flow visualization Inspired aeroacoustics by Time Resolved Tomographic Particle Image Velocimetry

Project Aim

Development of advanced experimental techniques for the aeroacoustic analysis of turbulent flows of relevance in aerodynamics. The research is based on the extensive use of advanced flow diagnostics and in particular of time-resolved 3D velocimetry by Tomography. The technique is based on acoustic source detection and sound emission modelling based on acoustic analogies. The applications cover aircraft aerodynamics (trailing-edge noise) propulsion (jet noise) and include the area of wind turbines (rotor blade tip and trailing aerodynamics).

Progress

Advances in Tomographic PIV. In 2010 the tomographic reconstruction of 3D particle fields based on two exposures (motion tracking enhanced MTE-MART) has been experimentally verified, with significantly improved capabilities in highly seeded flows. Time resolved analysis of transitional jets. Experiments performed by high-resolution time-resolved tomographic PIV were performed on circular, chevron and swirled jets (collaboration with University of Naples). The data show that the Powell acoustic source can be identified and associated to specific flow structures. Time-resolved Tomo-PIV of the flow past a NACA-0012 airfoil. The study is conducted to characterize the statistical properties of turbulence undergoing the airfoil sharp edge. First evidence is obtained of counter-hairpin vortices contributing in the mixing process in the near wake. High-speed PIV is applied to determine the body-forces applied on a fluid under the effect of a plasma actuator. The work is based on the application of the solution of the fluid momentum equation by measurement of unsteady terms and estimation of the pressure-gradient term.

Dissertations

-

Scientific Publications

1. Violato D, Scarano F, Three-dimensional evolution of flow structures in transitional circular and chevron jets, Physics of Fluids 23, article 124104.
2. Ghaemi S, Scarano F, Counter-hairpin vortices in the turbulent wake of a sharp trailing edge, Journal of Fluid Mechanics 689, pp 317-356.
3. Moore P, Violato D, Scarano F, Two techniques for PIV-based aeroacoustic prediction and their application to a rod-airfoil experiment, Experiments in Fluids, 50.
4. Kotsonis M, Ghaemi S, Veldhuis L, Scarano F, Measurement of the body force field of plasma actuators, Journal of Physics D-Applied Physics, 44, article 045204.
5. Novara M, Scarano F, Performances of motion tracking enhanced Tomo-PIV on turbulent shear flows, Experiments in Fluids, DOI: 10.1007/s00348-011-1187-y.
6. Scarano F, Moore P, An advection model to increase the time-resolution of PIV time-series, Experiments in Fluids, DOI: 10.1007/s00348-011-1158-3.

Projectleaders

F Scarano

Researchtheme

Advanced experimental methods for fluid flow analysis

Participants

P Moore, M Novara, D Violato, S Ghaemi, A Ianiro, R Theunissen, K Lynch

Cooperations

Nationaal Luchtvaart Lab. (NLR)
German Aerospace Centre (DLR)
LaVision GmbH, University of Naples
University of Poitiers

Funded

European Research Council (ERC)

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

Start of the project

2008

Information

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PROJECTLEADERS
FFJ Schrijer, F Scarano, BW van Oudheusden
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
Z Sun, K Lynch, R Giepman
COOPERATIONS
ESA, VKI, DLR, NLR, ASTRIUM, TNO
FUNDED

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

START OF THE PROJECT
2003
INFORMATION
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PROJECT AIM

Development and implementation of non-intrusive measurement techniques for high-speed compressible flows with special focus on particle image velocimetry. The measurements techniques are subsequently used to investigate flow phenomena that are pertinent to launchers, high-speed air transport systems and reentry vehicles. Specific topics that are studied are shockwave boundary layer interaction, compressible boundary layer transition and compressible baseflows.

PROGRESS

1) Investigation of the flow over a micro-ramp in a Mach 2 turbulent boundary layer by means of TOMO-PIV.

2) Investigation of transonic buffeting on rocket afterbodies. The unsteady flow field over a generic rocket after-body was studied by means of high speed PIV. Furthermore, measurements were performed on a 1:60 scale of an Ariane V launcher using HS-PIV within an ESA technical research program (TRP).

3) Development of nano-scale tracer particles for use in high speed compressible flows

4) Investigation of Görtler vortices in a Mach 7.5 double compression ramp flow.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Schrijer, FFJ, Sciacchitano, A, Scarano, F,Hannemann, K, Pallegoix J-F., Maseland JEJ & Schwane, R. (2011). Experimental investigation of base flow buffeting on the Ariane 5 launcher using high speed PIV. In G Saccoccia (Ed.), Conference proceedings 7th European Aerothermodynamics Symposium on Space Vehicles (pp. 1-8). Noordwijk: ESA-ESTEC.
2. Hannemann, K, Pallegoix, J.F., Lambaré, H, Maseland, J., Frey, AM, Deck, S, Schrijer, FFJ & Schwane, R. (2011). Launch vehicle base buffeting - recent experimental and numerical investigations. In G Saccoccia (Ed.), Conference proceedings 7th European Aerothermodynamics Symposium on Space Vehicles (pp. 1-8). Noordwijk: ESA-ESTEC.
3. Sun, Z, Schrijer, FFJ, Scarano, F & van Oudheusden, BW (2011) 3D Flow Organization Generated by a Micro-Ramp in a Supersonic Boundary Layer. Conference proceedings 28th International Symposium on Shock Waves, 2011, 17-22 July, Manchester.

Efficient Navier Stokes based simulation of non-linear aeroelasticity and validation of the aeroelastic solver by means of experiments

Project Aim

To couple a Navier Stokes based flow solver (RANS) to a non-linear aeroelastic structural model, whereby the main focus is on improving the accuracy of the solution and reduce the computational time in order to enable aeroelastic RANS computations for wind turbines. Furthermore, validation of the aeroelastic solver is a key-issue. Hereto, aeroelastic experimental work must be conducted.

Progress

In the first part of 2011 a new aeroelastic experiment is conducted to investigate fluid structure interactions for a wing having 1 degree of freedom (DOF) with an oscillating flap. The degree of freedom is the plunging motion. Postprocessing of the experimental data is conducted, consisting of PIV data and sensor read outs. Furthermore, simulations are performed to assess wind tunnel wall corrections for the unsteady problem under consideration. In the last part of 2011 a paper is written about a previous experiment where the unsteady flow about a wing with oscillating flap is investigated.

Dissertations

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Scientific Publications

1. J.J.H.M. Sterenborg, A.H. Van Zuijlen and H. Bijl. Experimental benchmark and numerical validation of a free heaving airfoil. IV International conference on computational methods for coupled problems in science and engineering.

Projectleaders

H Bijl

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

JJHM Sterenborg, H Bijl, AH van Zuijlen

Cooperations

Numeca International, ECN, WMC

Funded

SenterNovem, EOSLT-04001 (INNWIND)

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

Start of the project

2008

Information

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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	100 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT
2010
INFORMATION
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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. The experimental work has two components: 1) the study of related generic aeroelastic phenomena and 2) a more detailed characterization of the DelFly aerodynamics (wake structure; forward flight regime). A flow visualization study was performed in a water tank to investigate the effect of isotropic wing flexibility in hovering flight and clap-and-fling interactions. A second study was directed towards the characterization of the DelFly flapping-wing vortex wake in fowrad fligth configuration in a wind tunnel.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. G.C.H.E. de Croon, B.W. van Oudheusden, B. Remes, C. De Wagter, R. Ruijsink: Aerodynamics and Autonomy of the DelFly, International Workshop on Bio-Inspired Robots, Nantes, France, 6-8 April 2011.
2. M.Perçin, Y.Hu, B.W.van Oudheusden, B.Remes, F.Scarano: Wing flexibility effects in clap-and-fling, International Micro Air Vehicle Conference and Flight Competition (IMAV 2011), ‘t Harde, The Netherlands, 12-15 Sept. 2011, 8 pp.
3. W.B. Tay, H.Bijl, B.W. van Oudheusden: Analysis of tail effects in flapping flight, International Micro Air Vehicle Conference and Flight Competition (IMAV 2011), ‘t Harde, The Netherlands, 12-15 Sept. 2011.

PIV-based non-intrusive determination of unsteady aerodynamic loads

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 in low-speed aerodynamics and industrial fluid dynamics. 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. A combined analysis was made using theoretical predictions and a numerical simulation ("synthetic experiment") to identify critical parameters. Verification with experimental investigation of a bluff body (square cross-section prism) in which acquisition of both planar and volumetric ("thin-tomo") PIV data were carried out, to assess the impact of 3D flow information. In the experimental study, the pressure results were validated against reference data obtained with dynamic surface-mounted pressure sensors.

2) Determination of pressure fields and integral loads under compressible flow conditions: extension to the study of sectional loads on a propeller blade, based on phase-locked multiple-plane stereo-PIV (cooperation with DNW). After a single-plane study, the method was extended to a multiple-plane approach in order to cover the three-dimensional flow near the tip region and, ultimately, the entire propeller blade was represented (see figure).

Dissertations

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Scientific Publications

1. D.Ragni, B.W. van Oudheusden, F.Scarano: Non-intrusive aerodynamic loads analysis of a scaled DHC Beaver aircraft propeller blade, 3AF 46th Symposium of Applied Aerodynamics, Orléans, France, 28-30 March, 2011.
2. D.Ragni, B.W. van Oudheusden, F.Scarano: Drag coefficient accuracy improvement by means of particle image velocimetry for a transonic NACA0012 airfoil. Measurement Science & Technology, Vol.22 (2011), Issue: 1, Article Number: 017003, 5 pp.
3. D.Ragni, B.W. van Oudheusden, F.Scarano: Non-intrusive aerodynamic loads analysis of an aircraft propeller blade, Exp. in Fluids, Vol.51, No.2, 2011, pp. 397-409.
4. D.Ragni, B.W. van Oudheusden, F.Scarano: 3D pressure imaging of a propeller blade tip region by phase-locked stereoscopic PIV, Exp. Fluids, DOI 10.1007/s00348-011-1236-6, 15 pp. (published online december 2011).
5. R.de Kat, B.W. van Oudheusden: Instantaneous planar pressure determination from PIV in turbulent flow, Exp. in Fluids, DOI 10.1007/s00348-011-1237-5, 18 pp. (published online december 2011).

Projectleaders
BW van Oudheusden, F Scarano

Researchtheme
Complex dynamics of fluids

Participants
R de Kat, D Ragni

Cooperations
DNW, NLR

Funded
STW

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

Start of the project
2006

Information
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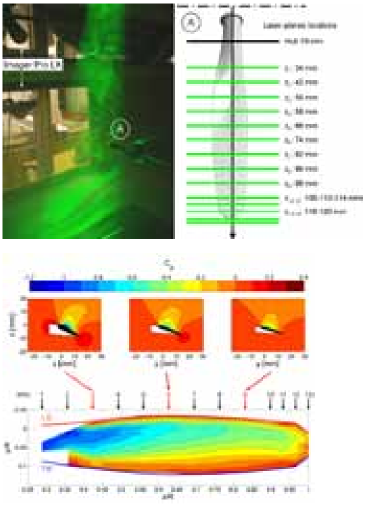
Three-dimensional pressure field and surface pressure distribution of a propeller blade obtained from PIV.



Dielectric barrier discharge plasma actuators for flow control

Projectleaders
LLM Veldhuis, M Kotsonis
Researchtheme
Complex dynamics of fluids
Participants
M Kotsonis
Cooperations
-
Funded
TU Delft

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

Start of the project
2007
Information
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Project Aim

Advanced diagnostics and characterization of Dielectric Barrier Discharge (DBD) plasma actuators. The project is concerned with the elucidation of the momentum transfer processes, attributed to plasma actuators, with special emphasis on unsteady flow control. Time resolved PIV, in conjunction with decomposition of Navier Stokes terms has been employed for the extraction of the plasma induced force field. Additionally, time resolved PIV has been applied in conjunction with phase shifting techniques. These have provided insight into the unsteady, periodic forcing of the actuator within the actuation period. Lastly, numerical studies on flow control concepts such as active transition delay have been conducted.

Progress

1) Extraction of the distributed body force field exerted by the actuator on the flow. Novel methods based on time resolved PIV and Navier Stokes terms decomposition have been developed and applied.

2) Fundamental investigations on the unsteady forcing behavior of the actuator, using time resolved PIV and phase shifting techniques. Several actuation waveforms have been tested and compared, further elucidating the effect of voltage waveform shape.

3) Capitalization of the investigated forcing mechanisms for the creation of novel actuation waveforms. These are based on asymmetric shapes which have been found to increase force production while maintaining low power consumption

4) Numerical investigation on the concept of active Tollmien-Schlichting wave cancellation using plasma actuators. The actuators have been modelled using the previously extracted force fields. An adaptive controller based on the filtered-x LMS algorithm has been directly implemented into the OpenFOAM environment. Successful control of TS instabilities has been demonstrated.

Dissertations

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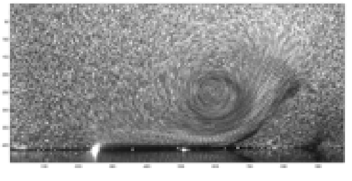

Visualization of the induced flowfield due to the plasma actuator

Scientific Publications

1. Kotsonis, M., Ghaemi, S., Veldhuis, L. and Scarano, F. Measurement of the body force field of plasma actuators. Journal of Physics D: Applied Physics, 44, 2011.
2. Giepman, R. and Kotsonis, M. On the mechanical efficiency of dielectric barrier discharge plasma actuators. Applied Physics Letters, 98, 2011.
3. Kotsonis, M. and Ghaemi, S. Forcing Mechanisms of DBD Plasma Actuators at Carrier Frequency of 625 Hz. Journal of Applied Physics, 110, 2011.
4. Kotsonis, M, and Ghaemi, S. Performance Improvement of Plasma Actuators using Asymmetric High Voltage Waveforms. Journal of Physics D: Applied Physics , 45, 2012.
5. Kotsonis, M., Giepman, R. and Ghaemi, S. Numerical Study on Control of Tollmien-Schlichting Waves Using Plasma Actuators. In 29th AIAA Applied Aerodynamics Conference, 2011, Honolulu, USA.

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.

Progress

1) Goal-oriented techniques have been applied to the determination of enrichment functions for finite-element discretizations which minimize the total number of degrees of freedom required near boundaries.

2) Goal-oriented techniques have been applied to the calibration of stabilization parameters for anisotropic solutions

3) An interior penalty discontinuous Galerkin method has been developed for a class of monotone quasilinear elliptic problems

4) Preliminary LES computations have been performed to examine the near-wall excitations provided by nanopulse plasma actuators.

Dissertations

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Scientific Publications

1. Hulshoff, S. J., Munts, E. A. and Labrujere, J.: Wall-stress boundary conditions for variational-multiscale LES., International Journal for Numerical Methods in Fluids, Volume 66, Issue 11, pages 1341–1353, 20 August 2011.
2. T.M. van Opstal, S.J. Hulshoff and C.V. Verhoosel.: A Robust Solution Procedure for the Transonic Small-Disturbance Equation in Fluid-Structure Interactions, The Open Aerospace Engineering Journal, pages 1-10, 22 March, 2011.

Projectleaders

SJ Hulshoff, H Bijl

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

L Chen, L Cheng, W Edeling P Fick, I Popov

Cooperations

University of Texas, Austin

Funded

STW, Chinese Scholarship Council (CSC)

University	25 %
FOM	-
STW	10 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	65 %

Start of the project

2008

Information

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NEW SIMULATION TECHNIQUES FOR FLOWS INTERACTING WITH TRANSFORMING STRUCTURES

PROJECTLEADERS
H Bijl, AH van Zuijlen
RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
J Kreeft, V Kazemi Kamyab
COOPERATIONS
Tata Steel, Philips. Numeca Int.
FUNDED
STW

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

START OF THE PROJECT
2008
INFORMATION
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PROJECT AIM

Development, implementation and application of revolutionary, but generic, numerical algorithms for problems where gas or fluid flows interact with material structures being cooled through a phase transformation. Material properties change dramatically due to phase transformation and, as a result, so does the interaction between the materials structure and the flow. This interaction of multi-physics and multi-scale is present in industrial applications like the continuous casting of steel slabs. New simulation techniques are required for the accurate, robust and fast simulation of such problems.

PROGRESS

To obtained time-accurate solution of conjugate heat transfer problems: Performed stability and convergence analysis for loosely coupling with higher order IMEX (ESDIRK-ERK) schemes for time integration. It was implemented in OpenFoam. Unsteady Rhie-Chow interpolation was used to preserve design order for INS flow. For stongly coupled partitioned fluid-structure interaction: An quasi-Newton underrelaxation technique was used to stabilize and accelerate the subiteration procedure. Efficiency of the coupling algorithm was gained by introducing a defect-correction update using adaptive multilevel technique.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. Kazemi Kamyab, V, Zuijlen, AH van & Bijl, H (2011). Higher Order Time Integration Schemes for Thermal Coupling of Flows and Structures. IV International Conference on Computational Methods for Coupled Problems in Science and Engineering COUPLED PROBLEMS 2011, M. Papadrakakis, E. Onate & B. Schrefler (Eds.).
2. Kreeft. J.J., Weghs, M., Zuijlen, AH van & Bijl, H (2011). Multi-level and quasi-Newton acceleration for strongly coupled partitioned fluid-structure interaction. IV International Conference on Computational Methods for Coupled Problems in Science and Engineering COUPLED PROBLEMS 2011, M. Papadrakakis, E. Onate & B. Schrefler (Eds.).

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.

Fine sediment dynamics markermeer

Project Aim

To increase our understanding on the water bed exchange processes, as well as to establish a long term sediment balance for Markermeer fine sediments. To contribute to the overall understanding of Markermeer as an eco-system.

Progress

Execution of a large field campaign, in which a large amount of data and samples was collected. Post-processing was performed on most of the samples collected at the field campaign, comprising: bulk density determination, granulometry, erosion experiments, etc. An extensive study was done on the erodibility of soft fresh water sediments, and the role and oxidation and bioturbation on it. Flocculation experiments were executed: small scale and large scale: study of the possible aggregation between inorganic sediments and algae.

Dissertations

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Scientific Publications

-

Projectleaders

JC Winterwerp, WSJ Uijttewaal

Researchtheme

Complex dynamics of fluids

Participants

MA de Lucas, JC Winterwerp, T van Kessel, WSJ Uijttewaal

Cooperations

ANT network, BwN network

Funded

Ecoshape

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

Start of the project

2009

Information

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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
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Project Aim

The main goal is to provide insights on the development of the morphodynamic pattern of rivers with sand-gravel mixtures during unsteady conditions. Considering the influence on morphodynamics change on the evolution of bedform geometry, stochastics of bedform geometry and sorting. This will be reached creating a new extensive experimental dataset for models with an experimental research of the bed river response to unsteady conditions with mixed sediments.

Progress

During the first year of my PhD research I worked on the literature study on bed grain size distribution measurements and morphodynamic modeling. The activities carried out in the laboratory were focused on the measurements techniques to characterize the grain size distribution and to test bed sampling techniques. The techniques in which I focused my work has been the image analysis combined with particle coloring, 3D reconstructions of bed samples and Multibeam echosounder. Moreover I worked for the planning for the flume experiment design and experimental program for the introductory tests.

Dissertations

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Scientific Publications

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The development of unstructured grid model for tsunami study with accurate flooding and drying

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

An unstructured grid, finite volume ocean model has been developed which is suitable for flooding and drying problems. A paper on this new model has been published. The model has been extended to non-hydrostatic and has been validated through many standard test cases. A paper about the implementation of the non-hydrostatic is under writing. A improve the efficiency of the model, a reduced two-layer scheme is proposed, which apply two layers for the momentum equation, while keep only one unknown of the non-hydrostatic pressure in the vertical. This new method can achieve higher linear dispersion accuracy than depth-integrated model, while pay the same computation efforts. Another paper about this method is also under preparation.

Dissertations

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Scientific Publications

-

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

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Projectleaders
GS Stelling, JD Pietrzak
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
O Kleptsova, JD Pietrzak, GS Stelling
Cooperations
-
Funded
Speerpunt Water

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

Start of the project
2005
Information
O Kleptsova
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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

Deepeer insight gained into reconstruction of a velocity field out of spacially distributed vector components. Such a reconstruction is often required in C-grid models for calculation of momentum advection and Coriolis force. Previously developed reconstruction procedure was extended to the 3D case. It was shown that in the presence of multiple z-layers Coriolis term can become an additional source of the staircase problem leading to accuracy and stability problem. In order to prevent a model from creation of an artificial vertical structure a layer remapping procedure needs to be employed.

Dissertations

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Scientific Publications

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Quantifying mobilization and transport of metal ions in fine sediments

Project Aim

In order to dispose safely of or reuse dredged sediments, users are facing the following questions:

- Can dewatering techniques be improved?
- How are the flocculation properties of clays affected by the water chemistry?
- How (im)mobile are metal ions within the sediment?
- How many will be leaching out in a defined period of time estimated from decades to centuries?

We intend to help answering these questions by using electrokinetic techniques (electrophoresis, electroosmosis, …) which allow to couple the geochemical and geophysical properties of clays and fine sediments, within tailings, slurries or consolidated beds.

Progress

- Population Balance Equations (PBE) have been set-up in the past years to simulate the evolution of the sediment flocculation behavior
- The flocculation behavior has been related to the sediment 's zeta potential
- This zeta potential is affected by the properties of the suspending medium, like pH and salinity

Recently we applied these findings to industrial projects about the properties of tar-sands tailings in the context of oil recovery (CNRL) and the transport properties of iron oxide (RioTinto).

We are now improving the models by studying the influence of flocculant and organic matter. We also aim to develop our electrokinetic equipment so as to investigate the transport of ions and water within consolidated beds.

Dissertations

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Scientific Publications

1. On the behavior of mud floc size distribution: model calibration and model behavior. Mietta Francesca; Chassagne Claire; Verney Romaric; et al. OCEAN DYNAMICS Volume: 61 Issue: 2-3 Special Issue: SI Pages: 257-271 DOI: 10.1007/s10236-010-0330-2 Published: MAR 2011.

Projectleaders

C Chassagne

Researchtheme

Complex dynamics of fluids

Participants

M Ibanez

Cooperations

Deltares

Funded

CNRL, RioTinto

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

Start of the project

2009

Information

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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
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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

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Scientific Publications

1. Ottevanger, W., Blanckaert, K. & Uijttewaal. W. S. J. A parameter study in bank shear stresses in curved open channel flow by means of large-eddy simulation. Proceedings of the 7th IAHR symposium on river, coastal and estuarine morphodynamics. pp 1917-1927. (2011).
2. Ottevanger, W., Blanckaert, K. & Uijttewaal. W. S. J. A parameter study on bank shear stresses in curved open channel flow by means of large-eddy simulation. NCR-days 2011: Controlling the Dutch Rivers. p32. (2011).
3. Ottevanger, W., Blanckaert, K. & Uijttewaal, W. S. J. Processes governing the flow redistribution in sharp river bends. Geomorphology. ISSN 0169-555X. doi:10.1016/j.geomorph.2011.04.049 (2011).

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.

PROGRESS

A new source term formulation (the n-k2d model) for depth-induced breaking had been developed, calibrated and verified to account for normalised wave length, local slope and directional spreading. The model is supplemented by a simple relaxation model to account for the effects of breaking persistence. Current work is now focused on improving the source term for triad wave-wave interactions. Analysis of spectral evolution is being carried out by USACE and Shell IEP.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Re-scaling the Battjes-Janssen model for depth-induced wave-breaking (Salmon, J.E. and L.H.Holthuijsen 2011) 12th International Workshop of Wave Hindcasting and Coastal Hazards.

PROJECTLEADERS

GPh van Vledder, LH Holthuijsen

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

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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
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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 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 an expansion loss form drag model and has been compared with the experimental data. In the 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 numerical study of the rapidly varying flow over weir-like obstacles has been conducted by using RANS modelling 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 by numerical simulations in this particular study.

Dissertations

-

Scientific Publications

1. Ali, S & Uijttewaal, WSJ (2011). Flow resistance of vegetated oblique weir-like obstacles during high water stages. In EM Valentine (Ed.), Proceeding of the 34th IAHR world congress (pp. 3321-3329).
2. Ali, S & Uijttewaal, WSJ (2011). Numerical and physical modelling of rapidly varying flow over weir-like obstacles in rivers and floodplains. In E Mostert & LJE Bouaziz (Eds.), Proceedings of the NRC-days 2011: Controlling the Dutch Rivers (pp. 11-12).

A typical cross section of the lowland rivers in the Netherlands

Simulating waves till shore (SWASH)

Project Aim

The long term goal is the development of the SWASH (Simulating WAves till SHore) 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: Coupling with SWAN – a third generation wind wave model. The standard k-ε model with log wall-law for vertical mixing. Irregular, multidirectional waves described by any 2D spectrum as boundary condition. SWASH can be run in parallel under Windows XP/Vista/7 using MPICH2. Wave breaking mechanism is considerably improved. SWASH can be downloaded from http://swash.sf.net. There were about 500 downloads by the end of 2011 since the launch of SWASH at the website (as of February 9, 2011).

Dissertations

-

Scientific Publications

1. Zijlema, M., Stelling, G. and Smit, P. (2011). SWASH: An operational public domain code for simulating wave fields and rapidly varied flows in coastal waters, Coast. Engng., 58, 992-1012.

Projectleaders

G Stelling, M Zijlema

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

PB Smit, DP Rijnsdorp

Cooperations

-

Funded

TUD

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

Start of the project

2010

Information

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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
University of Notre Dame, Indiana;
San Francisco State University, California.

Funded
Office of Navel Research

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

Start of the project
2006

Information
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Project Aim

The project aim is to develop a conceptual extension of spectral energy wave models to be able to capture spatial inhomogenities in the wavefield (due to f.i. 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 first principles we derived a transport equation for the second order inhomogeneous wave statistics (an extended energy balance) that accounts for cross-variance contributions, and can thus resolve coherent structures in wave fields such as those typically found in focal and diffraction zones. We have compared the model to analytical solutions and are at present extending the model to account for coherent structures induced by the variable topography (e.g. interference/diffraction patterns behind a topographical lens). Furthermore, we've formulated the basic transport equation for the three-wave correlators, which will allow us to account for wave-wave interactions (triads).

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. and Janssen, T.T. "Coherent interference and diffraction in random waves. " 12th International Workshop on Wave Hindcasting and Forecasting & 3rd Coastal Hazard Symposium. Oct. 30-Nov. 4, 2011 Kohala Coast, Hawaii.

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. Uijttewaal, WSJ (2011). Horizontal mixing in shallow flows. In EM Valentine (Ed.), Proceeding of the 34th IAHR world congress (pp. 3808-3814).
2. Ottevanger, W., Blanckaert, K. & Uijttewaal, W. S. J. Processes governing the flow redistribution in sharp river bends. Geomorphology. ISSN 0169-555X. doi:10.1016/j.geomorph.2011.04.049 (2011).
3. Schnauder I., and Garcia X-F. 2011. Experimental study on shear stress triggering benthic drift. In: Proc. of EUROMECH [523]: Ecohydraulics: linckages between hydraulics and ecological processes in rivers, Clermont-Ferrand, France, June 15-17, 2011, 49-53.

Projectleaders

WSJ Uijttewaal

Researchtheme

Complex dynamics of fluids

Participants

W Ottevanger, K Blanckaert, I Schnauder, A Sukhodolov

Cooperations

IGB Berlin Germany

Funded

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

Start of the project

2009

Information

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

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

START OF THE PROJECT
2009
INFORMATION
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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.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

-

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 floating body 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). 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. 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 in SWASH, which provides an accurate forcing of infragravity waves at the 'wave maker'.

Progress

At present, the second order boundary condition is implemented in SWASH and the boundary condition is validated using both analytical solutions and flume experiments. The (preliminary) results will be presented at the International Conference on Coastal Engineering, 1 July-7 July in Santander, Spain.

Dissertations

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Scientific Publications

-

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

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Hydraulic impact of overtopping waves on a multifunctional dike

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
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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 that are part of a multi-functional flood defence.

Progress

A start was made with the literature study.

Dissertations

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Scientific Publications

-

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

Deepeer insight gained into reconstruction of a velocity field out of spacially distributed vector components. Such a reconstruction is often required in C-grid models for calculation of momentum advection and Coriolis force. Previously developed reconstruction procedure was extended to the 3D case. It was shown that in the presence of multiple z-layers Coriolis term can become an additional source of the staircase problem leading to accuracy and stability problem. In order to prevent a model from creation of an artificial vertical structure a layer remapping procedure needs to be employed.

Dissertations

-

Scientific Publications

-

Projectleaders

GS Stelling, JD Pietrzak

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

O Kleptsova, JD Pietrzak, GS Stelling

Cooperations

-

Funded

Speerpunt Water

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

Start of the project

2005

Information

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Mesoscopic Transport Phenomena

Prof.dr.ir. AA Darhuber

Prof.dr.ir. F Toschi

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.

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, F Toschi

Researchtheme

Complex dynamics of fluids

Participants

A Hirschberg, X Pelorson, AM 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
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Flow-induced pulsations in gas transport systems: prediction, prevention and influence on volume flow measurements

Projectleaders
AA Darhuber, F Toschi

Researchtheme
Complex dynamics of fluids

Participants
A Hirschberg, G Nakiboglu, D Tonon, 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
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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 sidebranch system with up to 20 side-branches. Within the framework of a STW project the whistling of corrgated 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. The sound radiation from musical instruments/toys has been studied.

Dissertations

1. D. Tonon,. Aeroacoustics of shear layers in internal flows, PhD thesis, Eindhoven University of Technology, Eindhoven, The Netherlands.

Scientific Publications

1. D. Tonon, A Hirschberg , J Golliard, S Ziada, Aeroacoustics of pipe systems with closed branches, Int. J. Aeroacoustics, 10 (2011) 201-276.
2. D Tonon, JFH Willems, A Hirschberg, Self-sustained oscillations in pipe systems with muktiple deep-side branches: prediction and prevention by detuning, J. Sound Vibr. 330 (2011) 5894-5912.
3. J. Olsman, JFH Willems, A Hirschberg, T Colonius, RR Trieling, Flow around a NACA 0018 airfoil with a cavity and its response to dynamical forcing, Exp. Fluids, 51 (2011) 493-509.
4. G. Nakiboglu, SPC Belfroid, J Golliard, A Hirschberg, On the wistling of corrugated pipes: effect of pipe length and flow profile, J. Fluid Mech., 672 (2011) 78-108.

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 formation of emulsions stabilized by ellipsoidal particles was studied. To understand the physical properties of these emulsions, a single particle as well as a collection of particles at a flat fluid-fluid interface was explored.

Dissertations

-

Scientific Publications

1. Nanoparticles as emulsion stabilizers. J. Harting, F. Jansen, S. Frijters, \ F. Janoschek, F. Günther. inSiDE 9, Number 1, 48 (2011)

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

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PROJECTLEADERS
F Toschi, J Harting
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
F Janoschek
COOPERATIONS
TU/e: ACB Bogaerds, FN van de Vosse (Biomed. eng.); PD Anderson, HEH Meijer (Mech. eng.)
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
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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

The beginning of 2011 was dedicated to the presentation of previous work in scientific publications and at national and European conferences. Later during the year, our simulation code was optimized with regards to scalability on massively parallel supercomputers and extended with a new boundary condition which serves for feeding the flow through the system under study with fluid configurations as produced by an infinitely long channel that–in the case of dense suspensions of objects of finite size–are not known previously. By means of this method, we studied the behavior of suspensions in a constricted channel while varying parameters such as the lumen of the constriction, the volume concentration, or the stiffness of the particles. This work resulted in a continuous model for the augmented diffusion induced by suspended particles whose refinement and validation is current work in progress.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Rotational behavior of red blood cells in suspension–a mesoscale simulation study. F. Janoschek, F. Mancini, J. Harting, F. Toschi. Phil. Trans. R. Soc. London Series A 369, 2337-2344 (2011).
2. Simulations of Blood Flow in Plain Cylindrical and Constricted Vessels with Single Cell Resolution. F. Janoschek, F. Toschi, J. Harting. Macromolecular Theory and Simulations 20, 562-570 (2011).
3. Lattice-Boltzmann Methods in Fluid Dynamics: Turbulence and Complex Colloidal Fluids. D. Groen, O. Henrich, F. Janoschek, P. V. Coveney, J. Harting in Jülich Blue Gene/P Extreme Scaling Workshop 2011, ed. Bernd Mohr, Wolfgang Frings, Jülich Supercomputing Centre, Germany (2011).
4. Coupled Lattice Boltzmann and Molecular Dynamics simulations on massively parallel computers. J. Harting, S. Frijters, F. Janoschek, F. Günther. Technical Report, Forschungszentrum Jülich, Germany (2011).

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. Simulations of binary and ternary mixtures in porous media, implementation and preparation. Application and improvement of boundary conditions to phenomenological model systems exhibiting surface slip. Implementation work in debugging and code optimisation.

Dissertations

-

Scientific Publications

1. S. Schmieschek, J. Harting, Comm. Comput. Phys. 9 (5), 1165 (2011)

Projectleaders

J Harting

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Schmieschek

Cooperations

University of Stuttgart, University College London

Funded

University of Stuttgart, University College London

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

Start of the project

2009

Information

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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
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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

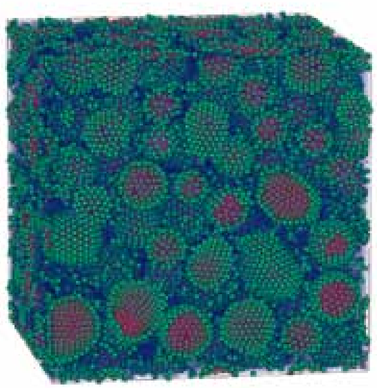
The effect of nanoparticles at the interface of a fluid-in-fluid droplet has been studied numerically and has been compared to the effect of surfactant. While surfactants change the interfacial free energy by lowering surface tension, particles reduce this free energy by removing expensive fluid-fluid interfacial area. When subjected to shear, a droplet can deform. Deformation at constant shear is increased by surfactants because of the lowered surface tension. At high capillary number and high particle density, nanoparticles also promote deformation of a droplet. Similarly, droplet breakup is facilitated by these particles.

Dissertations

-

Scientific Publications

1. J. Harting, F. Jansen, S. Frijters, F. Janoschek, F. Günther. Nanoparticles as emulsion stabilizers. inSiDE 9, Number 1, 48 , 2011.
2. F. Jansen and J. Harting. From Bijels to Pickering emulsions: A lattice Boltzmann study. Phys. Rev. E, 83:046707, 2011.
3. J. Harting, S. Frijters, F. Janoschek, F. Günther. Coupled Lattice Boltzmann and Molecular Dynamics simulations on massively parallel computers. Technical Report , Forschungszentrum Juelich, 2011.
4. F. Günther, F. Janoschek, S. Frijters, J. Harting. Lattice Boltzmann simulations of anisotropic particles at liquid interfaces. http://arxiv.org/abs/1109.3277, submitted for publication, sept. 2011.



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 is currently being finalized. A third setup for moving airjets has been designed and is currently being finalized.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. C. W.J. Berendsen, J. C.H. Zeegers, A. A. Darhuber, Proceedings 3rd Micro and Nano Flows Conference, Thessaloniki, Greece, 22-24 August 2011.

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

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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
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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 initiated.

Dissertations

-

Scientific Publications

1. M. Hanyak, A. A. Darhuber, and M. Ren. Journal of Applied Physics 109, 074905 (2011).
2. D. K. N. Sinz, M. Hanyak, J. Zeegers, and A. A. Darhuber. Physical Chemistry Chemical Physics 13, 9768–9777 (2011).
3. D. K. N. Sinz, M. Hanyak, and A. A. Darhuber. Journal of Colloid and Interface Science 364, 519–529 (2011).

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

-

SCIENTIFIC PUBLICATIONS

1. B. J. Brasjen and A. A. Darhuber. Microfluidics & Nanofluidics 11, 703-716 (2011).
2. J. A. Vieyra Salas, A. A. Darhuber. Chemical Engineering & Processing 50, 583 (2011).
3. B. J. Brasjen, A.W. van Cuijk and A. A. Darhuber. Chemical Engineering & Processing: 50, 565 (2011)..

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

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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
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Project Aim

Developing a vortex tube swirling flow system to separate condensate out of gas flow.

Progress

Apparatus has been bought to do measurements. Currently we are building up equipment to start measurements.

Dissertations

-

Scientific Publications

-

PROJECT AIM

Design, analysis and development of a small scale thermoacoustic traveling wave cooler.

PROGRESS

The project itself has ended in 2010 and a PhD thesis was completed in 2011 with a promotion.

DISSERTATIONS

1. Yan Li. Thermoacoustic Refrigerators: Experiments and scaling analysis.

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS

J Zeegers, HJM ter Brake

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

Y Li, J Zeegers, HJM ter Brake

COOPERATIONS

-

FUNDED

MicroNed

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

START OF THE PROJECT

2005

INFORMATION

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Vortex Dynamics and Turbulence

Prof.dr. HJH Clercx

Prof.dr.ir. BJ Geurts

Prof.dr.ir. GJF van Heijst

Prof.dr. F Toschi

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

The following main lines of research can be distinguished:

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

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

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), field observations (Deltares) and laboratory experiments (WUR).

PROGRESS

The dispersion 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. These ingredients are considered in our modeling approach.
We have identified that a proper time scaling is required due to the difference existing between flow time scale and biological time scale. The coupled model shows the dispersion of phytoplankton and its difference with light inertial particles in homogeneous isotropic turbulence. As a first result we have shown the dependence of vertical particle concentration with turbulent characteristics of geophysical flow. A paper has been submitted.

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),
KB Winters (Scripps,USA),
RE Uittenbogaard (Deltares),
M Scheffer (WUR)

FUNDED

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

START OF THE PROJECT

2009

INFORMATION

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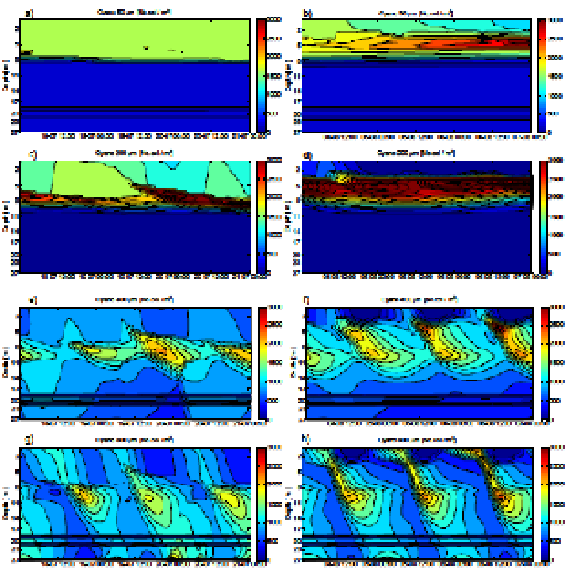

Vertical distribution of Microcystis colonies in Lake Vlietland. Left panels corresponds to high wind speed conditions and right panels corresponds to low wind conditions.
a),b) Colonies of 50 μm,
c),d) colonies of 200 μm,
e),f) colonies of 400 μm,
g),h) colonies of 800 μm.
Color bar indicates relative colony number density. Red indicates high concentration, blue indicates low concentration.

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
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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)
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

Due to its geometrical simplicity (no internal elements as in Kenics mixers) the Rotated Arc Mixer (RAM) is an ideal inline mixer for development and testing of numerical and experimental tools and understanding of mixing concepts. The 3D geometry of the actual RAM is simplified to a 2D geometry in such a way that the temporal evolution of flow and temperature fields in 2D RAM represents the cross-sectional evolution of these fields during axial progression in the actual 3D case. An experimental set-up of 2D simplified RAM has been designed by means of CFD simulations and laboratory tests and is currently being built. 2D Particle Image Velocimetry (PIV) and Infrared (IR) camera system will be used for mixing and heat transfer analysis of periodically forced shallow viscous flow in 2D simplified RAM.

Dissertations

-

Scientific Publications

-

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

Previous studies indicate that the Stokes number St of the flow (a ratio between the reaction time of the droplet and a timescale of the flow) plays an important role in the behavior of the droplets. A properly characterized aerosol is crucial to achieve a well defined St. In order to produce a mono-disperse aerosol, a spinning disk aerosol generator (SDAG) has been fabricated. This exercise has proven challenging, but droplet measurements using Interferometric Particle Imaging (IPI) indicate that droplets with the required diameters are being produced. Figure 1 shows an image of IPI data. Progress has also been made in the tagging of regions in a droplet cloud. Problems with multiple diffraction as well as arriving to an optimal phosphorescent solution have been encountered and addressed. Figure 2 shows a frame sequence of tagged droplets after a laser beam was pulsed. The deformation of the tagged region can be observed as time progresses.

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
STW

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

START OF THE PROJECT
2009

INFORMATION
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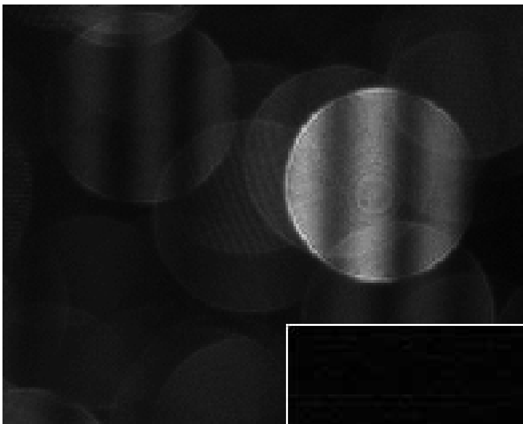
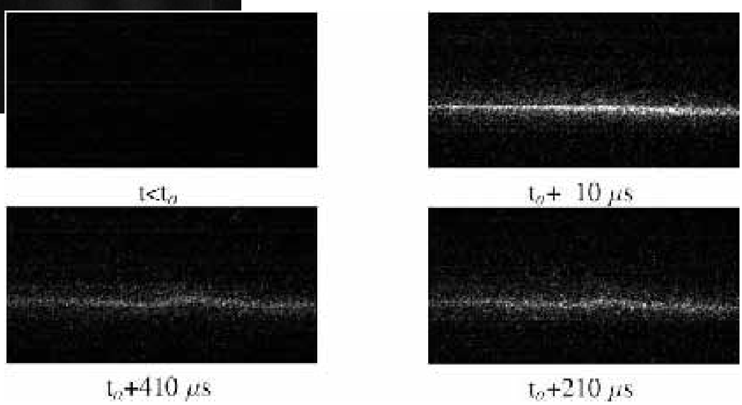


Data frame obtained through IPI. The interference pattern arises due to the path length difference between the reflection (zeroth order refraction) and the 1st order refraction of polarized light. Each fringe represents a path length difference of a wavelength λ. This difference can be related to the particle diameter through geometric relations.



Frame sequence after a line was 'written' inside a cloud of droplets.

EXPERIMENTS ON LAGRANGIAN STATISTICS IN ROTATING TURBULENCE

PROJECTLEADERS
HJH Clercx

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
L Del Castello, HJH Clercx

COOPERATIONS
C Cambon (ENS Lyon, France), A Tsinober (Univ. Tel Aviv, Israel), W Kinzelbach (ETH Zürich, Switzerland), B Luethi (ETH Zürich, Switzerland).

FUNDED
NWO-VICI

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

START OF THE PROJECT
2005

INFORMATION
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PROJECT AIM

It is the aim of this research project to develop insight in the Lagrangian statistics of rotating turbulence and the single- and pair-dispersion properties of small particles in rotating turbulence. For this purpose an existing 3D Particle Tracking Velocimetry method will be made suitable for rotating turbulence experiments. PDFs of the horizontal (left) and vertical (right) components of the acceleration for all (non-)rotating experiments. The emergence of large scale columnar flow structures is reflected in these PDFs. Rotation enhances the tails of the horizontal acceleration PDFs while those of the vertical acceleration PDFs are suppressed.

PROGRESS

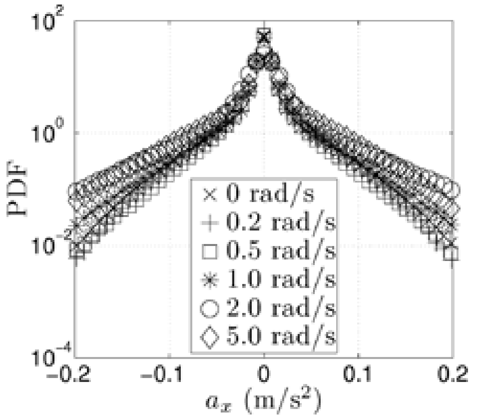
This project has been finished with the thesis of L. Del Castello (Oct. 2010).

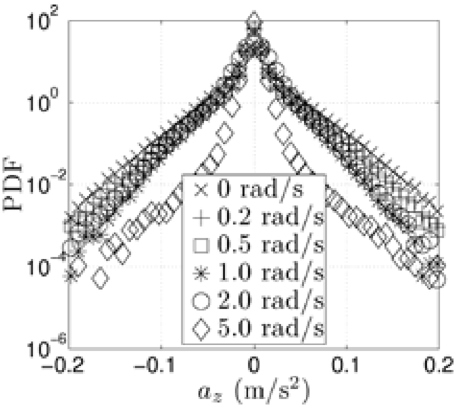
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Del Castello, L. H.J.H. Clercx - Lagrangian velocity autocorrelations in statistically steady rotating turbulence, Phys. Rev. E. 83, 056316 (2011).
2. Del Castello, L. & H.J.H. Clercx - Lagrangian Acceleration of Passive Tracers in Statistically Steady Rotating Turbulence, Phys. Rev. Lett. 107, 214502 (2011).
3. Del Castello, L. and H.J.H. Clercx, Lagrangian velocity and acceleration autocorrelations in rotating turbulence. In: Advances in Turbulence XIII. Proceedings of the 13th EUROMECH European Turbulence Conference, September 12-15, 2011, Warsaw, Poland. Eds. K. Bajer. J. Phys.: Conf. Ser. 318 052028 1-9 (2011).





PDFs of the horizontal (left) and vertical (right) components of the acceleration for all (non-)rotating experiments. The emergence of large scale columnar flow structures is reflected in these PDFs. Rotation enhances the tails of the horizontal acceleration PDFs while those of the vertical acceleration PDFs are suppressed.

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 techniques.

PROGRESS

In the first stage of this project a theoretical method was developed to predict the shape of actually observed atmospheric wind and temperature profiles from external forcing parameters like the large-scale pressure gradient. This is achieved by coupling a simple Ekman model to a rudimentary surface energy balance. Profile predictions are validated against an independent data set that covers 11 years of observations at Cabauw (The Netherlands). It is shown that the characteristic profiles in response to external forcings are well-captured by the conceptual model. For this period the observational climatology is in close agreement with ECMWF reanalysis data. In the next stage, numerical stability analysis on those typical profiles will be performed in order to predict flow instabilities.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Van de Wiel, B.J.H. , S. Basu, A.F. Moene, H.J.J. Jonker, G-J Steeneveld, A.A.M. Holtslag, - Comments on ''An Extremum Solution of the Monin–Obukhov Similarity Equations''. J. Atmos. Sci., 68, 1405-1408 (2011).
2. Baas, P., B.J.H. van de Wiel, L. Van den Brink, and A.A.M. Holtslag - Composite hodographs and inertial oscillations in the nocturnal boundary layer. Quart. J. Roy. Meteor. Soc. DOI:10.1002/qj.941 (2011).
3. Wiel, B.J.H. van de, Moene, A.F., Jonker, H.J.J. & Clercx, H.J.H. (2011). The collapse of turbulence in the atmospheric boundary layer. In K. Bajer (Ed.), Proceedings of the European Turbulence Conference (ETC 13), September 12-15, 2011, Warsaw, Poland. (Journal of Physics: Conference Series, Vol. 318, pp. 032037-1/6).

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

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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 (Israel)

Funded

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

Start of the project
2006

Information
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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).

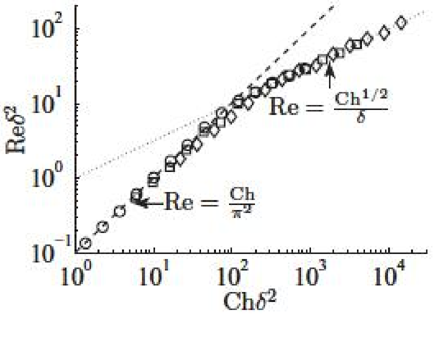
Dissertations

-

Scientific Publications

1. Duran Matute, M., R.R. Trieling & G.J.F. van Heijst - Scaling and symmetry in an electromagnetically forced dipolar flow structure. Phys. Rev. E 83, 016306 1-5 (2011).

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



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 hydro dynamical forces has been implemented. Some test simulations have been performed. The following steps include simulation of particles in turbulence with homogeneous shear.

Dissertations

-

Scientific Publications

1. Hinsberg, M.A.T. van, J.H.M. ten Thije Boonkkamp & H.J.H. Clercx - An efficient, second order method for the approximation of the Basset history force, J. Comp. Phys. 230, 1465-1478 (2011).
2. Hinsberg, M.A.T. van, J.H.M. ten Thije Boonkkamp, B.J.H. van de Wiel, F. Toschi and H.J.H. Clercx, Interpolation error in DNS simulations of turbulence: consequences for particle tracking. In: Advances in Turbulence XIII. Proceedings of the 13th EUROMECH European Turbulence Conference, September 12-15, 2011, Warsaw, Poland. Eds. K. Bajer. J. Phys.: Conf. Ser. 318, 052022 1-6 (2011).
3. Hinsberg, M.A.T. van, Thije Boonkkamp, J.H.M. ten, Toschi, F. & Clercx, H.J.H. (2011). On the efficiency and accuracy of interpolation methods for spectral codes. CASA Report No. 11-50, Eindhoven: Technische Universiteit Eindhoven, 19 pp.

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

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Population dynamics in turbulent flows: numerical simulations

Projectleaders
F Toschi, HJH Clercx
Researchtheme
Complex dynamics of fluids
Participants
P Perekar, HJH Clercx, F Toschi
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
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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 normally known to increases mixing and diffusion; but, remarkably, population dynamics in a turbulent environment shows 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

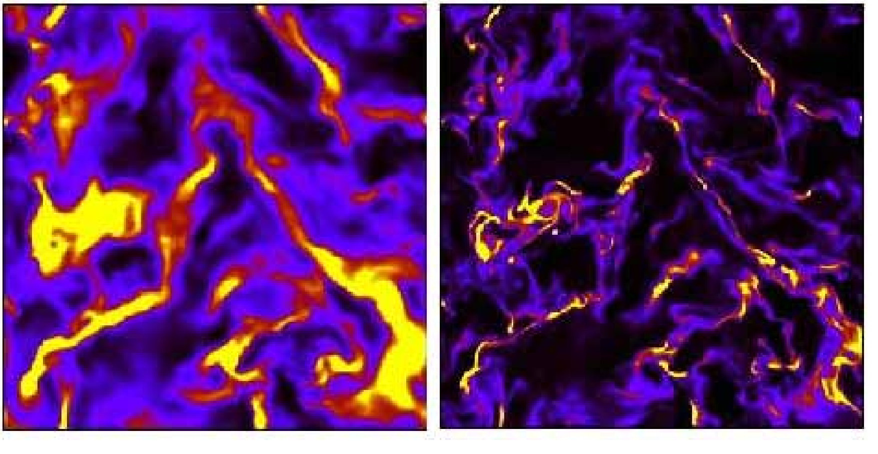
The results of our study on population dynamics for single species in a turbulent surface flow, highlighting the role of turbulence on population patchiness (see Fig. 1), were published and submitted to various journals. We also implemented the discrete population rules to understand the effect of turbulence on the fixation time of species. The results of these studies have been published. The next step is to conduct a detailed study emphasizing the interplay between the discrete population rules to understand the effect of turbulence on the fixation time of species. Experimental investigation of populations under simple flow conditions will be started soon.

Dissertations

-

Scientific Publications

1. P. Perlekar, R. Benzi, D.R. Nelson, and F. Toschi, Cumulative compressibility effects on population dynamics in turbulent flows, arXiv:1111.0905 (submitted to Europhys. Lett.).
2. P. Perlekar, R. Benzi, S. Pigolotti, and F. Toschi, Particle algorithms for population dynamics in flows, J. Phys.: Conf. Ser. 333, 012013 (2011).
3. P. Perlekar, R. Benzi, D.R. Nelson, and F. Toschi, Statistics of population dynamics in turbulence, J. Phys.: Conf. Ser. 318, 092025 (2011).



Pseudo-color plot of the population concentration in a compressible turbulent surface flow for large (Sc=0.1) and small diffusivity (Sc=10). Yellow indicates the region of high population concentration whereas black regions indicate low population concentration.

PROJECT AIM

It is the aim of these research projects to develop a better insight in the spectral and transport properties of quasi-two-dimensional flows, the dynamics of vortices in rotating and stratified fluids, and the effects of domain boundaries (solid walls) on (quasi-)2D turbulence.

PROGRESS

This project has been finished with the thesis by G.H. Keetels (June 2008).

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Keetels, G.H., W. Kramer, H.J.H. Clercx & G.J.F. van Heijst - On the Reynolds number scaling of vorticity production at no-slip walls during vortex-wall collisions, Theor. Comput. Fluid Dyn. 25, 293-300 (2011).
2. Kramer, W., G. H. Keetels, H. J. H. Clercx, and G. J. F. van Heijst - Structure-function scaling of bounded two-dimensional turbulence, Phys. Rev. E 84, 026310 (2011).

PROJECTLEADERS

HJH Clercx, GJF van Heijst

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

GH Keetels, W Kramer, GJF van Heijst, HJH Clercx

COOPERATIONS

K Schneider (Univ. Marseille, France), CH Bruneau (Univ. of Bordeaux, France), BK Shivamoggi (UCL, Orlando, USA), JJ Rasmussen (DTU-Risoe, Denmark)

FUNDED

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

START OF THE PROJECT

2003

INFORMATION

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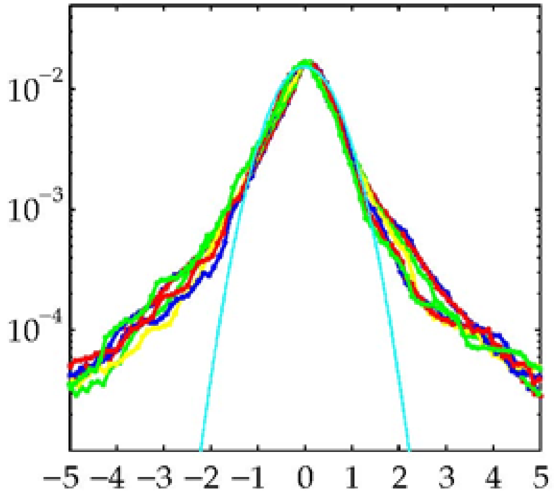

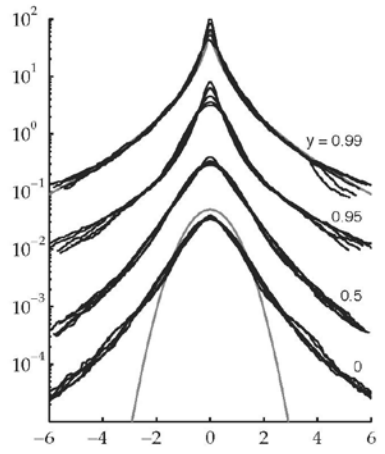

Probability density functions for forced 2D turbulence in bounded domains. Left: bounded square domain; right: periodic channel domain. A Gaussian distribution is given for comparison. The interior flow is in both cases characterized by similar PDFs: Gaussian core and exponential tails. Close to the no-slip walls the probability of observing very weak and very strong vorticity increments is increased at the expense of fluctuations at average intensity.

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

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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. Comparisons fluid–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

The first year of this project was focused on the design of an experimental set-up for the investigation of the effect of shear on turbulent transport in shallow flows. Two main questions have been addressed. The first one concerned the question which working fluid should be used for an optimal flow profile and for control properties: a liquid metal or an electrolyte solution. The second issue to be addressed is the required flow geometry: an annular geometry or straight channel geometry. This was theoretically and numerically investigated (using COMSOL). This investigation allowed us to conclude that the best option is to use salty water instead of a liquid metal, and a channel configuration instead of an annular geometry. Some preliminary experimental tests, using a straight channel configuration, are being conducted..

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Unravelling 3D mixing near the surface of actuated beads

Project Aim

This project is part of a larger research programme 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 modelling 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

A detailed transport study revealed that perturbation of the flow around a piecewise-steadily translating and/or rotating sphere is essential to attain (locally) chaotic mixing. The impact of this perturbation on the mixing properties has been explored for various actuation protocols via symmetry analysis, simulation of 3D fluid trajectories and computation of Poincaré sections ('stroboscopic maps' of particle positions). The observed mixing behaviour is similar to that recently reported for 3D lid-driven cavity flows and thus strongly suggests that the perturbation is qualitatively representative for physical effects as e.g. fluid inertia or oscillations of the beads. Parallel to the above study, we have designed and manufactured a macro-scale experiment in order to address the scavenging properties of the sphere in a viscous fluid by measuring the target flux to the sphere surface..

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

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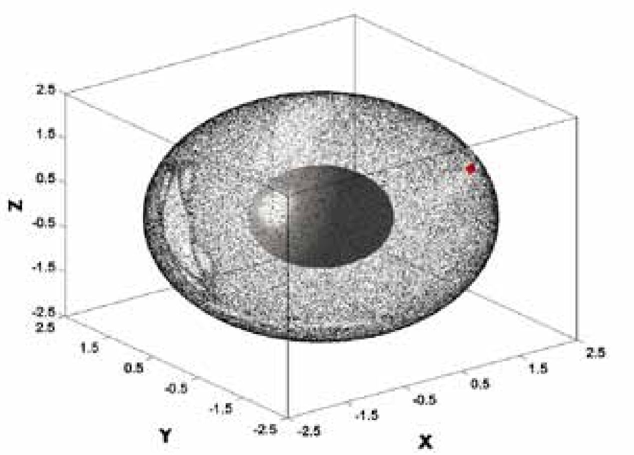

Poincaré map showing typical intra-surface dynamics containing elliptic islands and chaotic regions. The red marker indicates the initial position of a single tracer whereas the black points represent the subsequent positions of the same tracer at integral time periods.

Dynamic behaviour of a High-Altitude Long-Endurance (HALE) wing

Projectleaders
GJF van Heijst

Researchtheme
Complex dynamics of fluids

Participants
WFJ Olsman, RR Trieling,
GJF van Heijst

Cooperations
A Hirschberg (TU/e-TN),
SH Hulshoff (TUD),
R Savelsberg (Univ of Southampton, UK)

Funded

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

Start of the project
2006

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Project Aim

A new design High-Altitude Long-Endurance wing is currently under development in the EU project Vortexcell2050. For several reasons (structural and fuel load) it is desirable to have relatively thick wings. However, thick wings promote flow separation and/or massive vortex shedding, reducing flight performance significantly. The new design airfoil will be equipped with a cavity "vortex cell" in the wing in order to prevent flow separation. In this cavity a vortex will be trapped with active flow control. The goal of the current PhD project is to gain insight in the dynamic behavior of such a wing with a cavity and to explore which numerical CFD methods are suitable for estimating the unsteady forces on such an airfoil.

Progress

This project has been finished with the thesis of W.F.J. Olsman (May 2010).

Dissertations

-

Scientific Publications

1. Olsman, W. F. J. & T. Colonius - Numerical Simulation of Flow over an Airfoil with a Cavity, AIAA Journal 49, 143-149 (2011).
2. W.F.J. Olsman, J.F.H. Willems, A. Hirschberg, T. Colonius & R.R. Trieling – Flow around a NACA0018 airfoil with a cavity and its dynamical response to acoustic forcing. Exper. Fluids 51, 493–509 (2011).

PROJECT AIM

Droplet emulsions are key to many natural and industrial processes. In presence of an external flow, droplets undergo deformation, breakup and coagulation. We study the breakup of droplets in a stationary homogeneous and isotropic flow. We consider droplets with the same density of the transporting fluid. The droplets and the fluid are numerically modeled by means of a multicomponent Lattice-Boltzmann method.

PROGRESS

We have completed a study of droplet breakup dynamics in a turbulent flow. Our study clearly brings out the interplay between the surface tension and turbulence that govern the breakup of the droplets (see Fig. 1). The next step is to study the additional effects of density and/or viscosity contrasts on droplet dynamics.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. P. Perlekar, L. Biferale, M. Sbragaglia, S. Srivastava, and F. Toschi, Droplet size distribution in homogeneous isotropic turbulence, arXiv:1112.6041.
2. L. Biferale, , P. Perlekar, M. Sbragaglia, S. Srivastava, and F. Toschi, A Lattice Boltzmann method for turbulent emulsions, J. Phys.: Conf. Ser. 318, 052017 (2011).

PROJECTLEADERS

F Toschi

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

P Perlekar, S Srivastava, F Toschi

COOPERATIONS

L Biferale, M Sbragaglia (Univ. Tor Vergata, Italy)

FUNDED

TUE

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

START OF THE PROJECT

2010

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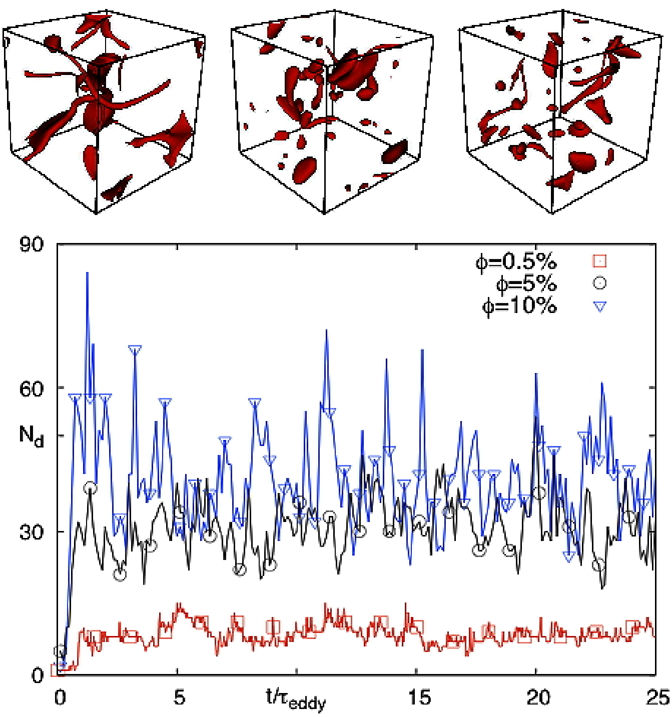

Number of droplets versus time for different initial droplet volume fractions. An increase in the volume fraction leads to an increase in the total droplets number. Top panel shows the droplet dispersions at the intermediate and the steady state configurations

Transport in Rayleigh-Bénard cells

Projectleaders
HJH Clercx

Researchtheme
Complex dynamics of fluids

Participants
RJAM Stevens, V Lavezzo, 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), EMJ Komen (NRG-ECB), RPJ Kunnen (TU/e-TN).

Funded
FOM

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

Start of the project
2008

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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

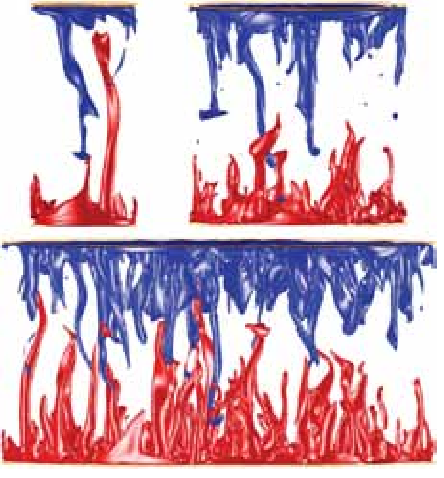
Nusselt measurements have been conducted for rotating RBC in cylinders with diameter over height aspect ratios equal to one, four-third and two. Together with numerical simulations it is shown that for high rotation rates the heat transfer becomes independent of the aspect ratio. This study has been completed with the thesis of Richard Stevens (at UT). The currently available numerical codes for computation of turbulent RBC between two parallel plates have been restructured for High Performance Computing applications. The dynamics of particles with (thermal) inertia has been included and large-scale numerical simulations have been conducted with and without gravity acting on the particles (within the DCCP programme of NWO-NCF).

Dissertations

1. Stevens, R.J.A.M. – Rayleigh-Bénard Turbulence,PhD thesis, University of Twente , The Netherlands (2011).

Scientific Publications

1. Kunnen, R.P.J., R.J.A.M. Stevens, J.Overkamp, C. Sun, G.J.F. van Heijst & H.J.H. Clercx - The role of Stewartson and Ekman layers in turbulent rotating Rayleigh-Bénard convection, J. Fluid Mech 688, 422-442 (2011).
2. Stevens, J.A.M, H.J.H. Clercx & D. Lohse - Effect of plumes on measuring the large scale circulation in turbulent Rayleigh-Bénard convection, Phys. Fluids 23, 095110 (2011).



Three-dimensional visualization of the temperature isosurfaces, indicating also the vertically-aligned vortices, in a cylindrical sample for Ra = 3×108, 1/Ro = 3.33, and Γ = 0.5 (left plot), Γ = 1.0 (middle plot), and Γ = 2.0 (right plot).

3. Stevens, R. J.A.M., J. Overkamp,D. Lohse & H.J.H. Clercx - Effect of aspect ratio on vortex distribution and heat transfer in rotating Rayleigh-Bénard convection, Phys. Rev. E 84, 056313 (2011).
4. Lavezzo, V., H.J.H. Clercx, and F. Toschi, Role of thermal plumes on particle dispersion in a turbulent Rayleigh-Benard cell. In: Advances in Turbulence XIII. Proceedings of the 13th EUROMECH European Turbulence Conference, September 12-15, 2011, Warsaw, Poland. Eds. K. Bajer. J. Phys.: Conf. Ser.318, 052011 1-9 (2011).
5. Lavezzo, V., H.J.H. Clercx, and F. Toschi, Rayleigh Benard convection via Lattice Boltzmann method: code validation and grid resolution effects. In: Particles in Turbulence, eds. M. Abel, E. Bodenschatz and F. Toschi. J. Phys.: Conf. Ser. 333, 012011 1-8 (2011).
6. Overkamp, J., R.J.A.M. Stevens, D. Lohse, and H.J.H. Clercx, Effect of aspectratioon vortex distribution and heat transfer in rotating Rayleigh-Benard convection. In: Advances in Turbulence XIII. Proceedings of the 13th EUROMECH European Turbulence Conference, September 12-15, 2011, Warsaw, Poland. Eds. K. Bajer. J. Phys.: Conf. Ser. 318, 082009 1-8 (2011).
7. Stevens, R.J.A.M., H.J.H. Clercx, and D. Lohse, Numerical simulations of rotating Rayleigh-Benard convection. In: Direct and Large-Eddy Simulation VIII, eds. J.G.M. Kuerten, B.J. Geurts, V. Armenio, and J. Frohlich, Springer, pp. 359-364 (2011).
8. Clercx, H.J.H., Lavezzo, V. & Toschi, F. (2011). Direct numerical simulation and Lagragian particle tracking in turbulent Rayleigh Bénard convection. In H. Kuerten, B. Geurts, V. Armenio & J. Fröhlich (Eds.), Direct and Large-Eddy Simulation VIII. (pp. 365-370) Springer.
9. Kunnen, R.P.J., Clercx, H.J.H. & Geurts, B.J. (2011). Structure functions in rotating Rayleigh-Bénard convection. In K. Bajer (Ed.), Proceedings of the European Turbulence Conference (ETC 13), September 12-15, 2011, Warsaw, Poland. (Journal of Physics: Conference Series, Vol. 318, pp. 082006-1/10).

Attributing the sources of tropospheric ozone from space: Constraining biogenic VOC emissions and emissions from biomass burning.

Projectleaders
KF Boersma, PF Levelt,
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

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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 use satellite data as top-down constraints on emissions of isoprene, and derive emissions of HCHO and NOx from biomass burning. We focus on 3 tasks, the first two focused on biogenic emissions, the third on 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

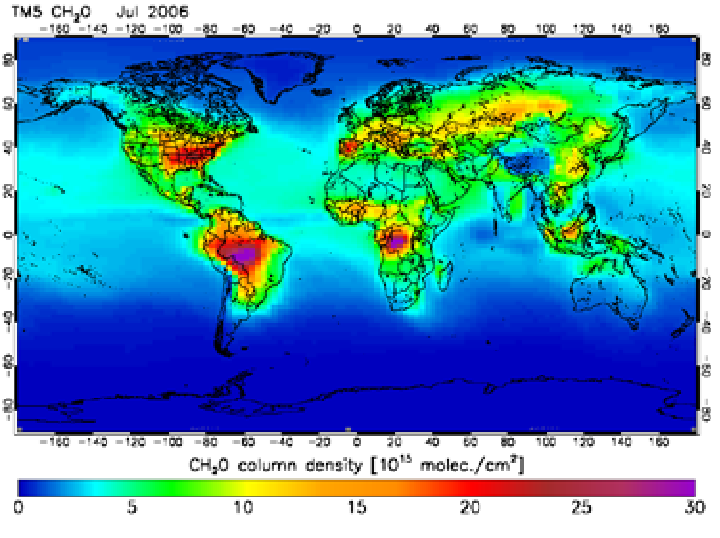
The PhD candidate has simulated isoprene and HCHO concentrations using the global 3-D chemistry transport model TM5. She has applied two different isoprene emission models and evaluated the isoprene chemistry in TM5 using aircraft observations from the AMMA campaign. In line with previous studies she found that the TM5 model simulates insufficient OH over tropical forests, which results in too high isoprene concentrations and an erroneous yield of HCHO from isoprene that would strongly bias the inversion. She is therefore working on the implementation of recently proposed isoprene oxidation schemes to replace the standard TM5 CBM-IV isoprene + OH reaction.

Dissertations

-

Scientific Publications

-



Attributing the sources of tropospheric ozone from space: Evaluating time series of free tropospheric ozone observed from space with a chemical transport model

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

We have processed TES satellite data (Tropospheric Emission Spectrometer onboard NASA's EOS-Aura satellite) to analyze tropospheric ozone between 2005 and 2010 (for example a 2005 and 2009 global ozone image of July is shown). To validate the TES observations, we compared them with independent balloon soundings. This validation exercise showed that TES ozone concentrations are biased high by 4-8 ppbv on average, but the bias remains constant over 2005-2010, demonstrating the usefulness for trend analyses. In order to correct for this positive bias in TES ozone, we generated a bias correction map for free tropospheric ozone for TES with somehow stronger corrections for the northern midlatitudes than elsewhere. A preliminary trend analysis was conducted on the TES ozone time series for the region of Eastern Asia revealing a clear increase of tropospheric ozone in this region from 2005 on. This increase was also simulated with the TM5 chemistry transport model with constant emissions in the 2005- 2010 period. 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 an increasingly favorable regime for ozone formation over eastern Asia.

Dissertations

-

Scientific Publications

-

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

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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

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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

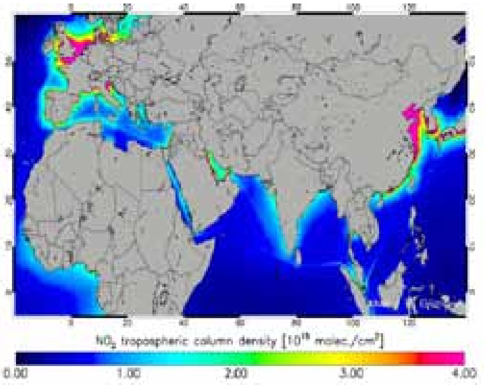
The PhD-candidate used a Gaussian dispersion plume model to simulate the chemical evolution of atmospheric trace gas concentrations after emissions in a ship plume, and implemented this in a global chemistry transport model (GEOS-Chem) to account for the non-linear chemistry in ship plumes. This work has been presented at the bi-annual global GEOS-CHEM meeting and was published in Atmospheric Chemistry and Physics [Vinken et al., 2011]. Using this ship emissions treatment the candidate simulated tropospheric NO2 columns over Europe for 2005-2006 using the high-resolution (0.5°x0.667°) nested version of GEOS-Chem, and used these columns to improve the OMI retrieval (DOMINO v2.0). The candidate will use the improved model and observations to provide constraints on the emissions in ship tracks that are visible from space (see figure below).

Dissertations

-

Scientific Publications

1. Vinken, G. C. M., Boersma, K. F., Jacob, D. J., and Meijer, E. W.: Accounting for non-linear chemistry of ship plumes in the GEOS-Chem global chemistry transport model, Atmos. Chem. Phys., 11, 11707-11722, doi:10.5194/acp-11-11707-2011, 2011.
2. Vinken, G. C. M., and K. F. Boersma, From ship smokestack to global air pollution: bridging the scales to better constrain ship NOx emissions from space, SOLAS Newsletter, 8-9, www.solas-int.org, September, 2011.



Validation of tropospheric trace gas retrieval (focus on nitrogen dioxide) by satellites with ground based measurements.

Project Aim

Ground-based NO2 observations for satellite validation. The aim of the project is to retrieve tropospheric nitrogen dioxide (NO2) concentrations from high resolution spectral observations of scattered sunlight. This NO2 product is used to validate retrievals from the OMI and SCIAMACHY satellite instruments.

Progress

This project has been finished with the thesis of T. Vlemmix (december 2011).

Dissertations

1. Vlemmix, T. - Tropospheric nitrogen dioxide inversions based on spectral measurements of scattered sunlight. PhD thesis, Eindhoven University of Technology, The Netherlands (2011).

Scientific Publications

1. Vlemmix, T., Eskes, H. J., Piters, A. J. M., Kelder, H., and Levelt, P. F. MAX-DOAS tropospheric nitrogen dioxide column measurements compared with the Lotos-Euros air quality model, Atmos. Chem. Phys. Discuss., 11, 28895-28944, doi:10.5194/acpd-11-28895-2011, 2011.

Projectleaders

HM Kelder, PF Levelt, GJF van Heijst

Researchtheme

Complex dynamics of fluids

Participants

T Vlemmix, AJM Piters, HM Kelder, PF Levelt

Cooperations

KNMI

Funded

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

Start of the project

2007

Information

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Dynamics, collisions and coalescence of droplets in turbulence

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

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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

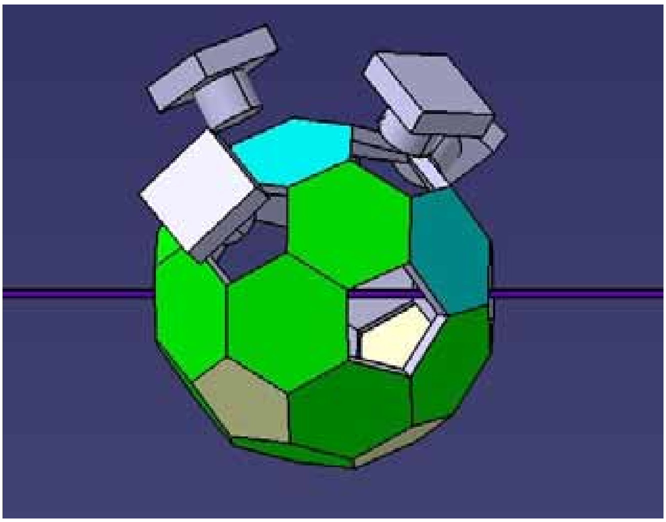
A PhD student, Altug Yavuz, started working on the project in September 2011. The design of the turbulence chamber is finalized.

Dissertations

-

Scientific Publications

-



Dynamics, collisions and coalescence of the droplets in a range of 10-30 μm will be investigated in a football (truncated icosahedrons) shaped turbulence chamber. The flow conditions will be tried to be tuned with 20 loudspeakers to homogeneous, axisymmetric and no shear and no mean flow conditions. The projected experimental techniques are 3D-PTV and PDA. In the figure the necessary locations of 4 cameras and the laser beam demonstrated for the 3D-PTV method.

Combustion Technology

Prof.dr. LPH de Goey

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 experimental setup/methods were investigated during the phd work. Numerical methods (Fluent and LamFla2D)are being explored to calculate the acoustic response of different flames.

Dissertations

1. Manohar, "Thermo-acoustics of Bunsen type premised flames" March 2011, TU Eindhoven; Prom./coprom.: prof.dr. L.P.H. de Goey & dr. V.N. Kornilov.

Scientific Publications

1. Manohar, M., Kornilov, V.N. & Goey, L.P.H. de (2011). Acoustic response of multiple flame perforated burners. ICSV18, International congress on sound and vibration, july 10-14- 2011, Rio de Janeiro, Brazil, (18). Rio de Jenerio.

Projectleaders

I Lopez, V Kornilov, H Nijmeijer, LPH de Goey

Researchtheme

Complex dynamics of fluids

Participants

Manohar, M hoeijmaakers, 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

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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
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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

Investigations of Mild combustion have been initiated by adopting 1D counterflow diffusion flames. NO formation has been studied in detail by excluding various kinetic routes of Zeldovich, Fenimore and N2O in the model. Under MILD conditions, prompt NO becomes the dominant NO formation route. To simulate a coflow burner with GRI 3.0 mechanism, a new parallel code is adopted. This code is developed at the Univ. of Toronto and it is written in C++. It has been adapted for the configuration of the coflow burner of RuG. Numerical results show a very good agreement of flame temperature and major species with the experiments. NO is predicted reasonably well. In the tip of the flame the NO concentration is over predicted. Improvements in NO predictions have been obtained by including radiation effects in the numerical model.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. S.E. Abtahizadeh, J.A. van Oijen and L.P.H. de Goey; "Numerical investigation of the main characteristics of Mild combustion flames with different diluted reactants." Proceeding of the European Combustion Meeting (ECM) 2011.
2. S.E. Abtahizadeh, J.A. van Oijen and L.P.H. de Goey, "Numerical study of igniting counterflow diffusion flames with diluted and preheated air and/or fuel streams for Mild combustion", Proceeding of the International Conference of Numerical Combustion,(ICNC) 2011.

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

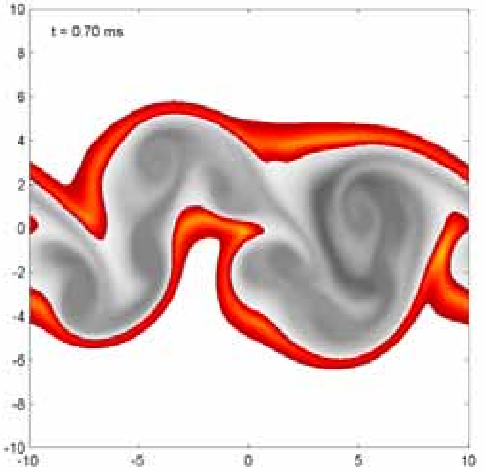
Combustion at MILD conditions has been investigated in numerical simulations of one-dimensional laminar counterflow diffusion flames employing detailed chemistry and transport models. These so-called flamelets will be used to generate look-up tables for accurate and efficient modeling of chemical kinetics 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. An existing large-eddy simulation solver has been extended with transport equations for conserved scalars and their variances, which will be used for chemistry tabulation and modelling of MILD combustion.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



PROJECTLEADERS

JA van Oijen

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

FE Hernandez Perez, JA van Oijen

COOPERATIONS

-

FUNDED

NWO (VIDI)

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

START OF THE PROJECT

2010

INFORMATION

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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
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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 model is currently being validated. Furthermore, a start is made with the implementation of a flamelet-based chemistry model (FGM) in the commercial solver used by Bosch Thermotechnik.

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: Development of a tool for manifold construction. Ansys-CFX implementation of FGM technique in the one-dimensional manifold case. Testing in a simple 2D geometry. Implementation of the 2D FGM considering heat loss inclusion.

Sudipto: Development of Filtered FGM (FFGM) with correction factors, Testing and validation of corrected FFGM with 1D laminar methane-air flames.

Dissertations

-

Scientific Publications

1. Donini A, Bastiaans R.J.M. Oijen, J.A. van and Goey L.P.H. de ; European Combustion Meeting, Cardiff 2011. “A Priori Analysis of Lean Turbulent Premixed Hydrogen Combustion DNS Simulation - FGM testing and Sub-Grid scale analysis”.

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

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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
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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 deg 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. Measurements of pressure upto 5 bar for CH4 and Syngas completed using Heat Flux Burner and a already available small high pressure cell.
2. A high pressure setup has been conceptualized and manufactured. The final assembly of the parts is in process. Other necessary safety requirements were fulfilled in the laboratory for handling of gases like H2 and CO.
3. A chemical reaction mechanism suitable for high pressure (up to 20 bar) syngas combustion was evaluated and validated with experimental data from literature
4. Simulations in CHEM1D and FLUENT are a part of this project. Fluent simulations were used to evaluate vital design parameters for the burner to be used.

Dissertations

-

Scientific Publications

1. M. Goswami, S. Derks, K. Coumans, A.A Konnov, R.J.M Bastiaans, M.H. de Andradec Oliveira, C.C.M Luijten, L.P.H de Goey; 'Effect of Elevated Pressures on Laminar Burning Velocity of Methane+Air Mixtures', International Colloqium on Dynamics of Explosion and Reacting Sytems, Irvine, California, USA, July 24-29, 2011.
2. M. Goswami, A.A Konnov, R.J.M Bastiaans, L.P.H de Goey; 'Updated Chemical Reaction Mechanism for Methane Combustion at High Pressure', International Conference on Chemical Kinetics, Cambridge, Massachusetts , USA, July 10-14.
3. M. Goswami, A.A Konnov, R.J.M Bastiaans, L.P.H de Goey; 'Syngas Combustion at High pressure', European Combustion Meeting, June 28 –July 1, 2011, Cardiff, Wales, UK.

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

Setting up of Flamelet Generated Manifold technique on Open FOAM for 1D case using a 2D geometry. Work in progress is now on the:

- 2D table case in order to include heat loss.
- Inclusion of beta PDF for turbulent combustion using a 3D geometry (DLR jet flame)
- Hydrogen effects and preferential diffusion.

Dissertations

-

Scientific Publications

1. Alessio Fancello, R.J.M. Bastiaans, and L.P.H. de Goey - RANS and LES of Turbulent Combustion based on Flamelet Generated Manifolds - 6th OpenFOAM Workshop -PennState University, USA 13-16 June 2011.
2. A. Fancello, R.J.M. Bastiaans, L.P.H. de Goey - Numerical Simulation of Turbulent Combustion using RANS and LES models based on Flamelet Generated Manifolds - Proceedings of the European Combustion Meeting 2011 – Cardiff (UK).

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

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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

Funded
STW

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

Start of the project
2009

Information
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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

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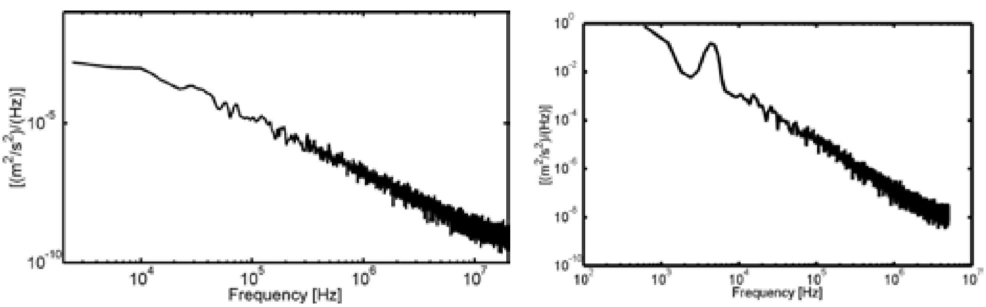
Scientific Publications

1. T. CARDOSO DE SOUZA, R.J.M. BASTIAANS, B.J. GEURTS, L.P.H DE GOEY: Large Eddy simulations of stabilized premixed combustion using FGM. ECM 2011 – Cardiff.
2. T.CARDOSO DE SOUZA, R.J.M. BASTIAANS, B.J. GEURTS, L.P.H DE GOEY: LES and RANS of premixed combustion in a gas-turbine like combustor using the Flamelet Generated Manifold approach. ASME Turbo Expo 2011 – Vancouver.



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.

A methodology to design fuel flexible gas turbine combustors using thermokinetic equilibrium, nearly global mechanism and one-dimensional approach

Project Aim

This study seeks qualitative information aiming at reaching an optimized design of a fuel flexible gas turbine combustor burning conventional and alternative fuels. Other objective of this study is developing a methodology applied in a FORTRAN code as a computational tool. This study may be used as the starting point for other optimization studies such CFD or CNR analysis.

Progress

During the past year, conventional fuels as diesel, kerosene and alternative fuels as ethanol, methanol and methane were investigated in gas turbine combustors. Currently, it is being developed a subroutine for temperature distribution in flexible gas turbine combustor zones, which will be used on the implementation of CRN analysis for the designed flexible gas turbine combustor.

Dissertations

-

Scientific Publications

1. W.O.I. Bohorquez, J.R. Barbosa, R.J.M. Bastiaans, P. de Goey, Numerical Simulation for the Preliminary Design of Fuel Flexible Stationary Gas Turbine Combustors Using Conventional and Alternative Fuels, ASME-IGTI Turbo Expo 2012, Copenhagen, Denmark, June, 11th-15th, 2012, accepted in 2011.
2. W.O.I. Bohorquez, J.R. Barbosa, Simplified Methodology to Assess the Use of Alternative Fuels at Fuel Flexible Gas Turbine Combustors Design Stage Using Thermokinetic Equilibrium and Nearby-Global Mechanisms, Ibero-American Journal of Mechanical Engineering, Paper RIBIM RI-11 _001059 (accepted), 2011.
3. W.O.I. Bohorquez, J.R. Barbosa, L.A.H. Nogueira, Operation Analysis and Thermoeconomic Evaluation of a Cogeneration Power Plant Operating as Self-Generator in the Ecuadorian Electrical Market and Sugar Industry, Journal Energy Resources Technology, ASME, Paper JERT 10 1164 (accepted), 2011.
4. W.O.I. Bohorquez, J.R. Barbosa, Preliminary Design of Gas Turbine Tubular Combustion Chamber Using Potential Alternative Fuels for Stationary Gas Turbines in the Brazilian Context, 21st International Congress of Mechanical Engineering, Natal, RN, Brazil, October, 24th-28th, 2011.
5. W.O.I. Bohorquez, J.R. Barbosa, L.A.H. Nogueira, Alcohol Fuels in Fuel Flex Gas Turbines: Numerical Simulations to Assess their Effects at the Combustor Design Stage, XIXº International Symposium on Alcohol Fuels, Verona, Italy, October, 10th-14th, 2011.
6. W.O.I. Bohorquez, J.R. Barbosa, Numerical Simulation for the Assessment of the Use of Alternative Fuels in Flexible Gas Turbines, X Ibero-American Congress of Mechanical Engineering, Porto, Portugal, September, 4th-7th, 2011.
7. W.O.I. Bohorquez, J.R. Barbosa, Functional Analysis and Exergoeconomic Evaluation for the Combined Production of Electromechanical Power and Useful Heat of a Cogeneration Power Plant, ASME-IGTI Turbo Expo 2011, Vancouver, Canada, June, 6th-10th, 2011.

Projectleaders
RJM Bastiaans

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
WOI Bohorquez

Cooperations
Instituto Tecnológico de Aeronáutica, Department of Aerospace Science and Technology, Brazilian Air Force, Brazil, São José dos Campos, São Paulo Brazil

Funded
CNPq: National Council for Scientific and Technological Development, financed by the Ministry of Science and Technology (MCT), Brazil

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

Start of the project
2011

Information

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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
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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 for a constant volume chamber. The database for chemistry generation is created by homogeneous reactors and counter-flow diffusion flamelets. The method is validated by comparing the results with ECN database for baseline n-heptane cases. Many tests have been done on the metal engine, consisting of fuel tests with bio-derived oxygenates, direct injection of butane-diesel blends, and gasoline-diesel dual fuel combustion. A start has been made with the application of the latter reactivity controlled concept to low-cost and renewable fuels. The optical engine has been further improved and initial tests have been done for the high-speed visualization of minor combustion species.

Dissertations

-

Scientific Publications

1. Egüz et al., Multi-zone modelling of PCCI combustion. International Journal of Vehicle Design, 55(1): 76-90.
2. Leermakers et al., Experimental study of fuel composition impact on PCCI combustion in a heavy duty diesel engine. SAE Technical Papers, 2011-01-1351
3. Leermakers et al. Direct injection of diesel-butane blends in a heavy duty engine. SAE International Journal of Fuels and Lubricants, 4(2): 179-187, 2011-01-2400.
4. Leermakers et al., Gasoline–diesel dual fuel : effect of injection timing and fuel balance. SAE Technical Papers, 2011-01-2437.

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

- Using FGM methodology to model detailed chemistry of diesel combustion, in a way to reduce the cost and time involved in numerical simulation.
- Accurate predictions of Ignition delay using counterflow diffusion flamelets
- Accounting heatlosses using enthalpy variation effect during HDDI diesel engine combustion
- Modeling diesel soot.

Progress

(1) ECN Spray Modeling: In order to evaluate and improve the prediction capability of FGM method to predict ignition delay accurately, experimental data from ECN (Engine Combustion Network) has been used to validate model predictions. ECN is an international collaboration (http://www.sandia.gov/ecn/) with the intention to provide unambiguous reference data to develop and test numerical models for Diesel combustion. An optimum setting of mesh size and time step along with turbulence model obtained based on non-reacting spray simulations. Subsequently, the pre-dictions of the combustion properties (ignition delay, lift-off length) have been studied applying FGM combustion model for Spray-H. The model is run at few O2 concentrations to study the sensitivity of the model along with validating against ECN experimental data. The first stage of our work resulted in SAE publication (with Ulas Egüz)[1]. Further to these studies, effect of FGM table resolution on Ignition delay has been studied more in-detailed. PDF integrated FGM table has 4 dimensions with mean and variances of both mixture fraction and progress variable. Table resolution is an important feature as it improves the accuracy for interpolation of reaction source terms which is fed into CFD coupling. Finer the table resolution betters the predictions (as shown in Fig. 1). The next level of investigation is to identify the optimum size of the table resolution. (2) Enthalpy Integration: Enthalpy variable as an addition control variable is needed to be incorporated in FGM tabulation, in-order to consider the heat loss effect on chemistry data interpolation during CFD simulations. All the simulations are so far performed with one enthalpy level of Oxidizer and Fuel. To start with, three levels of enthalpy conditions for counter flow flames and in-combination with Homogeneous reactors might be sufficient to tabulate the evolution of enthalpy data in engine simulations. However, the enthalpy variable value (Thermo-chemical) read from STARCD is not very apprehensible. Basic simulations have been performed to understand how Enthalpy and Temperatures are calculated (coupled) in STARCD. This is crucial as this variable will be used as a control variable for interpolation. (3) Soot Modeling: A collaborative work with the group of D'Anna from University of Napoli, Italy has been in-progress to implement 2equation model on generic conditions (Phi-T maps).

Dissertations

-

Scientific Publications

-

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

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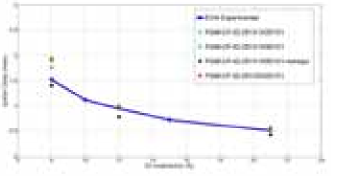

Effect of table resolution on Ignition delay sensitivity of O2 concentration

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
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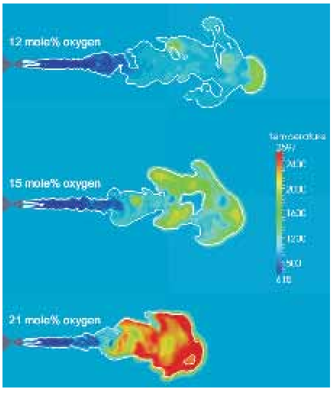
FGM-LES results. Instantaneous spray cross-sections of 3 different cases showing temperature contours shortly after auto-ignition.



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. Concerning ignition and combustion a tabulated chemistry approach (FGM) is to be adopted. In order to apply these models successfully in the design of engines, appropriate and accurate diesel fuel characteristics have to be captured. On one hand, the thermo-physical properties of the fluid are important due to the vaporization and mixing processes that are involved. On the other hand, reaction kinetics plays an important role as the gas phase combusts. 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

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Scientific Publications

1. C. Bekdemir, L.M.T. Somers, L.P.H. de Goey, Modeling diesel engine combustion using pressure dependent Flamelet Generated Manifolds, Proceedings of the Combustion Institute 33 (2011) 2887-2894.
2. M.Meijer, L.M.T. Somers, L.P.H. de Goey. Engine Combustion Network: implementation and analysis of combustion vessel spray A conditions, Illass-Americas NA 2011 23rd conference, paper 151.

Engine Efficieny : Modeling fuel-air mixing and auto-ignition in a diesel engine-like environment

Project Aim

The purpose of this project is to study fuel-air mixing and its effect on auto-ignition and combustion in partially premixed (i.e. premixed enough) compression ignition engines, using CFD tools such as STAR-CD (CD-adapco). Flamelet-Generated Manifolds (FGM) approach (TU/e) will be used for combustion modeling. Diesel and gasoline surrogate fuels will be studied, which features different auto-ignition time. Simulation work will be validated against experiments done in the Combustion Research Unit (CRU), a constant volume combustion chamber in the Fuels Technology Group of Shell Global Solutions. The diagnostics of interest will be ignition delay, pressure rise, etc.

Progress

Experiments were performed in a constant volume vessel (CRU), with fuel sprays injected into the vessel at selected pressure and temperature conditions that are typical of a diesel engine at cold start, with the objective of studying fuel composition, temperature and pressure effects on mixing and combustion. N-heptane and iso-octane were used. CFD modeling of combustion for these two fuels at the selected experimental conditions were thus conducted adopting a semi-detailed mechanism, FGM method together with platform STAR-CD. Effects from different fuels are examined experimentally, while effects from different conditions for n-heptane injection are examined from both experimental and simulation results. Furthermore, Livengood-Wu method as well as FGM method are investigated for auto-ignition modeling.

Dissertations

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Scientific Publications

1. 13th International Conference of Numerical Combustion, Corfu, Greece "Numerical Investigation of Livengood-Wu Method in Modeling Autoignition in Diesel Engine Combustion".
2. 8th International Symposium,Towards Clean Diesel Engines, TCDE 2011, Chester, "Modeling Constant Volume Chamber Combustion at Diesel Engine Condition".
3. 5th European Combustion Meeting, Cardiff, "Modeling Liquid Fuel Injection and Autoignition in Constant Volume Vessel".

Projectleaders

LMT Somers

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Zhixin Hu

Cooperations

Shell Global Solutions, UK

Funded

European Commission, Shell Global Solutions

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

Start of the project

2009

Information

LMT Somers
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Fuel(s)(spray) characterization and optimization for new engine combustion concepts

Projectleaders
CCM Luijten

Researchtheme
Complex dynamics of fluids

Participants
CCM Luijten, MH de Andrade Oliveira, M Yu, RPC Zegers, MD Boot, CAJ Leermakers

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
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Project Aim

This project aims to make a cross-coupling between developments in fuels and engines. On the engine side, the most important (class of) new combustion concept is PCCI: premixed charge compression ignition. PCCI, however, puts different requirements to the fuel than conventional combustion (more specifically, a lower CN is required to enhance premixing). On the fuels side, important trends are introduction of alternative fuels such as LPG, CNG, biodiesel, ethanol and synthetic fuels, but also more dedicated fuels that were identified as promising with respect to (low) emissions in earlier research.
By studying these “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 data is gathered on their combustion behavior. These experimental data also enable verification of numerical simulations.

Progress

In 2011, one last paper resulting from the PhD work of M.D. Boot was published on flame lift-off and soot production of oxygenated fuels, in cooperation with RUN. Significant work was done in 2010 and 2011 on testing various fuels and fuel combinations in the Cyclops engine (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 has led to three publications: one paper resulting from the graduation work of ir. C.A.J. Leermakers, comparing different fuel blends and specifically looking at the effect of combustion delay (combination of ignition delay and combustion duration) on engine efficiency and emissions. Another paper was published together with Vialle Alternative Fuel Systems, on the efficiency and emission effects of direct injection of premixed liquid butane/diesel blends.

Dissertations

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Scientific Publications

1. Donkerbroek, A.J., Boot, M.D., Luijten, C.C.M., Dam, N.J. & Meulen, J.J. ter (2011). Flame lift-off length and soot production of oxygenated fuels in relation with ignition delay in a DI heavy-duty diesel engine. Combustion and Flame, 158(3), 525-538.
2. Leermakers, C.A.J., Berge, B. van den, Luijten, C.C.M., Goey, L.P.H. de & Jaasma, S. (2011). Direct injection of diesel-butane blends in a heavy duty engine. SAE International Journal of Fuels and Lubricants, 4(2), 2011-01-2400.
3. Leermakers, C.A.J., Luijten, C.C.M., Somers, L.M.T., Kalghatgi, G.T. & Albrecht, B.A. (2011). Experimental study of fuel composition impact on PCCI combustion in a heavy-duty diesel engine. SAE Technical Papers, -, 2011-01-1351-1/20.
4. Leermakers, C.A.J., Berge, B. van den, Luijten, C.C.M., Somers, L.M.T., Goey, L.P.H. de & Albrecht, B.A. (2011). Gasoline–diesel dual fuel : effect of injection timing and fuel balance. SAE International Journal of Engines, 4(3), 2011-01-2437, submitted / in press.
5. Luijten, C.C.M. & Kerkhof, E. (2011). Jatropha oil and biogas in a dual fuel CI engine for rural electrification. Energy Conversion and Management, 52(2), 1426-1438.

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

It is attempted to build a bridge between laminar flame and the much more complex and demanding environment found in practical combustion engines. This is accomplished by designing and constructing a High Pressure Vessel and Burner (HPVB) and integrating these with an evaporation system. This setup will enable the study of automotive (bio-) fuels, applying advanced optical diagnostics techniques that will be assessed in cooperation with the Lund Institute of Technology. This assessment will shed light on the applicability of these methods in sooty environments at high pressure.

Progress

The experimental measurements and data analysis carried out with the HPVB setup were finalized. 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 submitted to the to the Proceedings of the Combustion Institute. A feasibility of using the heat flux method in a high pressure environment was investigated by integrating the heat flux burner in the high pressure vessel of the HPVB setup. A PhD thesis was written and at the moment is under evaluation of the core committee.

Dissertations

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Scientific Publications

1. Zhou, L., Dam, N.J., Andrade Oliveira, M.H. de, Luijten, C.C.M., Leermakers, C.A.J., Boot, M.D. & Goey, L.P.H. de (2011). Laser Diagnostics of Soot Formation by Alternative Fuels. Proceedings of the Summer School: "Energy and Materials from the Sun", 20-23 June 2011, Kerkrade, The Netherlands, (pp. 1-16).

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

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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
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Project Aim

Premixed charge compression ignition (PCCI) is one of the most promising combustion strategies for internal combustion engines, since PCCI combustion is able to realize very low soot and nitric oxide emissions while maintaining high fuel efficiency. To obtain a more detailed understanding of PCCI combustion process, we aim to investigate a limit set of fuel spray mixing/reacting events. The objectives include: Characterize of flow/temperature field prior to fuel injection (thermo-phosphor, Rayleigh Scattering, Raman Scattering etc.); Image the spray behavior and mixing progress during/after injection (Schlieren, LIF, etc.); Build an experimental database for numerical models.

Progress

In total, four laser diagnostic methods are evaluated in the EHPC for 2D temperature measurement. The Rayleigh Scattering suffers from bad Signal/noise ratio and Raman Scattering method suffers weak signal. Laser Induced Fluorescence (LIF) is chosen to measure the temperature field of an n-heptane spray injected in PCCI condition. In this LIF measurements, toluene is chosen to be the tracer for its high signal/noise ratio (SNR) and simple implementation. Toluene-LIF is excited by a 248 nm Excimer laser. Calibration is done in an optically accessible engine. Laser Induced Phosphorescence (LIP) is chosen to measure the temperature field of the pre-combustion residual gas. The BAM (BaMgAl10O17:Eu2+) is chosen to be the tracer phosphor for its high SNR and its capability to survive the pre-combustion. A seeding device was designed and implemented to seed the ~3 µm solid particles in gaseous flow. BAM-LIP is excited by a 355 nm YAG laser. The spatial resolution is 2 mm. The calibration is done in the EHPC. Results show that the BAM-LIP can be used to measure the temperature field of the residual gas in the EHPC below 700 K. The precision is about 30 K. The toluene-LIF is capable of measuring the temperature distribution of n-heptane sprays as it is injected into ambient gas temperature less than 700K. Above 700 K, the SNR became too low for measurement. A theoretical model is implemented which describe the physical processed in a fuel spray, as it is injected into stagnant ambient gas. The model is used to predict the influence of the temperature of the ambient gas on the temperature distribution in the diesel spray. Results show that a higher ambient temperature will not only result in a higher temperature in the fully developed spray, but also result in shorter liquid length and a faster temperature increase. The cooling process that is initiated by pre-combustion in the EHPC is analyzed. The analysis is based on experimental observations and analytical modeling. The results show that turbulent convective heat transfer is the dominant factor in the heat transfer at the boundary.Experimental work on Dual fuel injection has been performed but the injector is not suitable for the Eindhoven Higher Pressure Cell (EHPC) condition..

Dissertations

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Scientific Publications

1. Yu, M., Bakel, B.J.C. van, Luijten, C.C.M., Dam, N.J. & Goey, L.P.H. de (2011). Two dimensional temperature measurement of a diesel spray. proceedings of the 8th International Symposium: towards clean diesel engines (TCDE 2011), 08-09 June 2011, Chester, UK, (pp. 24-25). Chester, UK: Shell Global Solutions.

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 one of the most promising combustion strategies for internal combustion engines, since PCCI combustion is able 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 will be investigated. In this project methods are investigated to achieve and measure charge stratification. The mixing process is investigated by measuring in-cylinder velocities during fuel injection using high speed particle image velocimetry (HS-PIV). In-cylinder and spray temperatures are measured using Toluene Laser induced fluorescence. PCCI combustion has been investigated by determining the flame position as function of ignition delay using a high speed OH chemilunescence technique.

Progress

All experiments have been conducted and results are submitted or under investigation. The HS-PIV results duing injection of fuel have been submitted to Experiments in fluids. Toluene LIF results are currently being analyzed and combined with the results from the sub-project of M. Yu. PCCI combustion results are currently in preparation for publication.

Dissertations

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Scientific Publications

1. Bakel, B.J.C. van, Zegers, R.P.C., Luijten, C.C.M., Dam, N.J. & Goey, L.P.H. de (2011). Toluene planar LIF in an optically accessible engine.Proceedings of COMBURA'11 - Book of Abstracts, 10-11 october 2011, Ede, The Netherlands, (pp. 49-50). Ede, The Netherlands.
2. Aussems, J.E.E., Zegers, R.P.C., Leermakers, C.A.J., Somers, L.M.T. & Goey, L.P.H. de (2011). Optical diagnostics on stratified charge compression ignition in a heavy-duty diesel engine. Proceedings of COMBURA'11 - Book of Abstracts, (pp. 21-22). Ede, The Netherlands.
3. Zegers, R.P.C., Aussems, J.E.E., Leermakers, C.A.J., Luijten, C.C.M., Dam, N.J., Dam, N.J. & Goey, L.P.H. de (2011). PCCI combustion in an optically accessible engine using reference fuels. proceedings of the 8th International Symposium: towards clean diesel engines (TCDE 2011), Chester UK: Shell Global Solutions.

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

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Process Technology

Prof.dr.ir. JJH Brouwers

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 of 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 is being developed for stochastic turbulence, which involves asymptotically exact solution methods and reveals the truncation errors. 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) ondensation and sublimation. The research is generic, aiming at results that are applicable in numeric codes 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.

Project Aim

This experimental and numerical investigation focuses on the effect of non-uniform suction flow on dynamic forces on the shaft of an impeller. Since these forces originate from the hydrodynamics of the internal flow they are classified as hydrodynamic forces, in contrast to forces due to, for example, system unbalance and gravitation. Measuring the hydrodynamic forces is generally very complicated and their relation to a distorted entrance flow field has never been studied extensively.

Progress

A closed-loop test rig is equipped with a scale model of a mixed-flow pump which is used for ship propulsion. A newly designed dynamometer is mounted between the shaft of the pump and the impeller. Dynamic forces on the impeller are measured accurately using six full bridges of strain gauges. In the testrig the velocity profile of the flow field entering the pump is adapted using various pipe bundles of a specific shape. Hydrodynamic forces on the impeller, resulting from non-uniform entrance flow, are measured for different operating conditions. It has been observed that a skewed axial velocity profile can lead to a considerable steady radial loading. Furthermore, blade excitation forces cause the impeller to whirl in a direction opposite to shaft rotation. Recent experimental and numerical research focused on the relation between the instability in the head curve and the magnitude of unsteady hydraulic forces. It is found that there is a strong influence of the extend of the clearance gap between impeller blades and casing. The spectral content of the forces shows evidence of rotating instabilities. It indicates that not only instability of the head curve and unsteady forces are interrelated, but also rotating instabilities play a role in this phenomenon.

Dissertations

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Scientific Publications

1. Esch, B.P.M. van, Cheng, L., 2011, Unstable operation of a mixed-flow pump and the influence of tip clearance, Proceedings of the ASME-JSME-KSME Joint Fluids Engineering Conference 2011, Hamamatsu, Shizuoka, Japan.

Projectleaders
BPM van Esch

Researchtheme
Complex dynamics of fluids

Participants
BPM van Esch, C Li, JJH Brouwers

Cooperations
Wärtsilä Propulsion Netherlands
Yangzhou University, China.

Funded
TU/e, Yangzhou University, China
Wärtsilä Propulsion Netherlands

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

Start of the project
2004

Information
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Injury and mortality to fish passing through centrifugal pumps

Projectleaders
BPM van Esch

Researchtheme
Complex dynamics of fluids

Participants
BPM van Esch

Cooperations
Bosman Watermanagement BV

Funded
Bosman Watermanagement BV

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

Start of the project
2011

Information
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Project Aim

Understanding the mechanisms that lead to injury and mortality of fish when they pass through centrifugal pumps.

Progress

Based on American studies on the biological criteria for fish injury, the most important mechanisms are identified as pressure changes, shear forces, and mechanical injury. A blade strike model was adapted to fish passing through centrifugal pumps of radial, mixed-flow, and axial type. It reveals the relation between fish injury and the type of pump, its size, shaft speed, and pressure head. The results correlate well with measurements in pumping stations in the Netherlands. The flow through a mixed-flow pump, typical for pumping stations, is calculated using CFD. The results show that pressure fluctuations and shear forces are not likely to add much to fish mortality. Guidelines for the design and selection of “fish-friendly pumps” in pumping stations are derived.

Dissertations

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Scientific Publications

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Project Aim

The aims of the project are the development and validation of a new physical model that can be used in the simulation of the heating process of fluids by direct steam injection at relatively high temperatures and short residence times. To this end a combination of the diffuse interface method and large-eddy simulation has been used and dedicated experiments have been be carried out.

Progress

The project has been finished in 2010, but there are a few publications in 2011.

Dissertations

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Scientific Publications

1. N. Clerx, L.T.M. van Deurzen, A. Pecenko, R. Liew, C.W.M. van der Geld, J.G.M. Kuerten, Temperature Fields Induced By Direct Contact Condensation of Steam in a Cross-Flow in a Channel, in Proceedings of the Sixth International Conference on Transport Phenomena in Multiphase Systems, Editors: M.E. Poniewski, S. Alabrudzinski, 247-254 (2011).
2. A. Pecenko, J.G.M. Kuerten, A priori analysis of an isothermal, turbulent two-phase flow, in Quality and reliability of large-eddy simulations II; Editors: M.V. Salvetti, B. Geurts, J. Meyers, P. Sagaut, Pisa, Italy, 111-120, (2011).
3. N. Clerx, L.T.M. van Deurzen, A. Pecenko, R. Liew, C.W.M. van der Geld, J.G.M. Kuerten, Temperature Fields Induced By Direct Contact Condensation of Steam in a Cross-Flow in a Channel. Heat and Mass Transfer, 47(8), 981-990, (2011).
4. A. Pecenko, L.T.M. van Deurzen, J.G.M. Kuerten, C.W.M. van der Geld, Non-isothermal two-phase flow with a diffuse-interface model. Int.J. Multiphase Flow, 37(2), 149-165, (2011).

Projectleaders

CWM van der Geld, JGM Kuerten

Researchtheme

Complex dynamics of fluids

Participants

N Clerx, A Pecenko, CWM van der Geld, JGM Kuerten

Cooperations

NIZO food research, Stork Food & Dairy Systems B.V.

Funded

STW

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

Start of the project

2006

Information

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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

Funded
STW, TU/e, DEISA

University	15 %
FOM	-
STW	85 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2003

Information
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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. The dynamic eddy-viscosity model and especially the approximate deconvolution model yield results which agree well with DNS results for a range of particle relaxation times. In 2011 DNS at Re_T=950 has been performed and results are compared with LES. Moreover, an equation for temperature as a passive scalar has been added. For the higher Reynolds number the quality of the dynamic eddy-viscosity subgrid model is better than at lower Reynolds number. The subgrid model for the particles has been implemented and tested in a CFD software package.

Dissertations

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Scientific Publications

1. J.G.M. Kuerten, C.W.M. van der Geld, B.J. Geurts, Turbulence modification and heat transfer enhancement by inertial particles in turbulent channel flow. Phys. Fluids, 23, 123301, (2011).
2. W.R. Michalek, R. Liew, J.G.M. Kuerten, J.C.H. Zeegers, LES of droplet-laden non-isothermal channel flow, J. Phys.: Conf. Ser. 318, 042056, (2011).
3. C. Marchioli, A. Soldati, M.V. Salvetti, J.G.M. Kuerten, A. Konan, P. Fede, O. Simonin, K.D. Squires, C. Gobert, M. Manhart. M. Jaszczur, L.M. Portela, Benchmark test on particle-laden channel flow with point-particle LES, in Direct and Large-Eddy Simulation VIII, Editors: H. Kuerten, B. Geurts, V. Armenio, J. Fröhlich, Eindhoven, The Netherlands, 177-182, (2011).
4. J.G.M. Kuerten, B.J. Geurts, C.W.M. van der Geld, Enhanced heat transfer by inertial particles in turbulent channel flow, in Proceedings of the Sixth International Conference on Transport Phenomena in Multiphase Systems, Editors: M.E. Poniewski, S. Alabrudzinski, 389-396 (2011).

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 2011 mass transfer between the gas and particles has been incorporated and tested for evaporating and condensing droplets in a turbulent channel flow.
A compressible DNS code has been developed with particles and two-way coupling.

Dissertations

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Scientific Publications

1. E. Russo, J.G.M. Kuerten, C.W.M. van der Geld, B.J. Geurts, Modeling water droplet condensation and evaporation in DNS of turbulent channel flow, J. Phys.: Conf. Ser. 318, 052019, (2011).

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

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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

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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 2011, an available test rig was redesigned, selection of fluids and experimental techniques was performed and a novel experimental technique to measure temperature fields with phosphoric tracers was explored. In addition, a new and accurate way was found to determine forces on a growing boiling bubble from high-speed videorecordings. In November 2011 J. Desmarais joined the team to work on the numerical modeling.

Dissertations

-

Scientific Publications

-

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

-

SCIENTIFIC PUBLICATIONS

1. D. Siregar and J.G.M. Kuerten, Numerical Simulation of the Drying of Inkjet-Printed Droplets, Proceedings of the 4th International Conference on Heat Transfer and Fluid Flow at Microscale, HTFFM-IV-031, (2011).

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

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Study of dropwise condensation

Projectleaders
CWM van der Geld
Researchtheme
Complex dynamics of fluids
Participants
M Grooten, CWM van der Geld
Cooperations
Klima, Verhulst, fac. Wsk, Innovation Handling
Funded
Faculteit W

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

Start of the project
2007
Information
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Project Aim

To increase our understanding of the basic mechanisms of dropwise condensation and of sublimation, and to apply the knowledge thus gained to the improvement of the design of compact condensers.

Progress

The thesis of Mart Grooten was written and the last two papers were completed. One of them is published in 2011, the other in January 2012. A post-doc from Irak will continue the work in 2012.

Dissertations

1. M.H.M. Grooten, Drainage control and diffusion resistance in dropwise condensation in a compact heat exchanger.

Scientific Publications

1. M.H.M. Grooten, C.W.M. van der Geld, Dropwise condensation from flowing air-steam mixtures: Diffusion resistance assessed by controlled drainage, DOI:10.1016/j.ijheatmasstransfer.2011.06.029, Int. J. of Heat and Mass Transfer, 54, 4507-4517, (2011).

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 2011, measurements were completed, an article conceived and part of the thesis of Jorge Goes 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

-

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

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Energy Technology

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 together with the study of practical systems. Our group restricts its fundamental research to the field of Heat Transfer and the practical system study to Small-scale Energy Systems with a strong emphasis on Sustainability.

The approach is to combine advanced experimental, analytical and numerical techniques to investigate fundamental issues 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) and better control of the boiling process (for heat removal and thermal homogenisation in, for example, lithographic systems). Another research line concentrates on laminar thermal transport in compact systems.

b. Micro-scale heat transfer

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 analyses to enhance the efficiency of compact heat storage and the dynamics of integrated fluid drivers in micro systems. On the smallest scales the physical processes on different scales are studied by coupling Molecular-Dynamics analyses with a Direct Simulation Monte Carlo model.

c. Heat-transfer engineering

The research activities in this area focus more on the system-level instead of the phenomenon-level. Main research projects are fouling of heat exchangers as used in waste- incinerators and biomass-gasifiers, design improvement of a humidity harvesting device and heat transfer models for the human body under normal and surgical conditions.

More information about the research activities in these areas can be found on our website: www.energy.tue.nl

PROJECT AIM

The focus in this research is the modified flow regime in the wake of a circular cylinder. The modification is obtained by placing a very thin wire at a particular position in the cylinder wake. The occurring transitional flow is denoted as Mode-C, in comparison to Mode-A and Mode-B transition for the non-wired cylinder. The flow structures have been investigated both experimentally and numerically for different Reynolds numbers (Re=100-250) using flow visualizations based on tin-precipitation method, velocity measurements using Particle Image Velocimetry and numerical simulations based on Spectral Element method.

PROGRESS

In the laminar two-dimensional flow regime Re=100, it is observed, both numerically and experimentally, that the wake of the cylinder is taking different trajectories with respect to the wire position. A hypothesis is formulated about the reasons of the wake deflection using a Point Vortex Model. The hypothesis is supported with the assessment of vortex trajectories, strengths, lift and drag characteristics. It is concluded that the deflection of the wake is primarily caused by a modification of the vortex arrangement in the wake. This modified vortex arrangement is caused by different formation times of the upper and lower vortices, by different vortex strengths or by both. A three-dimensional transition of the wired cylinder flow is observed for Re>170. This transition is characterized by the so-called Mode-C instability. The analysis of the experimental results shows that this Mode-C instability consists of secondary vortices with a period-doubling character, ie. the secondary vortices alternate sign from one shedding cycle to the next. It is shown that a feedback mechanism of the stream-wise vortices between the two consecutively shed upper von Karman vortices causes the period-doubling character of the wake. The analysis of Mode-C transition is further extended using the data from comprehensive PIV experiments. The three-dimensional wake structure and vortex dynamics are investigated with a particular focus on the energy distribution of the wake, vortex strengths and vortex trajectories. The secondary vortices are shown to be counter rotating vortex pairs with a span-wise wavelength of $\lambda Z/D=2.16$. In the final stage of the research, experiments are performed to evaluate the wake behind a rotating cylinder, particularly focusing on the so-called Shedding Mode II regime. In literature only numerical proof is found for the existence of this Shedding Mode II for which a single vortex is shed with a much lower frequency compared to non-rotating case. Both flow visualization and PIV techniques are used to investigate this kind of flow. Shedding Mode II is experimentally detected for a Reynolds number of Re=100 in the same rotation rate regime as in the numerical studies.

DISSERTATIONS

1. Yildirim, I. (2011). Transition of wire-disturbed cylinder wake flow. PhD-thesis Technische Universiteit Eindhoven. Promotor: prof.dr.ir. A.A. van Steenhoven, Co-promotor: dr.ir. C.C.M. Rindt.

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS
CCM Rindt, AA van Steenhoven

RESEARCHTHEME
Complex structures of fluids

PARTICIPANTS
I Yildirim, PR Bloemen

COOPERATIONS
GJF van Heijst, Fac. of Applied Physics, TU/e

FUNDED
FOM

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

START OF THE PROJECT
1996

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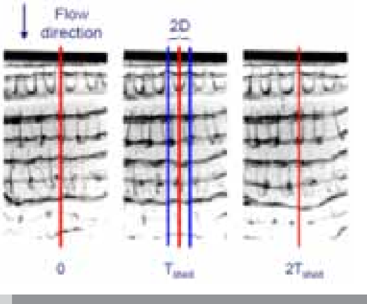
Flow visualization results showing period doubling of the wire-disturbed cylinder wake flow . Flow direction is from top to bottom. Blue and red lines indicate fixed span-wise positions



PROJECTLEADERS
HC de Lange, AA van Steenhoven
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
PR Bloemen, J Klinkenberg
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
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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

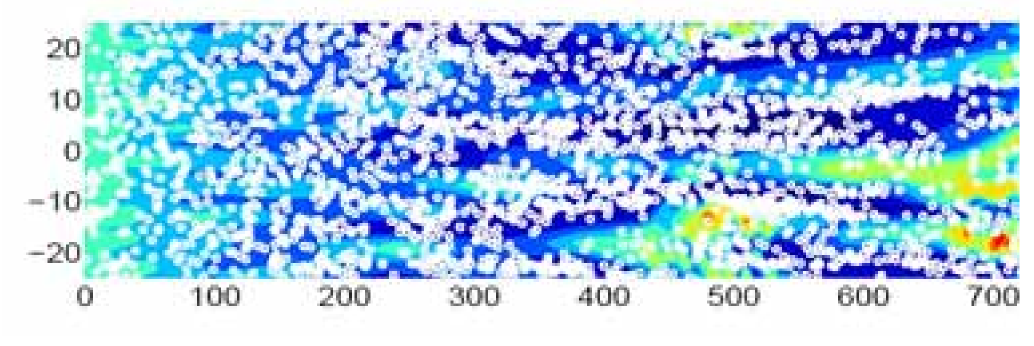
Flows laden with hard, spherical particles have been considered as control of transitional channel flow. Numerical analysis of a channel flow has been performed using both modal and non-modal analysis for heavy and light particles to investigate the initial stages to transition using a two-fluid model. 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 so far confirm the transient growth from the non-modal analysis and they also show that particles can delay turbulence under certain conditions. 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. 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. 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 clustering of particles. These results will be combined with those from numerical studies.

DISSERTATIONS

1. Klinkenberg J. (2011) Stability analysis of channel flow laden with small particles. Licentiate Thesis, KTH Engineering Sciences, Stockholm.

SCIENTIFIC PUBLICATIONS

1. Klinkenberg, J., Lange, H.C. de & Brandt, L. (2011). Modal and non-modal stability of particle-laden channel flow. Physics of Fluids, 23, 064110-1/13.



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)

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

An exhaustive literature survey on thermal issues in electric vehicles (EVs) and the potential for controlled pool boiling as a solution has been performed. The mathematical foundation of the 2D closed-loop model has been furth substabtiated by an extensive analysis on stability bounds by way of Lyapunov functions. This demarcated stability bounds as those shown in the left figure. Moreover, the stabilisability of essentially 3D hetereogeneous boiling states (right figure) has been investigated. This revealed that many of these states cannot be stabilised, meaning that the options for regulation of 3D boiling systems are limited. Finally, first exploratory experiments on application of pool-boiling for thermal management in EVs have been initiated and are currently in progress.

Dissertations

-

Scientific Publications

1. Gils, R.W. van, Speetjens, M.F.M. & Nijmeijer, H. (2011). Observer design for a nonlinear two-dimensional pool boiling system. In C. Ionescu, R. De Keyser & P. Guillaume (Eds.), Proceedings of the 30th Benelux Meeting on Systems and Control, 15 - 17 March 2011, Lommel, Belgium. (pp. 166). Gent: Universiteit Gent.
2. Gils, R.W. van, Speetjens, M.F.M. & Nijmeijer, H. (2011). Boiling Heat Transfer in Battery Electric vehicles. Proceedings of the European Electric Vehicle Congress, EEVC - 2011, 26-28 October 2011, Brussels, Belgium. (pp. 1-12).

Projectleaders

MFM Speetjens, H Nijmeijer

Researchtheme

Complex dynamics of fluids

Participants

RW van Gils

Cooperations

A Reusken & S Maier-Paape, Dept. Mathematics, RWTH, Aachen, Germany; W Marquardt, Dept. Mechanical Engineering, RWTH, Aachen, Germany; H Zwart, Applied Mathematics, Dept. Electrical Engineering, Mathematics and Computer Science, University of Twente; PHL 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	50 %
FOM	-
STW	-
NWO Other	50 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2008

Information

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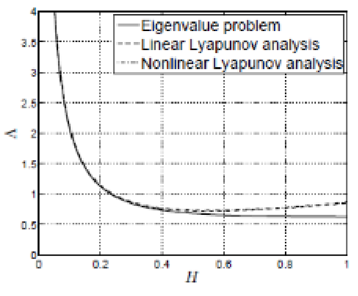

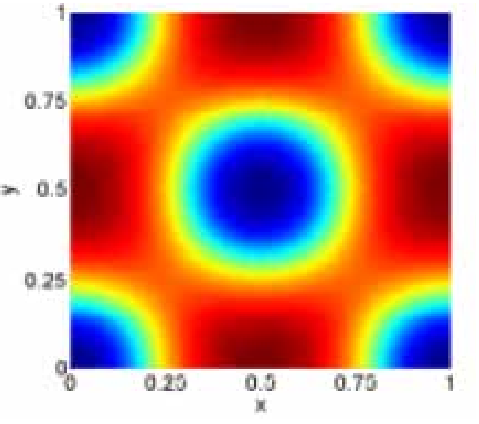

Dynamics of pool-boiling systems: (a) typical stability bound of the 2D closed-loop system isolated with the indicated method (the system is stable in the region above the curves); (b) temperature distribution in the fluid-heater interface corresponding with an unstable stateof the 3D open-loop system; bluish and redish regions are “low”’ (wet) and “high” (dry) temperature zone.

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, Melbourne, 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 (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

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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

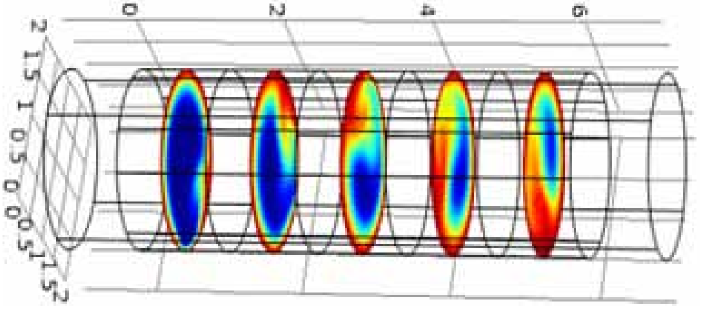
Computational tools for 2D and 3D simulations on flow and heat transfer have been developed. Numerical simulations on a 2D simplification of the Rotated Arc Mixer (RAM), a representative industrial heat-exchanger/mixer, have been performed in support of the design of a laboratory set-up for experimental studies in the companion PhD-project. As a first step towards 3D analyses, numerical simulations on the 3D mixing and heat-transfer properties of the RAM have been initiated (see figure). These efforts are currently ongoing.

Dissertations

-

Scientific Publications

1. Speetjens, M.F.M. & Steenhoven, A.A. van (2011). Visualisation of heat transfer in unsteady laminar flows. Computational Thermal Sciences, 3(1), 31-47.
2. Speetjens, M.F.M. & Steenhoven, A.A. van (2011). Heat and mass transfer made visible. Defect and Diffusion Forum, 312-315, 713-718.
3. Speetjens, M.F.M., Bijl, P., Golombok, M. & Smeulders, D.M.J. (2011). Viscosified flow control of enhanced geothermal systems. Proceedings of Sustainable Earth Sciences (SES 2011), November 8-10 2011, Valencia, Spain. European Association of Geoscientists and Engineers (EAGE).



Mixing versus heat transfer in the RAM: (a) typical cross-sectional mxing pattern visualised by axial Poincaré sectioning of the 3D streamline pattern (obtained by simplified 2.5D flow model); (b) downstream evolution of the 3D temperature field in case of a cold fluid (blue) entering a hot RAM (red) (axial throughflow from left to right).

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 have been performed on manipulation of the flow topology by way of AC electro-osmosis (ACEO), possibly in combination with other forcing. Goal was first 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), according to the method developed at Universität der Bundeswehr, München, have been performed. This revealed good qualitative agreement. Further experimental studies aimed at more detailed quantitative analyses are in progress.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Speetjens, M.F.M., Wispelaere, H.N.L. de & Steenhoven, A.A. van (2011). Multi-functional Lagrangian flow structures in three-dimensional AC electro-osmotic micro-flows. Fluid Dynamics Research, 43(3), 035503-1/25.
2. Speetjens, M.F.M., Wispelaere, H.N.L. de & Steenhoven, A.A. van (2011). Lagrangian flow structures in 3D AC electro-osmotic microflows. 3rd Micro and Nano Flows Conference, August 22-24, Thessaloniki, Greece.

PROJECTLEADERS

MFM Speetjens, AA van Steenhoven

RESEARCHTHEME

Complex structures of fluids

PARTICIPANTS

Z Liu, PR Bloemen

COOPERATIONS

HJH Clercx & GJF van Heijst, Dept. Applied Physics, TU/e; VV Meleshko, Kiev National Taras Shevchenko University, Ukraine; G Metcalfe, CSIRO-MMT, Melbourne, Australia; A Reusken, Dept. Mathematics, RWTH, Aachen, Germany; 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

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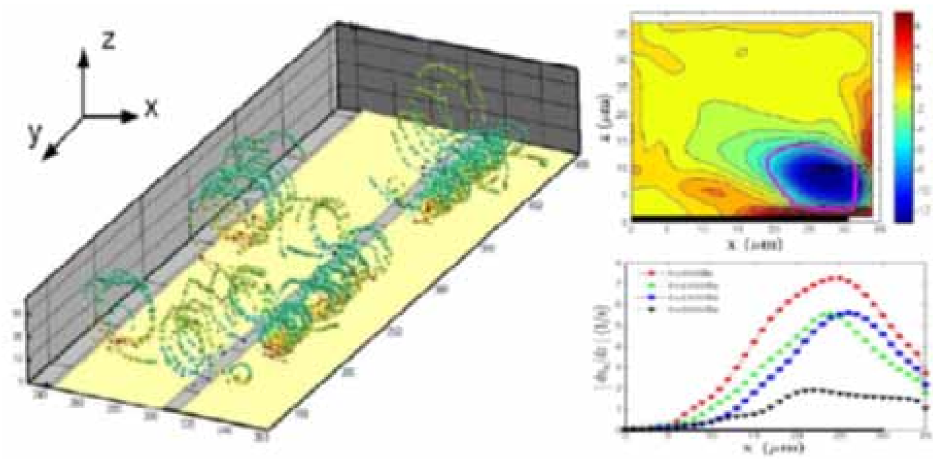

Flow measurements on a 3D ACEO micro-flow by 3DμPTV: (a) 3D particle trajectories; (b) mean spanwise vorticity (top) and wall shear rate above one half of an electrode (bottom).

PROJECTLEADERS
AJH Frijns, AA van Steenhoven
RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
JH Kim, EAT van den Akker, SV Gaastra-Nedea
COOPERATIONS
PAJ Hilbers, AJ Markvoort, Biomedical Engineering, TU/e, A Frezotti, Milan; J Reese, Y. Zhang, University of Strathclyde, UK
FUNDED
GASMEMS (Marie-Curie ,FP7)

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

START OF THE PROJECT
2009
INFORMATION
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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

Firstly, gas heating and choked subsonic flows in nanochannels subject to constant wall temperature was studied with MD simulation technique. The flow is driven by a pressure difference between the inlet and outlet. The flow parameters in the channel were obtained and analyzed with three different channel geometries that are commonly used in the industry: circular, rectangular (square), and slit channel. The effects on the velocity field and the accommodation coefficients were investigated. Furthermore, the model was extended to able to calculate local pressure. Stress tensor components were found for a microscopic system of particles by the Irving-Kirkwood method. According to this method the contribution of each particle to the stress tensor is in two parts, a configuration part and a kinetic part. The method has been used to study the effect of density gradient on the local pressure in micro- nano gas flows.

DISSERTATIONS

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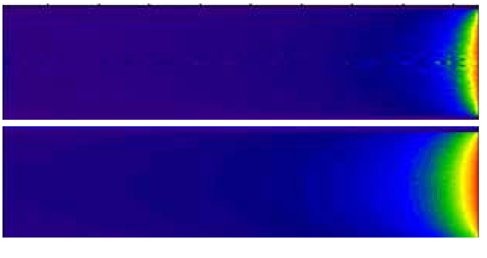
SCIENTIFIC PUBLICATIONS

1. Akker, E.A.T. van den, Frijns, A.J.H., Hilbers, P.A.J. & Steenhoven, A.A. van (2011). A molecular dynamics boundary condition for heat exchange between walls and a fluid. Molecular Simulation, 37(10), 855-864.
2. Kim, J., Frijns, A.J.H., Gaastra - Nedea, S.V. & Steenhoven, A.A. van (2011). DSMC and MD simulation on geometry and rarefaction effect. Proceedings of the 3rd GASMEMS Workshop, June 9-11 2011, Bertinoro, Italy. CD: GASMEMS.
3. Kim, J., Frijns, A.J.H., Gaastra - Nedea, S.V. & Steenhoven, A.A. van (2011). 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.



Velocity fields for a nano-slit and for nanochannels with circular cross-sections.

PROJECT AIM

As predictions of out-gassing processes and cooling of computer circuits are becoming more important, modeling of gas interactions with surfaces is a topic gaining increasing interest among researchers. The main aim of this appointment is to derive a technique which can qualitatively simulate multi-scale gas flow behavior, with emphasis on heat transfer, for dense or dilute gases. In order to simulate such cases a hybrid method will be implemented in the toolkit OpenFOAM. The hybrid method will involve molecular dynamics (MD) and direct simulation Monte Carlo, producing the solution of the Enskog equation (DSMC-ensk). Hybrid methods are promising for solving multi-scale gas flows since the most detailed gas/surface interactions can be captured by the precise MD method while the DSMC-ensk method provides a more cost efficient description of the bulk gas.

PROGRESS

The MD and the conventional DSMC methods have been coupled in the OpenFOAM toolkit. Simple validation of this hybrid method has been performed such as the burst membrane case illustrated in the figure. The burst membrane case is simulated in a box of size 10nm x 60nm x10nm having thermal walls set to 300 Kelvin. Ash the DSMC domain is initialized with 3211 molecules at 300 Kelvin the two methods approach an equal population of particles after a certain simulation time, as required. The next task will be to replace the DSMC method with the now implemented DSMC-ensk method.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Arlemark, E., Gaastra - Nedea, S.V., Frijns, A.J.H. & Steenhoven, A.A. van (2011). Comparing molecular dynamics and an Enskog based direct simulation. Monte Carlo method for high density gas flows. Proceedings of the 3rd GASMEMS Workshop, June 9-11 2011, Bertinoro, Italy. (pp. 1-8). CD: GASMEMS.
2. Gaastra - Nedea, S.V., Goga, N., Markvoort, A.J. & Steenhoven, A.A. van (2011). New multiscale heat transfer techniques. Materiale Plastice, 48(2), 132-137.

PROJECTLEADERS

SV Nedea, AA van Steenhoven

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

EJ Arlemark, Arjan Frijns

COOPERATIONS

GASMEMS (www.gesmems.eu)
AOES (www.aoes.com)
INFICON (www.inficon.com)

FUNDED

Seventh Framework Programme (ITN-FP7/2007-2013)
grant agreement n° 215504

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

START OF THE PROJECT

2010

INFORMATION

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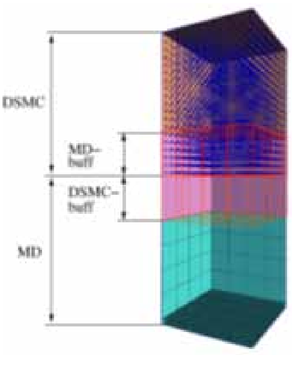

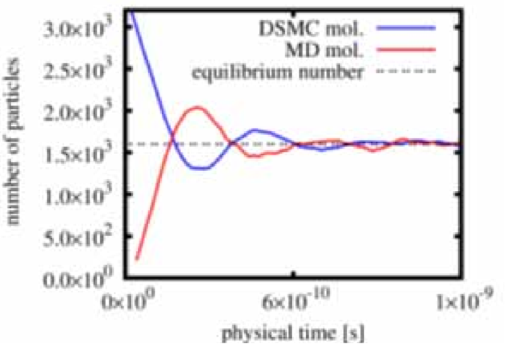

Left, simulated domain burst membrane case for hybrid solver. Right, results of number of particles in DSMC and MD domains respectively. Initial population is 3211 DSMC particles and expected equilibrium number is 1600 particles in each domain.

Characterization of the water vapor sorption process in salt hydrates used as thermochemical materials for seasonal heat storage

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

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Project Aim

A promising concept for the seasonal heat storage in the built environment is based on the reversible water vapor sorption process into crystalline salt hydrates. In order to develop an adequate sorption material for this application, it is necessary to optimize the structure, the composition and the heat- and vapor transport in these materials. In this project, experimental research is carried out on single crystals, grains and powder beds to establish the effect of the material properties on the heat- and vapor transport and to identify the kinetics and reaction enthalpies of the (de)hydration reactions.

Progress

In the first year of the project, the focus has been on establishing the state-of-the-art of the previous studies performed on salt hydrates to characterize the water vapor sorption process, and to reproduce the most important results. Two materials, Li2SO4.H2O and CuSO4.5H2O, have been taken as reference in this study and investigated under the practical conditions of seasonal heat storage. By means of thermal analyses, the kinetics of reactions for these materials have been identified and related to their variations of structure and composition by X-ray diffraction and Raman spectroscopy and to their textural changes (cracks, grains boundaries) observed by microscopic observations on monocrystals. Presently, these experiments have been extended to MgSO4.7H2O and MgCl2.6H2O which are promising materials for long-term heat storage.

Dissertations

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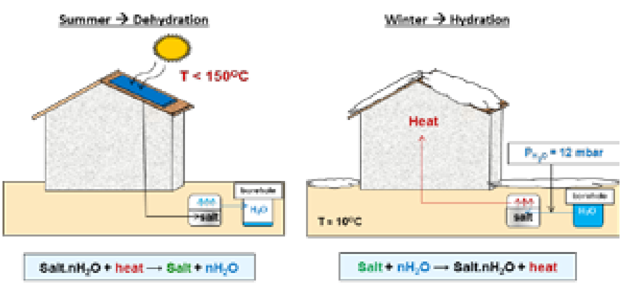
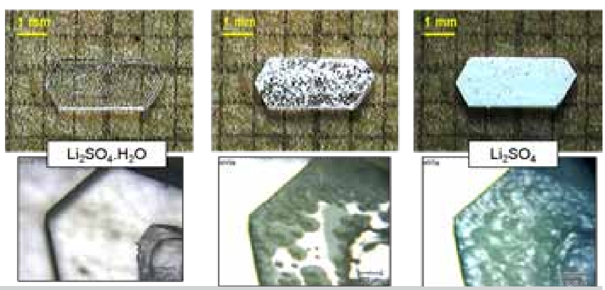
Scientific Publications

-



Scheme of the water vapor sorption process in salt hydrates during summer and winter



Textural observations on monocrystals of the water vapor sorption process of Li2SO4.H2O under the practical conditions of seasonal heat storage.

Development of micro- and meso-scale models for thermo-chemical heat storage materials

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

The project planning is set for the coming four years. A CFD tool box, OpenFOAM, is practiced to study its possibility and suitability in tackling combined heat and vapor transport problems. A benchmark problem, flow around one cylinder, is studied and good agreement between the OpenFOAM results and analytical results is obtained. A literature study about the pore-net work method, direct simulation Monte Carlo method and fictitious domain method is ongoing.

Dissertations

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Scientific Publications

-

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

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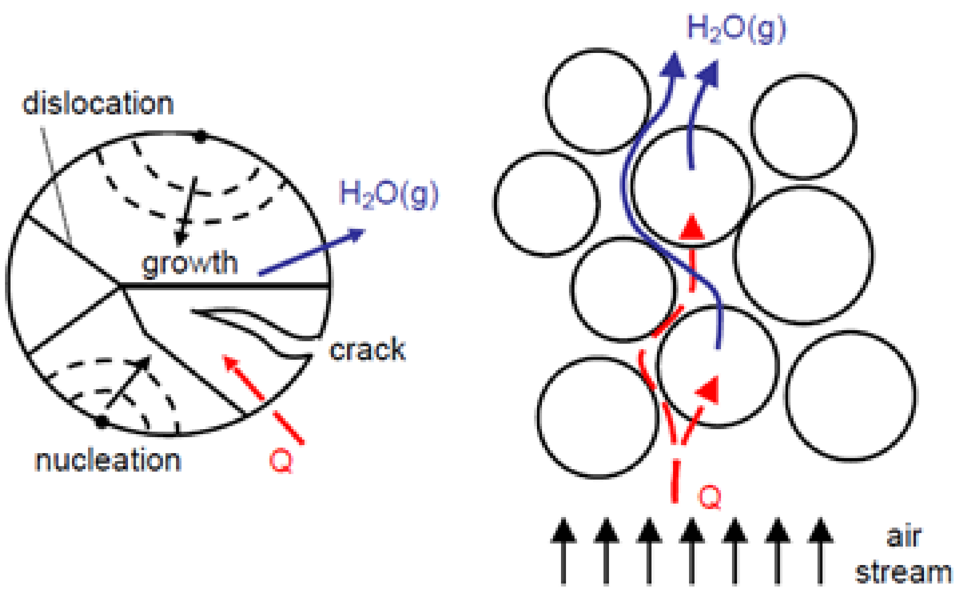

Schematic of heat and mass transfer processes

Molecular dynamics to enhance efficient compact heat storage

Projectleaders
CCM Rindt, SV Nedea, AA van Steenhoven

Researchtheme
Complex dynamics of fluids

Participants
E Iype

Cooperations
A van Duin, (Associate Professor, Mechanical and Nuclear Engineering, Penn State University.)
HA Zondag (ECN)

Funded
European Graduate School for Sustainable Energy (TU/e, TUM, DTU)

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

Start of the project
2009

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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 limits the kinetics and usability of salt hydrates as thermochemical heat storage materials. This study will help to classify such materials based on the storage efficiency, usability, kinetics, reusability etc. This information can be used to identify the best suitable material for thermochemical heat storage.

Progress

Density Functional Theory (DFT) studies has been conducted with the aim to optimize the reactive force field (ReaxFF) for MgSO4 hydrates. The calculations involved finding the accurate molecular structures of various hydrates of MgSO4, calculating the solid equation of states (EOS) for the hydrates of MgSO4. Bulk modulus of the crystals was derived from these EOS. In addition, the binding energy of water on MgSO4 slab is also calculated. Figure 1 shows the energy as a function of distance of separation between the slab and water molecule. The figure also shows the instantaneous molecular configurations as the water approaches the slab. The extreme left geometry in Figure 1 reveals the dissociation of water at the surface of the crystal. This calculation was extended for another molecule of water to see the effect of hydration on MgSO4 surface. The second water molecule did not show any evidence of dissociation. Nevertheless, the study reveals that the hydrates of MgSO4 are characterized by the presence of strong hydrogen bonds which significantly influence the dynamics of hydration dehydration process.

Dissertations

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Scientific Publications

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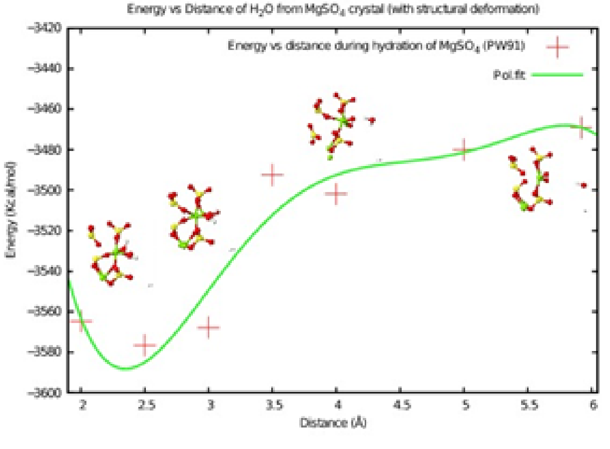

Binding energy of water on $MgSO_4$ slab as a function of the distance of separation between the slab and H_2O

Integrated micro-fluidic cooling in laminated flexible micro-systems

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

The project has started in 2011. The main focus has been on an integrated pulsating heat pipe. Manufacturing methods have been investigated and a numerical model for studying the onset of the pulsating motion has been developed. First tests have been performed.

Dissertations

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Scientific Publications

-

Projectleaders

AJH Frijns, AH Dietzel, AA van Steenhoven

Researchtheme

Complex dynamics of fluids

Participants

G Gürsel, T Ahmed

Cooperations

Holst Centre, IMEC, Philips

Funded

STW

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

Start of the project

2001

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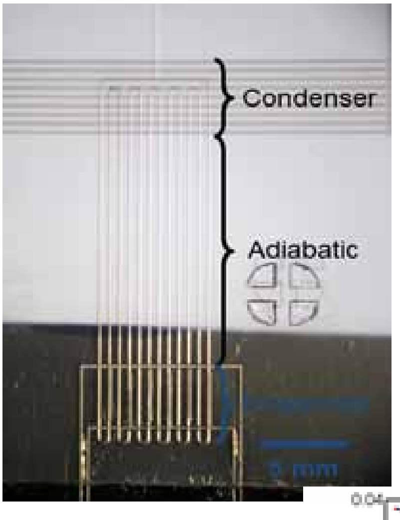
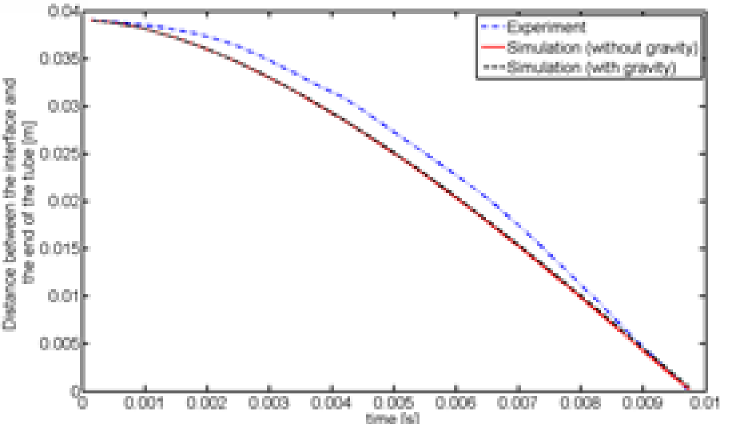


Left: foil with integrated pulsating heat pipe; below: onset of the pulsating motion in a capillary tube.



Gas sensor window

Projectleaders
AJH Frijns, AH Dietzel, AA van Steenhoven

Researchtheme
Complex structures of fluids

Participants
S van Pelt, RJS Derks

Cooperations
Holst Centre

Funded
CATRENE / PASTEUR

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

Start of the project
2009

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Project Aim

The aim of the project is to enhance the selectivity of gas-sensors by covering it with a window. Ideally this window will only transmit the targeted gas molecules and obstruct all other particles. In a first approach, passive polymer membranes will be used. Finally, an active system will be designed and tested to actively sample and operate at non-equilibrium to further enhance the selectivity and response-time of the sensor.

Progress

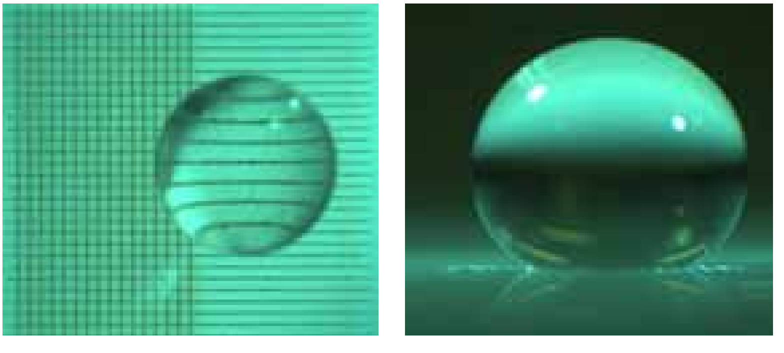
A setup has been designed and built to characterize the permeation of different gasses through different membranes. The built setup was outfitted with RH-sensors and a support for low-stiffness membranes. Simulations and experiments have been compared to each other and showed good agreement. A super-hydrophilic yet highly permeable membrane was made from PDMS using patterning by excimer laser ablation. The permeation for patterned and unpatterned membranes were compared to each other. The permeation was hardly affected by the structured surface, while the hydrophobicity is strongly affected.

Dissertations

-

Scientific Publications

1. Derks, R.J.S., Frijns, A.J.H., Prins, M.W.J. & Dietzel, A.H. (2011). Reversionary rotation of actuated particles for microfluidic near-surface mixing. Applied Physics Letters, 99, 024103-1/3.
2. S. van Pelt, J. Eggermont, A.J.H. Frijns, A. Dietzel (2011) “Patterned super-hydrophobic sensor windows for food monitoring”, Proceedings of MNE 2011, Berlin.



Droplet on a structured membrane

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 arbitrarily shaped microchannels and optical waveguides in fused silica, which allows optofluidic integration on a single substrate.

PROGRESS

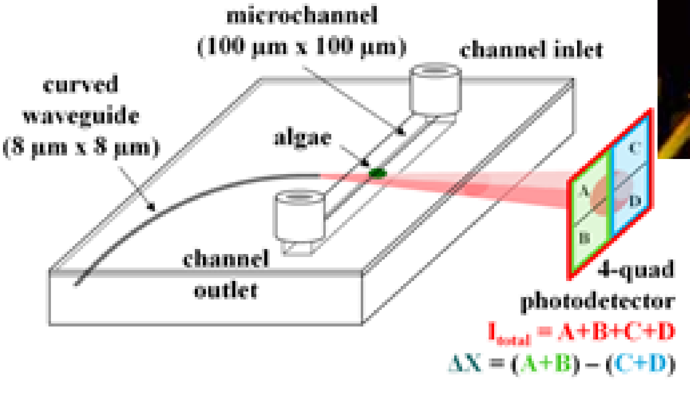
We use a glass-based microchip with a microchannel and waveguide included on a monolithic substrate, and demonstrate its use for identifying phytoplankton species. We have used this system to obtain an “algae library”, studying the optical signals obtained from hundreds of algae over nine different species. We have first shown that the signals can be correlated to the size of algae cells. Then, using a pattern-matching neural network, we demonstrate the successful classification of five algae species with an average 78% positive identification rate. Furthermore, as a proof-of-concept for field-operation, we show that the chip can be used to distinguish between detritus in field-collected water and the toxin-producing cyanobacterium Cyanothece. Present efforts are focused on modeling of the algae-light interaction, and the design of a second prototype.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. A. Schaap, Y. Bellouard, T. Rohrlack, “ Optofluidic lab-on-a-chip for rapid algae population screening”, Biomedical Optics Express, 2(3), 658-664, 2011.
2. A. Schaap, T. Rohrlack, Y. Bellouard, “An optofluidic chip for particle sizing and algae classification,” ISOT2011: International Symposium on Optomechatronic Technologies. Shatin, NT, Hong Kong, Nov. 2011.
3. A. Schaap, Y. Bellouard, T. Rohrlack, “An integrated glass microchip for algae identification,” First EOS Conference on Optofluidics. Munich, Germany, May 2011.



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

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

START OF THE PROJECT
2010

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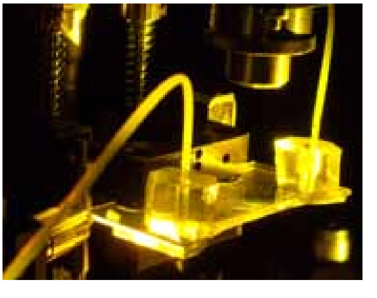

PROJECTLEADERS
CCM Rindt, AA van Steenhoven
RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
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COOPERATIONS
L Rabou, ECN Petten
FUNDED
Agentschap NL

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

START OF THE PROJECT
2007
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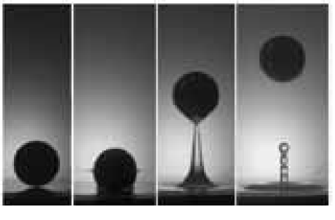

Snapshots of particle impaction over liquid coated surface

PROJECT AIM

The deposition of unwanted material is termed as fouling. Deposition of particulate matter like ash and chemical compounds over heat exchange equipment causes build up of an insulting fouling layer. This fouling layer has low thermal conductivity and drastically reduces the overall efficiency of the heat recovery systems. In the worst case, fouling leads to total failure of the heat exchanger with enormous economical consequences. The project focuses on understanding particle deposition from experimental and numerical point of view to evaluate the governing parameters.

PROGRESS

Experiments have been carried out to evaluate the sticking conditions for a particle impacting liquid coated substrates. The impaction process is quantified using the Stokes number which describes the ratio of inertia of the particle to viscosity of the liquid layer. Using the models for the dry impaction, the energy dissipated in the liquid layer can be evaluated which mostly determines if a particle sticks or not for a certain Stokes number. Apart from detailed impaction experiments, an experimental setup was designed and built to perform controlled fouling experiments at elevated temperatures. Fouling experiments indicated a strong influence of tube geometry, gas velocity and the presence of liquid layers. The experimental data of the impaction and controlled fouling experiments were used to develop a numerical model which can describe the process of particulate fouling under dry conditions and also in the presence of a liquid film. The numerical model is able to capture the fouling layer profile and asymptotic growth of the layer.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Abd-Elhady, M.S., Rindt, C.C.M. & Steenhoven, A.A. van (2011). Influence of the apex angle of cone shaped tubes on particulate fouling of heat exchangers. Heat Transfer Engineering, 32(3 & 4), 272-281.
2. Sathyanarayanarao Subbarao, K.K., Rindt, C.C.M. & Steenhoven, A.A. van (2011). Effect of condensable species on particulate fouling. In M.R. Malayeri, H. Muller-Steinhagen & A.P. Watkinson (Eds.), Proceedings of the International Conference on Heat Exchanger Fouling and Cleaning, 5-10 June 2011, Crete Island, Greece. (pp. 201-209).
3. Sathyanarayanarao Subbarao, K.K., Rindt, C.C.M. & Steenhoven, A.A. van (2011). Growth rates and morphology of dry particulate fouling under variable process conditions. In M.R. Malayeri, H. Muller-Steinhagen & A.P. Watkinson (Eds.), Proceedings of the International Conference on Heat Exchanger Fouling and Cleaning, 5-10 June 2011, Crete Island, Greece. (pp. 210-218).
4. Abd-Elhady, M.S., Zayed, S.I. & Rindt, C.C.M. (2011). Removal of dust particles from the surface of solar cells and solar collectors using surfactants. In M.R. Malayeri, H. Muller-Steinhagen & A.P. Watkinson (Eds.), Proceedings of the International Conference on Heat Exchanger Fouling and Cleaning, 5-10 June 2011, Crete Island, Greece. (pp. 342-348).

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 routine, based on the random movement of diffusing particles within a medium, was written in Matlab to estimate the water vapor permeance through a hollow fiber membrane depending on the feed speed, radius, length and permeability of the membrane unit. The model was validated with CFD simulations (Comsol) and has shown good agreement with the random-walker approach. The outcome so far, supports the theory, that water production will be feasible with a lower demand of energy. A lab-scale model was built that allows for the testing of permeabilities of different modules, as well as the testing of different membrane materials.

Dissertations

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Scientific Publications

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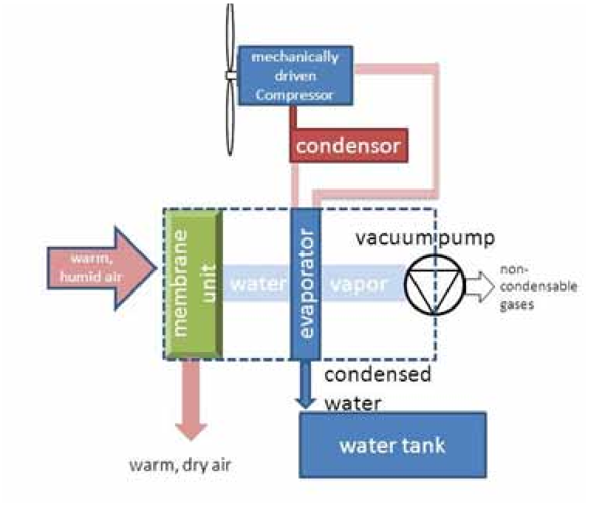

Schematic representation of an Atmospheric Water Vapor Processing system with a membrane module

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

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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

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Project Aim

The goal of this project is to develop dynamic and human specific thermo-physiological model to predict the heat transfer and temperature distribution in the human body. The 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

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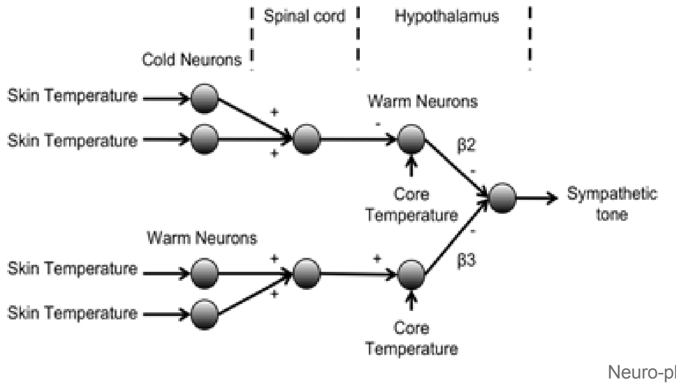
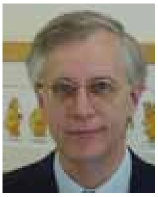
Scientific Publications

1. Kingma, B.R.M., Schellen, L., Frijns, A.J.H. & Marken Lichtenbelt, W. van (2011). Thermal sensation : a mathematical model based on neurophysiology. Indoor Air, 1-10.
2. Kingma, B.R.M., Frijns, A.J.H., Saris, W.H.M., Steenhoven, A.A. van & Marken Lichtenbelt, W. van (2011). Increased systolic blood pressure after mild cold and rewarming: relation to cold-induced thermogenesis and age. Acta Physiologica, 203(4), 419-427.
3. Kingma, B.R.M., Schellen, L., Frijns, A.J.H. & Marken Lichtenbelt, W. van (2011). Thermal sensation model based on neurophysiology of thermal reception. Proceedings of the 14th International Conference on Environmental Ergonomics, 10-15 July 2011, Nafplion, Greece. Nafplion, Greece.
4. Frijns, A.J.H., Marken Lichtenbelt, W. van & Kingma, B.R.M. (2011). Individueel thermisch comfort in thermische comfortmodellen: Integratie van de menselijke fysiologie. Verwarming Ventilatie Plus, september, 482-485.



Neuro-physiological thermoregulation model



Prof.dr. RMM Mattheij

Centre for Analysis, Scientific Computing and Applications (CASA)

The Centre for Analysis, Scientific Computing and Applications (CASA) combines all activities related to analysis at the Department of Mathematics and Computer Science of Eindhoven University of Technology. Its major research objective is to develop new and improve existing mathematical (both analytical and numerical) methods for a wide range of applications in science and engineering. More specifically, the research aims at developing and integrating methods and ideas from mathematical modelling, analysis of partial differential equations and scientific computing. This area of research is commonly known as Computational Science and Engineering (CSE). This is reflected by extensive collaboration with researchers in the technical sciences.

Also contact and cooperation with industrial partners is vital. The chairs participating in CASA are Applied Analysis, Variational Methods and Scientific Computing. Within CASA the research related to fluid dynamics deals with aero-acoustics, porous media, viscous and viscoelastic equations and CFD.

Acoustic liner – mean flow interaction

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

-

Scientific Publications

1. S.W. Rienstra, M.Darau Boundary-layer thickness effects of the hydrodynamic instability along an impedance wall J. Fluid Mech. 671: 559–573, 2011.
2. St. Balint, A.M. Balint, M. Darau Linear stability analysis of a non-slipping mean flow in a 2D straight duct with respect to modes type initial (instantaneous) perturbations, Applied Math. Modelling 35(3): 1081-1095, 2011.
3. E.J. Brambley, St. Balint, A.M. Balint, M. Darau Comments on "linear stability analysis of a non-slipping mean flow in a 2D straight duct with respect to modes type initial (instantaneous) perturbations" by Balint, Balint and Darau, Applied Math. Modelling 35(9): 4550-4553, 2011.
4. E.J. Brambley, M.Darau, S.W. Rienstra The critical layer in sheared flow, AIAA Paper AIAA 2011-2806.

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

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PROJECTLEADERS
RMM Mattheij

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
MA Etaati, AS Tijsseling

COOPERATIONS
Prof.dr. ATAM de Waele

FUNDED
STW

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

START OF THE PROJECT
2005

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PROJECT AIM

The project concerns pulse-tube refrigerators of the Stirling type for the important temperature region of 4 Kelvin and below. The system that we propose will operate at frequencies which are an order of magnitude higher and pressure amplitudes which are an order of magnitude lower than usual. A numerical model describing oscillating Helium flow in multi-stage coolers has been developed. The main goals in this project include numerical analysis of the fluid flow in the system as well as optimization in terms of geometry of single-stage and three-stage PTRs.

PROGRESS

The governing equations are conservation laws including the full Navier-Stokes equations. A one-dimensional model of a three-stage PTR both for tubes and regenerators has been developed. In this model the Van der Waals equation of state is used for the real gas. All material properties of the gas and the regenerator solids are considered to be temperature dependent. In the simulation six orifice settings are to be adjusted to reach the lowest possible temperature. This temperature occurs when the cooling power at the third stage becomes zero. We first validated our simulation against experimental work done at the Low Temperature Group of the Applied Physics Department of TU/e on a PTR operating at low frequency. In the second step a high-frequency three-stage PTR was simulated and analyzed. The developed software is intended to become a design tool for cryogenic engineers.

DISSERTATIONS

1. M.A. Etaati (2011) Numerical Simulation of a Three-stage Stirling-type Pulse-Tube Refrigerator. PhD Thesis, Department of Mathematics and Computer Science, Eindhoven University of Technology.

SCIENTIFIC PUBLICATIONS

-

PROJECT AIM

Numerical simulation and shape optimisation of blow moulding processes.

PROGRESS

A 2D axial-symmetrical blow moulding simulation model has been developed. This model simulates the blow stage of manufacturing hollow containers, e.g. bottles or jars. In a blow stage a preform is brought into a mould and subsequently blown into a mould shape. The simulation model is based on level set methods. Applications presented are glass blowing and PET stretch blow moulding. The inverse problem for glass blowing is to determine an optimal preform from the desired container shape. The solvability and sensitivity of the inverse problem are analysed. Numerical shape optimization is used to find a solution to the inverse problem. The method describes the glass-air interfaces of the preform by parametric curves, e.g. splines, Bezier curves, and finds the optimal positions of the control points of the curves.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Giannopapa, C. G., and Groot, J. A. W. M. Modeling the blow-blow forming process in glass container manufacturing: A comparison between computations and experiments. J. Fluids Eng. 133, 2 (2011), 021103.
2. Groot, J. A. W. M., Giannopapa, C. G., and Mattheij, R. M. M. An analytical approximation of the inverse problem of finding the parison shape in glass blowing (submitted/under review). J. Dyn. Syst. Meas. Control (2011).
3. Groot, J. A. W. M., Giannopapa, C. G., and Mattheij, R. M. M. Development of a numerical optimisation method for blowing glass parison shapes. J. Manuf. Sci. Eng. 133, 1 (2011), 011010.
4. Groot, J. A.W. M., Giannopapa, C. G., and Mattheij, R. M. M. Modelling stretch blow moulding of polymer containers using level set methods (submitted/under review). J. Manuf. Sci. Eng. (2011).
5. Groot, J. A. W. M., Giannopapa, C. G., and Mattheij, R. M. M. A numerical shape optimization method for blowing glass bottles. In Proceedings of the ASME 2011 Pressure Vessels & Piping Conference (Baltimore, USA, July 17-21, 2011).
6. Groot, J. A. W. M., Mattheij, R. M. M., and Giannopapa, C. G. Modelling preform and mould shapes in blow moulding (in print). In Progress in Industrial Mathematics at ECMI 2010, M. Günther, A. Bartel, M. Brunk, S. Schöps, and M. Striebel, Ed., Springer Verlag, 2011, pp. 319-326.
7. Groot, J. A. W. M. Numerical shape optimisation in blow moulding. PhD thesis, Eindhoven University of Technology, 2011.

PROJECTLEADERS

RMM Mattheij, CG Giannopapa

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

-

COOPERATIONS

-

FUNDED

TUE

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

START OF THE PROJECT

2007

INFORMATION

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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
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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 SPH method has been explored and applied to a set of two-dimensional test problems including dam break, impinging jet, gravity fountain and flow separation at a sharp bend. The SPH solutions have been succesfully validated against theoretical and numerical results from literature. The experimental data (obtained at Deltares) on the controlled filling and emptying of a large-scale pipeline have been analyzed in detail. Water-hammer equations with moving boundaries have been used to model the dynamics of pipe filling and draining. Two-dimensional SPH simulations have been used to investigate liquid slug impact at a sharp bend.

Dissertations

-

Scientific Publications

1. Bergant A., Hou Q., Keramat A., Tijsseling A.S. (2011) Experimental and numerical analysis of water hammer in a large-scale PVC pipeline apparatus. Proc. of the 4th IAHR Int. Meeting on Cavitation and Dynamic Problems in Hydraulic Machinery and Systems (Editors A. Gajic, M. Benisek, M. Nedeljkovic), Belgrade, Serbia, October 2011, pp. 27-36.
2. Hou Q., Zhang L.X., Tijsseling A.S., Kruisbrink A.C.H. (2011) Rapid filling of pipelines with the SPH particle method. Int. Conf. on Advances in Computational Modeling and Simulation, December 2011, Kunming, P.R. China. Procedia Engineering, Paper ACMS2011-0148.

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 numerical continuation has been continued. The code handles a segmented duct with locally reacting impedance walls, non-uniform mean flow and non-uniform temperature, where each segment has a different impedance. The combined effect of multiple segments is computed by using the mode-matching approach in combination with the scattering matrix formalism (which is numerically stable). The balance of acoustical energy was evaluated in order to validate the numerical approach. Numerical results have been compared to analytical WKB-type solutions for a duct (carying non-uniform mean flow and temperature) with a slowly varying impedance. Finally, first steps have been made to incorporate non-locally reacting wall impedances in the model; the possibility of computing axial wavenumbers (eigenvalues) with the aid of contour integration has been investigated.

Dissertations

-

Scientific Publications

1. M. Oppeneer, W.M.J. Lazeroms, S.W. Rienstra, P. Sijtsma, and R.M.M. Mattheij, "Acoustic modes in a duct with slowly varying impedance and non-uniform mean flow and temperature," 17th AIAA/CEAS Aeroacoustics Conference, Portland(OR), USA, No. AIAA 2011-2871, June 5-8 2011.

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

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PROJECTLEADERS
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RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
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COOPERATIONS
-

FUNDED
Ballast Nedam

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

START OF THE PROJECT
2008

INFORMATION
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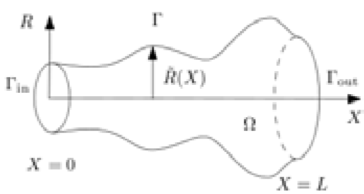

FIGURE 1. Axisymmetric pipe with center line along the X-axis. Γ stands for the wall of the pipe, Γ_{in} for the cross section at $X = 0$ and Γ_{out} the cross section at $X = L$.

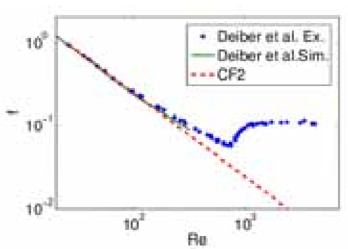

FIGURE 4. Experimental results (blue dots), 2D numerical solution (solid green line) for the friction factor by Deiber et al. [14, p. 642], and approximation obtained with correction factor $CF2$ (41) (dashed line).

PROJECT AIM

Development of techniques for the construction of lower dimensional models (nodal, or 1D models) and/or efficient CFD methods, for simulating fluid flow and heat transport in arbitrary shaped pipes. The models should be adequate for their use in the simulation of a network of interconnected process components, and for optimization purposes. The main effects to be captured are those realted to the wall-shape. Some of the effects to study are: wall heat transfer, natural convection, and turbulence.

PROGRESS

The case of laminar flow in axially symmetric pipes has been treated in analytically and numerically. By combining an analytical formula for the friction factor with the method of slow variations, we developed approximate expressions for the friction factor. These expressions appear in terms of one dimensional integrals, which are very fast to compute, when compared to traditional CFD methods. This result was published in a journal paper. The numerical alternative which is based on a FEM model for the problem of periodic corrugated pipes, has been validated and applied for studying the problem of wall-shape optimization. The results were published in a conference paper. We also developed a numerical model for simulating natural convecting flow in a thermosyphon loop. With basis of this model, we showed that is possible to optimize the wall-shape of the thermosyphon for improving the performance of the thermosyphon. The results were published in the Cryogenic Engineering Conference. Currently we are treating the efficient simulation of non-periodic (developing) flows, and the case of turbulent flow.

DISSERTATIONS

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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, (accepted for publication) 2012.
2. P.I. Rosen Esquivel, J.H.M ten Thije Boonkkamp, J.A.M. Dam, R.M.M. Mattheij. “Efficient estimation of the friciton factor for forced laminar flow in axially symetric corrugated pipes”. In Proceedings of the ASME 2010 3rd Joint US-European Fluids Engineering Summer Meeting and 8th International Conference on Nanochannels, Microchannels, and Minichannels (Montreal, Canada, August 2-4 2010), American Society of Mechanical Engineers, ASME. FEDSM 2010-ICNMM 2010.
3. P.I. Rosen Esquivel, J.H.M ten Thije Boonkkamp, J.A.M. Dam, R.M.M. Mattheij . “A parametric study of wall-shape on laminar flow in corrugated pipes”. In Proceedings of the ASME-JSME-KSME Joint Fluids Engineering Conference 2011 (Hamamatsu, Shizuoka, Japan, July 24-29 2011), American Society of Mechanical Engineers, ASME. AJK2011-FED.
4. P.I. Rosen Esquivel, J.H.M ten Thije Boonkkamp, J.A.M. Dam, R.M.M. Mattheij. “ Wall shape optimization for a thermosyphon loop featuring corrugated pipes”. In Proceedings of the 2011 Cryogenic Engineering Conference (CEC/ICMC 2011) (Spokane, Washington, June12-June 18 2011), American Institute of Physics, AIP. CEC/ICMC 2011.

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.

Thermo acoustics

Thermo acoustics, broadly speaking, deals with all kinds of acoustic effects in which heat conduction and entropy variations in the gaseous medium play a role. Although the study of these phenomena dates back to Lord Rayleigh, it has increasingly become an active area of research with lots of potential applications ranging from upgrading of industrial waste heat to environmentally friendly refrigeration. A focal area of interest is the development of mathematical models for the two main classes of thermo acoustic devices: prime movers that convert heat into sound and heat pumps that convert sound into heat.

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.

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

In 2011 we continued investigating the nonlinear and possibly degenerate models arising as two-phase flow porous media model involving a dynamic capillary pressure. After we proved the existence of the weak solution for the more complex model (where the degeneracy appears in the third order term) , 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. Further, the thesis 'Dynamic Capillarity in Porous Media – Mathematical Analysis' was elaborated and will be defended on Jan 31st, 2012.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Fan, Y. & Pop, I.S. (2011). A class of pseudo-parabolic equations: existence, uniqueness of weak solutions, and error estimates for the Euler-implicit discretization. Mathematical Methods in the Applied Sciences, 34(18), 2329-2339.

PROJECTLEADERS

CJ van Duijn

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

Y Fan, IS Pop, CJ van Duijn

COOPERATIONS

Dr. C. Cances (Paris), Dr. C. Choquet (Marseille), Prof. dr.ir. S.M. Hassanizadeh (Utrecht), Prof. dr.ir. R. Helmig (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

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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
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Prof. W. Jäger (Heidelberg)
Prof. A. Mikelić (Lyon)
Dr. M. Neuss-Radu (Heidelberg)
Funded
STW

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

Start of the project
2008
Information
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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.

Dissertations

-

Scientific Publications

1. Effective Dispersion Equations for reactive flows involving free boundaries at the microscale, with T.L van Noorden, I.S.Pop, SIAM Multiscale Modeling, 9 (2011), no. 1, 29-58.
2. Reconstruction of 3D morphology from optical sectioning of biological objects, with M. Rudnaya, M. Pisarenco, V. Savacenco, S. Srivastava, MICS, vol.3 (2011).
3. A multiscale domain decomposition approach for chemical vapor deposition, with J. Bogers, P.H.L Notten, J.F.M Oudenhoven, I. S. Pop, ACOMEN conference proceedings, 2011.

Constitutive modeling of concentrated solutions of main-chain liquid crystalline polymers

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

In 2011 the rod-spring model for the description of concentrated solutions of LCP was developed. The model incorporates hairpins and allows large deviations from highly-ordered state. In the limit of highly ordered state the model reduces to the model developed in previous year. The results were presented at the Annual European Society of Rheology (AERC2011). The results were also discussed in Dynacop Summer School. The code to simulate the viscorlastic and orientational properties in various types of flows is developed. On the basis of simulations the behavior of the monodomain LCP solution was analized. In November the progress was discussed in with people from Teijin. Last month of 2011 was devoted to writing thesis. This work is still in progress.

Dissertations

-

Scientific Publications

1. AERC2011 conference procedings. O.Matveichuk, J.J.M.Slot
   Constitutive modeling of highly-ordered solutions main-chain liquid crystalline polymers containing hairpins.

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

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Constitutive modeling of arbitrary branched polymer melts

Projectleaders
JJM Slot

Researchtheme
Complex dynamics of fluids

Participants
Volha Shchetnikava

Cooperations
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Funded
Dutch Polymer Institute (DPI)

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

Start of the project
2009

Information
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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 2011 the focus was on the development of a new computational approach, based on the earlier work of Evelyne van Ruymbeke and collaborators at the UCL in Louvain-la-Neuve, Belgium, to predict the linear rheological behavior of ldPE. The model of van Ruymbeke et al uses tube concepts and adopts a time marching strategy in order to account for the effects of dynamic tube dilation in the calculation of stress relaxation. The model was up to now only applied to systems consisting of polymers with simple topologies (linear, star, H-polymer etc). Using concepts such as seniority and peripheral relaxation allowed for the extension of the model to more complex systems like ldPE.

Dissertations

-

Scientific Publications

-

Cardiovascular Biomechanics

Prof.dr.ir. FN van de Vosse

The Cardiovascular Biomechanics group at the department of Biomedical Engineering aims to promote the use of experimentally validated predictive mathematical modeling, both in diagnosis and selection of therapy in clinical practice as well as in research and development in the medical device industry. The research in the group is divided in 4 areas of which the first is embedded in JMBC.

1. Hemodynamics

Hemodynamic factors such as like local pressure, velocity, wall shear stress and wall deformation are crucial for the proper functioning of the vascular system, the heart and its native valves. These factors play a key role in the genesis of vascular disease and, when measured properly, can also be predictive for the development of cardiovascular disease. Hemodynamics research in the group is focused on the development of mathematical models and the corresponding computational methods based on finite and spectral element approximations. These models are used to understand the functioning and response of the cardiovascular system. The models range from 0D lumped parameter and 1D wave propagation models of the entire cardiovascular system to 3D models of local fluid-structure interaction in specific arterial segments and heart valve dynamics. Both microscopic (blood as a suspension) as well as macroscopic (blood-wall interaction) scales are considered. In vitro laboratory experiments and measurement techniques are designed and used to validate the outcome of the computational simulations.

2. Mechanics and adaptation

Cardiovascular mechanics research is focused on the understanding of the mechanical response of vascular and cardiac tissue to mechanical loads, caused by the pulse wave propagation and cardiac contraction, as well as external forces caused by medical interventions.

3. Instrumentation and devices

Medical instrumentation and devices like ultrasound image modalities, pressure and flow sensors, particularly those used for advanced diagnostic measurements.

4. Clinical research

Through pilot or full clinical studies, in which patient data are gathered and used as input for patient specific modelling, evaluation of the predictive value of mathematical models to predict outcome of medical intervention can be performed.

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.

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 and the behavior of the network in large deformations. The network formation is modeled as a transition from a viscoelastic fluid to a viscoelastic solid, where the transition is governed by the fibrin kinetics. 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. Qualitative agreement is found between the model and experimental results.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

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

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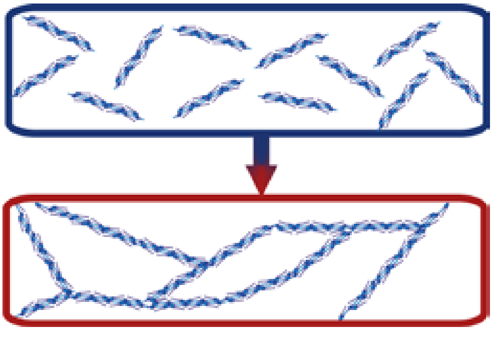

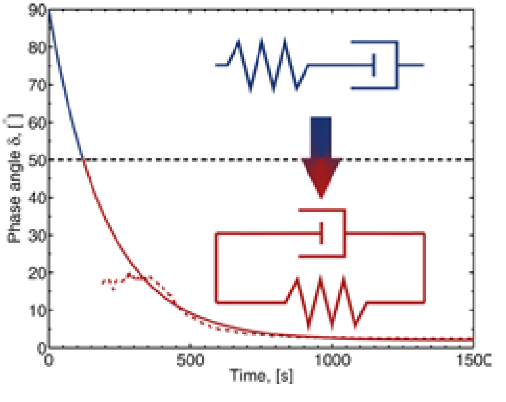

The fibrin network forms a fibrous structure within the blood clot (left). The formation of the fibrin network is modeled as a transition from a viscoelastic liquid to a viscoelastic solid (right).

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
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Project Aim

Hemostasis is the complex process by which blood forms clots. It involves the interplay between biochemical and physical processes that occur at different scales. All these factors can be summarized with the Virchow's triad: deviation from normal physiological hemodynamics, injuries to the vascular endothelium layer and changes of the constituents of blood. The aim of the project is to create a mathematical model that describes the blood clot formation. Particular attention is going to be given to the interaction between the blood flow and the porous clot.

Progress

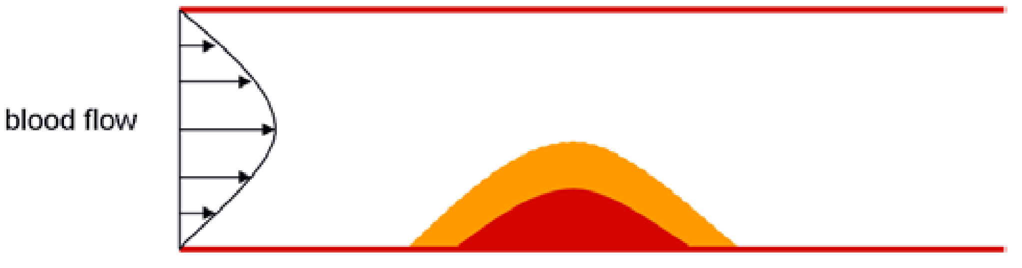
The inititation of the process is modelled through convection-reaction-diffusion equations. Unactivated platelets, activated platelets, chemical activators and chemical inhibitors are modelled as concentrations. All these factors represent the onset of the coagulation process. The interaction between the clot and the flow around it is going to be implemented with a coupled overlapping domain method (see project of Anna Catharina Verkaik, "Transitional flow through mechanical heart valves").

Dissertations

-

Scientific Publications

-



Schematic representation of the modeling of blood flow and blood clot formation. The inner part of the clot will be modeled as a poro-(visco)-elasticus solid (red) and the outer layer will be modeled as a porous fluid (yellow).

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.

PROGRESS

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. µPIV measurements on a spinning disk confocal microscope (right figure) indicate that flows sinusoidal in time can be produced at magnitudes from 10 to 100 nl/s and at frequencies from 0.1 to 10 Hz, which enables dynamic RBC deformations. Results of our ‘contactless’ experiments need to be compared to other methods. For this purpose, a validation experiment is performed currently, where RBCs are squeezed through micro channels containing a sudden narrowing.

PROJECTLEADERS
FN van de Vosse, ACB Bogaerds

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
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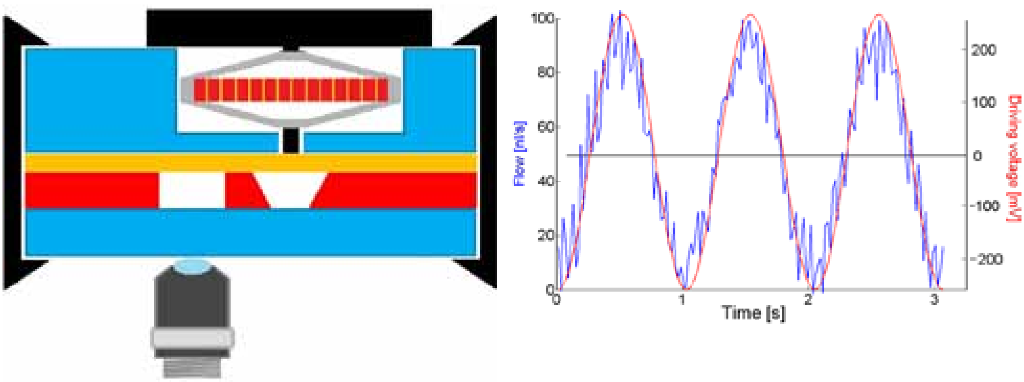
DISSERTATIONS

-

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: resulting flow (blue) from the pulsatile micropump, measured with µPIV. Driving voltage of the voice coil actuator is shown in red. Mean flow is50 nl/s, frequency is 1 Hz.

PROJECTLEADERS
FN van de Vosse
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
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PROJECT AIM

In healthy blood vessels, flow is in general laminar and standard computational methods like finite element or finite volume methods based on the linearized Navier-Stokes equations can be used. Distal to artificial heart valves also transitional (transition to turbulence) flow with small scale local velocity fluctuations can be found. This study will focus on the implementation of spectral elements for fluid structure interaction. The simulations will be compared to flow experiments obtained with PIV, LDA or ultra sound measurements in an in-vitro set-up.

PROGRESS

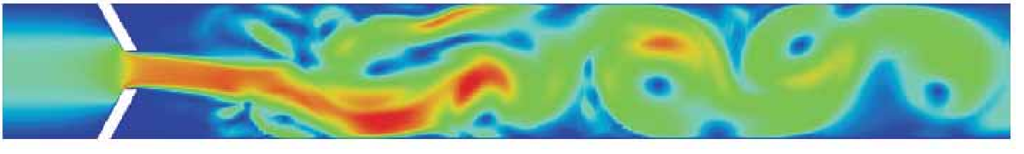
In previous period we proposed a fully Coupled Overlapping Domain (COD) technique to couple the fixed grid fluid domain with an Arbitrary Lagrangian Eulerian (ALE) moving grid fluid domain. This allows for an optimal conformal coupling between the fluid elements and the structural elements. Although the method that is proposed is not restricted to the choice of the discretizations of the fluid domains, we employed Crouzeix-Raviart elements on the ALE fluid domain and a spectral element equivalent (Q^N-P^{N-1}) on the background mesh. Last year we focused on studying the convergence of the spectral element solution (compared to a solution with finte element approximation) and the convergence of the COD technique for several benchmark problems.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. A.C.B. Bogaerds, A.C. Verkaik and F.N. van de Vosse, A fully coupled overlapping domain method for FSI problems, in 16th International Conference on Finite Elements for Flow computations (FEF); Munich, Germany 2011.



Transitional blood flow through a fixed heart valve.

Vascular remodeling after the creation of an arteriovenous fistula for hemodialysis

Project Aim

Hemodialysis dependent patients, need a well-functioning vascular access to connect them with the artificial kidney (dialyzer). Usually, the vascular access is surgically created by making a connection between an artery and a vein in the arm, i.e. an arteriovenous fistula (AVF). For the planning of the optimal location (upper- or lower arm) for AVF creation for each individual patient, it is very important to preoperatively predict the postoperative flow increase and vessel remodeling. A patient-specific computer simulation model, based on preoperative MRA and duplex data, is developed to give insight in the postoperative blood flow increase and failure incidence for different fistula configurations.

Progress

To make patient-specific predictions, model parameters need to be adapted to patient-specific conditions and thus clinical measurements are required. However, not all model parameters can be measured clinically and the burden on the patient should be minimized. Moreover, clinical measurements are hampered by uncertainty resulting in uncertainty in the predictions. Fortunately, the influence of each model parameter on the predictions differs and, therefore, a sensitivity analysis of the model was applied to identify the most influential model parameters and the model parameters that can be based on generic data. This sensitivity analysis gave us insight in how to personalize the model and this significantly reduces the number of parameters to be measured.

Dissertations

-

Scientific Publications

1. A.S. Bode, A. Caroli, W. Huberts, R.N. Planken, L. Antiga, E.M.H. Bosboom, A. Remuzzi, J.H.M. Tordoir, Clinical Study Protocol For The ARCH PROJECT – Computational modeling for improvement of outcome after vascular access creation, J. Vasc. Access, 12(4),369-76, (2011).

Projectleaders

FN van de Vosse, EMH Bosboom

Researchtheme

Complex dynamics of fluids

Participants

W Huberts

Cooperations

Maastricht Univ.Med.Centre (MUMC); Philips Research

Funded

FP7 ARCH

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

Start of the project

2007

Information

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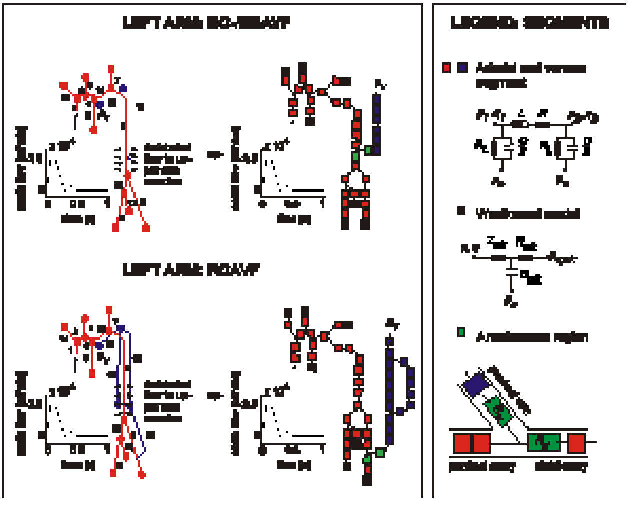

Vascular Network model to predict blood flow after vascular creation of an upper or lower arm AVF in the left arm (left). At the right the electrical analog for each segment is shown.

PROJECTLEADERS
FN van de Vosse, ACB Bogaerds
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
G Mulder
COOPERATIONS
Philips Helthcare, University of Sheffield
FUNDED
Philips Healthcare

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

START OF THE PROJECT
2006
INFORMATION
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PROJECT AIM

Cerebral aneurysms are localized, thin walled dilatations of the arterial wall in the brain. The major risk is rupture, for which a parametric estimate is sought. A 1D wave propagation model and 3D computational fluid dynamics (CFD) model are combined in order to make full use of each model's strength. A biomechanical analysis of flow and stress based on patientspecific input is used to improve the diagnostics. The computational methods are validated using clinical measurements of pressure and flow and 3D PIV measurements in in-vitro set-ups.

PROGRESS

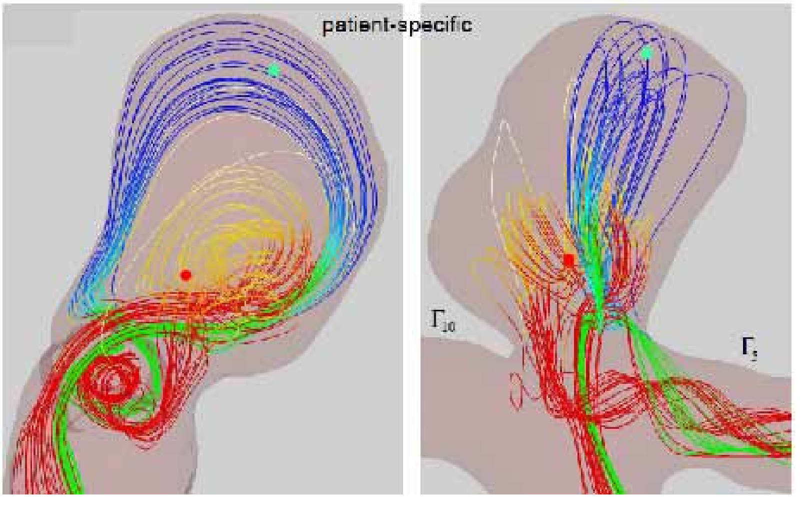
The aim of the study in this period was to evaluate the necessity of, and requirements for, full patient-specific modelling, i.e., both geometry and boundary conditions based on patient data. To this purpose, the flow waveforms obtained with several models from literature and a patient-specific geometry of the arterial tree has been compared and its influence on aneurismal flow patterns have been analysed.

DISSERTATIONS

1. G. Mulder, Patient-specific modelling of the cerebral circulation for aneurysm risk assessment, PhD. Thesis, 2011, TU/e.

SCIENTIFIC PUBLICATIONS

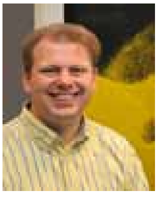
1. G. Mulder, A. Marzo, A. C. B. Bogaerds, S. C. Coley, P. Rongen, D. R. Hose and F. N. van de Vosse, Patient-Specific Modeling of Cerebral Blood Flow: Geometrical Variations in a 1D Model, Cardiovascular Engineering and Technology, 2, (4), 334-348, (2011).
2. F.N. van de F.N. van de Vosse, N. Stergiopulos, Pulse Wave Propagation in the Arterial Tree, Annu. Rev. Fluid Mech., 43, 467-499, (2011).
3. G. Mulder, A.C.B. Bogaerds, P.M.J. Rongen, F.N. van de Vosse, The influence of contrast agent injection on physiological flow in the circle of Willis, Med. Eng. Phys., 33(2), 195-203, (2011).



The intra-aneurysmal streamlines show the complexity of the aneurysm vortex.

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

The experimental setup for a spouted bed reactor has been constructed accomplished with digital camera for further analysis like particle image velocimetry (PIV) and digital image analysis (DIA). Furthermore, theoretical investigations are formed by considering combination of immersed boundary method and discrete particle model.

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

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PROJECTLEADERS
JAM Kuipers
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
M van Sint Annaland, T Kolkman
COOPERATIONS
-
FUNDED
Dutch Polymer Institute

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

START OF THE PROJECT
2008
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PROJECT AIM

The main objective of this research project is to develop detailed understanding and quantitative descriptive tools for dense fluidized gas-solid suspensions, in which one of the reactants and/or a dedicated component is injected into the bed as a liquid (through bottom or top spraying/atomization), taking into account the associated heat effects. The impact of operating conditions on the fluidization behavior will also be quantified experimentally. The results will be used in further development and validation of advanced in-house developed CFD models. These can subsequently be used to support the design and optimization of engineering-scale gas-phase polymerization reactors with special emphasis on the thermal aspects of the operation.

PROGRESS

Demonstration of unique novel experimental approach to directly observe and study agglomerates in and, simultaneously, the hydrodynamics of a fluidized bed with liquid injection using a combination of Particle Image Velocimetry and Infrared Thermography. Major extension of Discrete Particle Model to take into account mass and heat transfer.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Fundamentals of heterogenous bubbly flow

Project Aim

To simulate mass and heat transfer, a mass-transfer model has been built which is ready to implement in the Front Tracking model. To attain a validated Euler-Lagrange model for the description of heterogeneous bubbly flow, with the incorporation of coalescence and breakup of bubbles.

Progress

A front tracking model was used to simulate small bubbly flow systems in very much detail. The objective was to derive hydrodynamic and mass and heat transfer closures from the simulation results for the regime of high gas volume fractions (i.e. high superficial gas velocities). Swarm effects, i.e., the effects of the presence and behavior of neighboring bubbles, on the mass, momentum, and heat transfer rates were quantified in the form of correlations, which can be used to study bubbly flows on a larger scale (with higher level models). A breakup model has been implented in an Euler-Lagrange framework. Within this model, breakup of a bubble is based on a force balance between the turbulent stresses, which tend to deform the bubble shape, and the surface restoring forces (surface tension). Due to some arbitrary parameters in the model, simulations are performed to determine their effects on the overall bubbly flow. Also a drag closure derived from DNS, which takes into the account the swarm effects, has been implemented and investigated. Simulations have been run to derive a closure for the drag force on bubbles in a swarm, dependent on the gas fraction and the bubble size. In addition, we have simulated bi-disperse bubble swarms to derive a similar closure, but now also based on the swarm composition.

Dissertations

-

Scientific Publications

1. Roghair, I., Mercado, J.M., Sint Annaland, M.V., Kuipers, H., Sun, C., Lohse, D. (2011). Energy spectra and bubble velocity distributions in pseudo-turbulence: Numerical simulations vs. experiments. International Journal of Multiphase Flow 37 (9) , pp. 1093-1098.
2. Lau, Y.M., Roghair, I., Deen, N.G., van Sint Annaland, M., Kuipers, J.A.M. (2011). Numerical investigation of the drag closure for bubbles in bubble swarms. Chemical Engineering Science 66 (14) , pp. 3309-3316.
3. Roghair, I., Lau, Y.M., Deen, N.G., Slagter, H.M., Baltussen, M.W., Van Sint Annaland, M., Kuipers, J.A.M. (2011). On the drag force of bubbles in bubble swarms at intermediate and high Reynolds numbers. Chemical Engineering Science 66 (14) , pp. 3204-3211.

Projectleaders

JAM Kuipers, M Van Sint Annaland

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

I Roghair, YM Lau, NG Deen

Cooperations

D Lohse, J Martinez Mercado, R Lakkaraju

Funded

FOM, AkzoNobel, DSM, Shell, Tata Steel

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

Start of the project

2007

Information

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Cutting bubbles, micro-scale interaction mass and heat transfer

Projectleaders
NG Deen, JAM Kuipers

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
QIE Segers

Cooperations
-

Funded
European Research Council

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

Start of the project
2010

Information
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Project Aim

Selection of proper test system with dyes for concentration measurements in bubbly flows with and without wires. Measurement of heat and mass transfer rate as function of wire-mes layout and bubble-mesh distance in flat bubble column.

Progress

Literature study into Front Tracking method and Immersed Boundary method in computational fluid dynamics. Getting acquainted with the DNS code readily developed in the group. Calculation of some test cases in 2D and 3D and evaluating with literature.

Dissertations

-

Scientific Publications

-

Development of simulation models for polydispersed gas solid fluidized bed reactors

Project Aim

This project is concerned with the modeling at the largest scale, using the KTGF, with a focus on the effects of polydispersity, starting with bidispersity. For this, novel closures for the solid phase viscosity and gas-solid momentum exchange have to be developed and/or implemented. Subsequently, all the steps taken initially for binary systems of fluidized beds are to be extended to general poly-disperse systems.

Progress

Detailed and somewhat satisfactory comparison was made for mono-dispersed system between a newly developed Multi-Fluid Model and the more established Two Fluid Model and the Discrete Element Model. Further studies were carried out on the sensitivity of the MFM to key parameters like maximum particle fraction, restitution coefficient and drag models for bi-dispersed beds. Laboratory experiments conducted by Goldschmidt have been compared to DEM simulations. Furthermore. A new set-up has been designed and fabricated for the investigation of dynamics of particle mixtures, particularly the mixing, segregation and expansion of fluidized ternary mixtures.

Dissertations

-

Scientific Publications

-

Projectleaders

JAM Kuipers, MA van der Hoef

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

OO Olaofe

Cooperations

-

Funded

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

Start of the project

2008

Information

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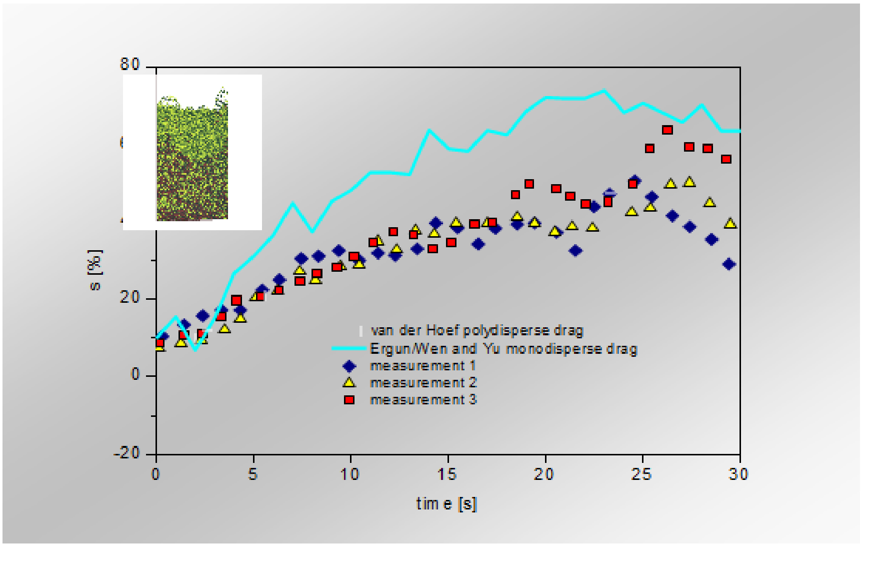

Segregation in bi-disperse fluidized beds

Autothermal membrane reactor for the production of ultra-pure hydrogen with integrated CO2 capture

Projectleaders
JAM Kuipers, M van Sint Annaland
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
JF de Jong
Cooperations
Inorganic Membrane Group, University of Twente, the Netherlands
Funded
SenterNovem

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

Start of the project
2007
Information
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Project Aim

By means of fundamental research and an experimental demonstration unit, this project aims to provide proof-of-principle on the novel reactor concept with palladium membranes as well as perovskite membranes for oxygen separation. The effect of the presence of – and permeation through – membranes inside a fluidized bed hydrodynamics (in particular particle circulation patterns and bubble size distribution) will form the basis for a strong reactor design. This reactor will be built and tested.

Progress

A pseudo-2D setup has been built to investigate the phenomena inside a fluidized bed using Particle Image Velocimetry (PIV). The focus lies in the beginning on permeation through vertical membranes for which gas addition as well as gas extraction is investigated. The experimental results are then compared to the Discrete Particle Model (DPM). In order to simulate membrane tubes, the Immersed Boundary Method (IBM) was implemented into the model and tested.

Dissertations

-

Scientific Publications

1. De Jong, J.F., van Sint Annaland, M., Kuipers, J.A.M. (2011). Experimental study on the effects of gas permeation through flat membranes on the hydrodynamics in membrane-assisted fluidized beds. Chemical Engineering Science 66 (11) , pp. 2398-2408.

Snapshot of eight immersed membrane tubes in a DPM simulation

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 wire 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

A literature study into the implementation of the Volume of Fluid model was performed. Furthermore, the individual tracking of bubbles was implemented in the Volume of Fluid model.

Dissertations

-

Scientific Publications

-

Projectleaders

JAM Kuipers, NG Deen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

MW Baltussen

Cooperations

-

Funded

European Research Council

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

Start of the project

2011

Information

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PROJECTLEADERS
NG Deen, JAM Kuipers

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
D Jain

COOPERATIONS
-

FUNDED
European Research Council

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

START OF THE PROJECT
2010

INFORMATION
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PROJECT AIM

The particle behavior varies within the liquid layer depending on the liquid physical properties such as viscosity, surface tension, layer thickness, and on particle properties as density ratio, impact velocity, etc. The project objective is to analyze and postulate the dependence of the coefficient of restitution of a particle in a liquid layer on various physical parameters. The simulation model used in current study is based on basic momentum (Navier-Stokes equation) and Continuity equations to overcome the disadvantages of phenomenological models. This model then will be used to find the correlations for restitution coefficient of particle-fluid interaction. This information will then be utilized to model the behavior in industrial scale fluidized beds.

PROGRESS

Literature study has been performed for the prevailing models and experimental results for the particle impaction and the analysis techniques have been studied. Results confirm that the thin liquid layers and high impact velocities lead to bounce back from the liquid layer while more thickness and low velocities lead to particle sticking back in liquid film. Moreover, trends for overall restitution coefficient values with varying impact velocities and film thicknesses match well with the experimental curves obtained from a previous study. Since, the results from our simulation model are found to be in good agreement with the experimental findings, we are looking forward understand the phenomenon at more basic level.

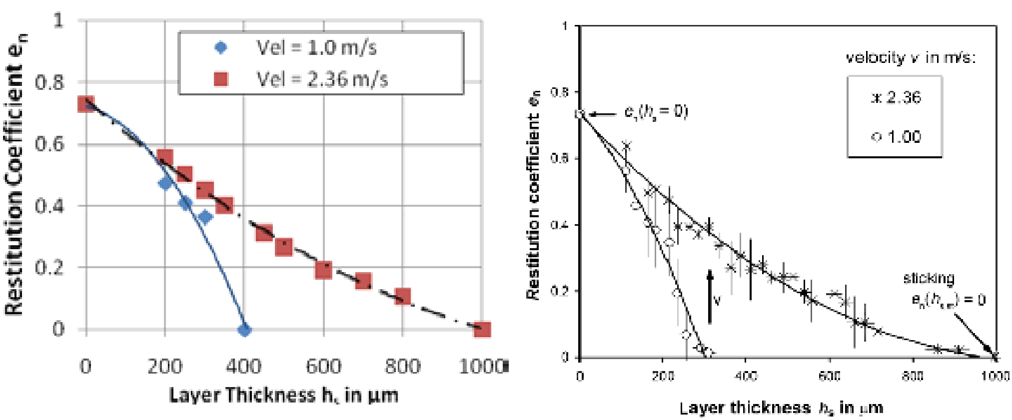
DISSERTATIONS

-

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



Next generation microreactors for ultra-pure H2 production

Project Aim

The objective of this research is to design a micro-fluidized bed membrane reactor for ultra-pure H2 production based on the studies in concerted action by detailed simulations using advanced fundamental models and advance experimental techniques.

Progress

Simulation works on the regime transition (specially the regime transition from bubbling fluidization to turbulent fluidization) in micro fluidized bed and the effect of gas permeation through membranes on the hydrodynamics of the membrane assisted micro fluidized bed have been carried out. Experimentally hydrodynamic study on the effect of gas permeation via membrane at different flow regime, bed configuration as well as Geldart type using Particle Image Velocimetry and Digital Image Analysis techniques was done. Infrared camera as a novel noninvasive experimental technique is being developed for multiphase mass exchange and gas back mixing study.

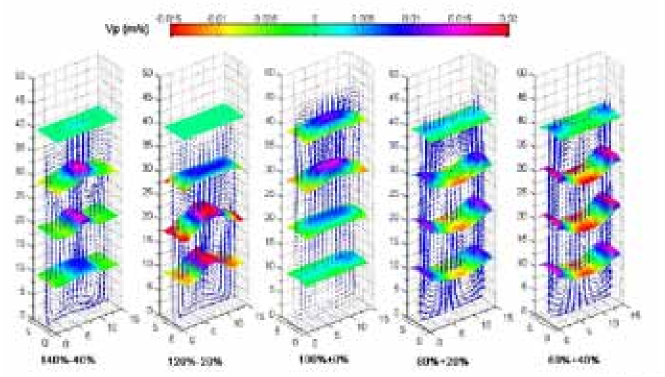
Dissertations

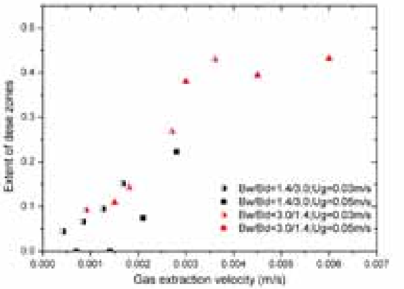
-

Scientific Publications

1. Wang, J., Tan, L., van der Hoef, M.A., van Sint Annaland, M., and Kuipers, J.A.M., 2011. From bubbling to turbulent fluidization: Advanced onset of regime transition in micro-fluidized beds. Chemical Engineering Science 66, 2001-2007.

Influence of gas permeation on the solids circulation pattern (left) and the effect of gas extraction velocity on the extent of dense zones forming close to membrane walls (right), based on numertical simulations.





Projectleaders

M van Sint Annaland

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

N Dang, L Tan, F Gallucci

Cooperations

-

Funded

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

Start of the project

2009

Information

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PROJECTLEADERS
M van Sint Annaland
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
HM Slagter
COOPERATIONS
-
FUNDED

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

START OF THE PROJECT
2010
INFORMATION
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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) is investigated in detail with a Discrete Particle Model. TGA experiments have been conducted to quantify the amount of material sorbed into polymer particles and its influence on the particle properties. Moreover, a pseudo-2D bed is constructed to investigate the effects of sorption on the hydrodynamic characteristics.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Direct numerical simulation of momentum and heat transfer in dense gas-solid flows

Project Aim

The objective of this study is to proposed new momentum and heat correlations for dense arrays of non-spherical particles (e.g. cylindrical particle) for both creeping flow and moderate Reynolds flow based on accurate numerical data from simulation. The basis of our research approach is the direct numerical simulation level of modeling, in which the exchange of mass, momentum and heat can be modeled without the use of any assumptions or empirical correlations.

Progress

Using the Immersed Boundary method, we calculate the drag force on an isolated cylinder in an unbounded fluid, for which theoretical estimates exist. To mimic an infinite array , we use periodic boundary conditions, so that we effectively model a very dilute square array of cylinders. A correction is applied to reduce the effect of the periodic images. The Immersed Boundary method has been extended to solve heat transfer problems.The simulations of some well known test cases have been conducted to validate the accuracy of the method on solving heat transfer problems.

Dissertations

-

Scientific Publications

-

Projectleaders

JAM Kuipers

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

H Tavassoli, MA van der Hoef

Cooperations

-

Funded

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

Start of the project

2010

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PROJECTLEADERS
JAM Kuipers
RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
A Patil. MA van der Hoef
COOPERATIONS
-
FUNDED
European Research Council

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

START OF THE PROJECT
2010
INFORMATION
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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

Presently a preliminary understanding of the Discrete particle model (DPM) code is being done in order to get the knowledge to build a new DPM code. The DPM code is primarily made of two parts: the Eulerian part which models the fluid flow and the Lagrangian part which models the descrete particle flow. The Eulerian flow is simulated on an grid and coupled with the solid phase flow using interaction parameters like drag coefficient. In order to evaluate such parameters the gas porosity of the grid cells are needed to be calculated. For this purpose solid volume in cells is calculated by directly evaluating volume of the particles in given cells. So the particles on the cell wall need to be evaluated with cut volume of the particles (sphere cap volume) only. In order to obtain computing efficiency a fictional cube of volume same as the sphere is used instead. This implementation was made to the DPM to evaluate the cut volume.

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

Implementation of coriolis and centrifugal forces has been done in discrete particle model to study the effect of rotation on flow behaviour of polydisperse granular particles on rotating and non-rotating chute. The simulation study of effect of different angles of inclination and different rotation rates of the chute on the flow behavior of dry monodisperse granular flow through an open chute/channel has been done. We have also done some preliminary results on simulations of bidisperse mixtures of different sized particles on an inclined chute with and without rotations. A chute flow setup has been built to investigate flow behaviour monodispersed and bidispersed granular flow through chute using Particle Image Velocimetry (PIV) for particle velocity, reflective optical probe for solid fraction and ultrasonic sensor for height measurement.

Dissertations

-

Scientific Publications

-

Projectleaders

JAM Kuipers, JT Padding, HJH Clercx

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

SS Shirsath

Cooperations

-

Funded

STW and Tata Steel

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

Start of the project

2010

Information

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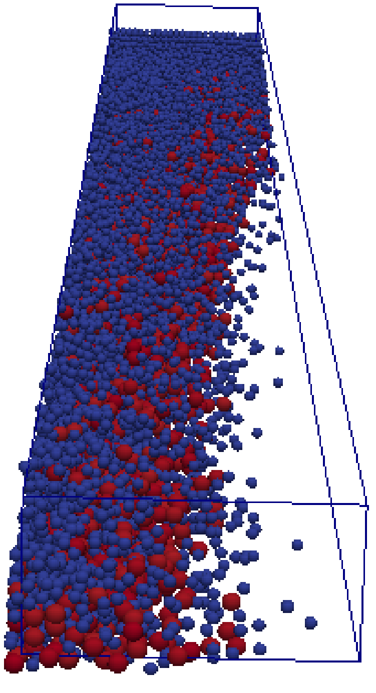

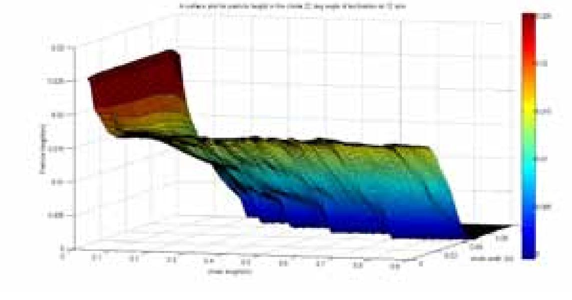

(a) Snapshots of simulation of binary mixture flowing through inclined chute at fixed angle of 22 degrees and 12 RPM
(b) Surface plot for particle height along the length of chute and width of chute for 12 RPM.

Toward a reliable model for industrial gas-fluidized bed reactors with poly-disperse particles

Projectleaders
JAM Kuipers
Researchtheme
Complex dynamics of fluids
Participants
SHL Kriebitzsch, MA van der Hoef
Cooperations
Prof. A.J.C. Ladd (Florida)
Funded
NWO

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

Start of the project
2006
Information
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Project Aim

Fully resolved simulations of industrially sized fluidized beds are still far beyond the capabilities of current computers. Thus coarsened models have to be used, which do not resolve the flow on length scales comparable to the size of the fluidized particles. To account for physical effects on these small scales, such as momentum exchange between gas and solids, closures are required. Aim of this project is to obtain closures for the drag force in poly-disperse particle gas system using results obtained from lattice Boltzmann and CFD–IBM simulations.

Progress

Two different immersed boundary methods were implemented in an in-house CFD code and extensively validated. The hydrodynamic force acting on particles in low-Reynolds number flow was compared to results obtained from lattice-Boltzmann simulations and to exact solutions of the Stokes equation, that were obtained by multipole expansion. Excellent agreement was found provided that a hydrodynamic diameter was used, which was obtained by comparison of the drag on particles in a dilute periodic simple cubic array. Simulations of small systems of O(1000) fluidized particles were done with CFD-IBM and compared with unresolved discrete particle simulations. It is found that the bed expansion is lower in the DP simulations. Detailed analysis of the IBM simulation data showed that the drag force predicted with current closures in the DP model is to low and hence also the bed expansion.

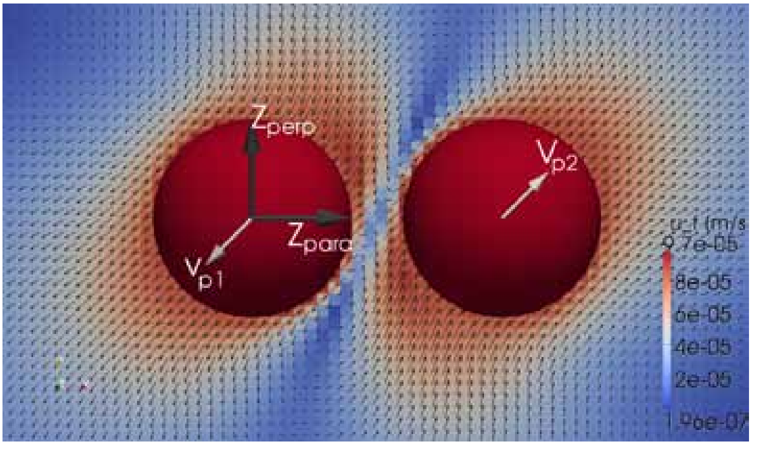
Dissertations

1. S.H.L. Kriebitzsch, "Direct Numerical Simulation of Dense Gas-Solid Flows", PhD thesis, Eindhoven University of Technology.

Scientific Publications

-

Hydrodynamic interaction of 2 particles



The effect of air on sand near the jamming point

Project Aim

To study in detail how the ambient, intersticial air influences the structure of loosely packed, static granular matter close to the jamming point.

Progress

The validation of the code which involves the Discrete Particle Model (DPM) and the Immersed Boundary Method (IBM) has been done under different cases. Then the viscosity of the fluidized granular solids is being investigated from the effective drag of a sphere being pulled trhough a homogeneous gas-fluidized bed with constant velocity.

Dissertations

-

Scientific Publications

-

Projectleaders

JAM Kuipers

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

MA van der Hoef, Y Xu

Cooperations

D van der Meer, D Lohse
Physics of Fluids group, UTwente

Funded

FOM-T-03 (Lohse)
FOM-T-19 (Kuipers)

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

Start of the project

2007

Information

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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
-
Funded
European Research Council

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

Start of the project
2010
Information
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Project Aim

The aim of the project is to develop a CFD model for cylindrical fluidised beds using Eulerian - Eulerian (Two-Fluid) approach based on Kinetic Theory of Granular flow. Further extending the model for heat tranfer study in fluidized beds. Development and application of experimental tools for detail validation of Multi-Scale CFD models in dense gas-solid flow, in particular X-ray tomography techniques.

Progress

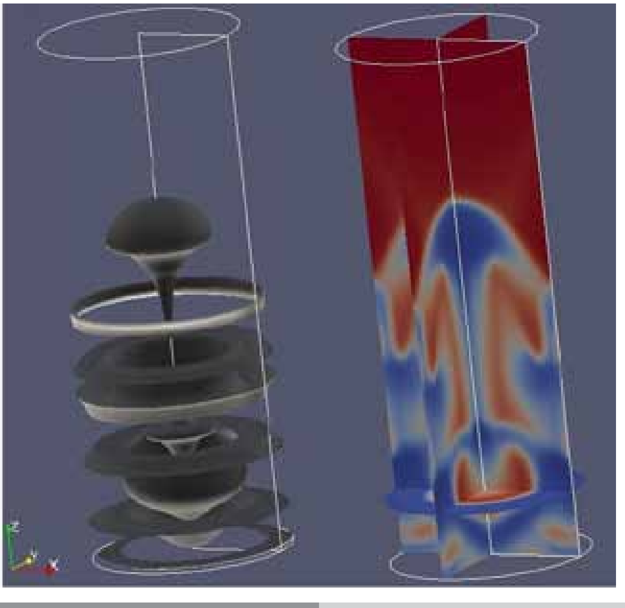
A litrature study has been performend for understanding flow dynamic in multiphase flow reactors, incorporateing different CFD models. Existing in-house Two Fluid model code for Cartesian coordinate system is studied and strategy for extension to cylindrical coordinates system was developed, where all governing equation, discritisation scheme and solution methods were focused. The Eulerian two fluid modeling approach is probably the most commonly used approach for predicting the dynamical behavior in fluid-particle systems. This approach describes both phases as interpenetrating continua and has more potential, compared to an Euler-Lagrangian approach, in situations where the dynamics of the system is of interest or the mass-loading of the dispersed phase is considerable. In TFM local instantaneous equations are averaged in a suitable way to allow coarser grids and longer time-steps being used in numerical simulations.At present TFM based on KTGF for cylinderical coordiante system is accomplished and testing and validation of the model is in progress. Experimental study on 3D-cylinderical fluidized beds using x-ray imaging technique is carried out in collaboration with HZDR, Dresden Germany.

Dissertations

-

Scientific Publications

-



Preliminary images of cylindrical fluidized beds, left shows 3D contours surface for 50% solid fraction at initial rising of the bed at superficial gas velocity of 2.0Umf. On right three different perpendicular planes shows bubble rising in the beds.

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 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

In the experimental study we analyze the jet behavior inside the spray dryer with the aid of particle image velocimetry (PIV) measurements. Jet precessing frequencies are found to be present in the system, exerting regular precession. We have implemented a sub grid scale turbulence model in the code for the analysis of jet behavior inside the spray dryer. The obtained experimental results are used to validate the turbulence model simulation results. Implementation of a direct simulation Monte Carlo approach is in progress for the investigation of collision, coalescence and agglomeration of the particles/droplets in a turbulent gas flow.

Dissertations

-

Scientific Publications

-

Projectleaders

JAM Kuipers

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

SK Pawar, JT Padding, NG Deen

Cooperations

Tetra Pak

Funded

Tetra Pak CPS Heerenveen

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

Start of the project

2010

Information

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Fundamentals of chemical looping for biomass gasification

Projectleaders
M van Sint Annaland, F Gallucci

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
I Campos Velarde

Cooperations
ECN

Funded
ADEM Project

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

Start of the project
2011

Information
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Project Aim

The aim of the project is to investigate in detail the interplay between the the multiphase hydrodynamics and reaction kinetics/heat transport in chemical looping biomass gasifier in order to understand how the operating conditions affect the gas phase and particle residence distribution and their effect on the reactor performance to develop a reliable model for design and scale-up of the process. A cold-flow and a separate high-temperature set-up will be constructed to experimentally investigate the reactor performance. Advanced experimental techniques, such as PIV (Particle Image Velocimetry)/DIA (Digital Image Analysis) for pseudo-2D set-ups will be used to measure the flow profiles and solids mixing to quantify the rate of heat and oxygen transport as a function of the operating conditions. An extended phenomenological model will be developed, based on the experimental results and detailed knowledge derived from more fundamental numerical models, which will be used for process optimization.

Progress

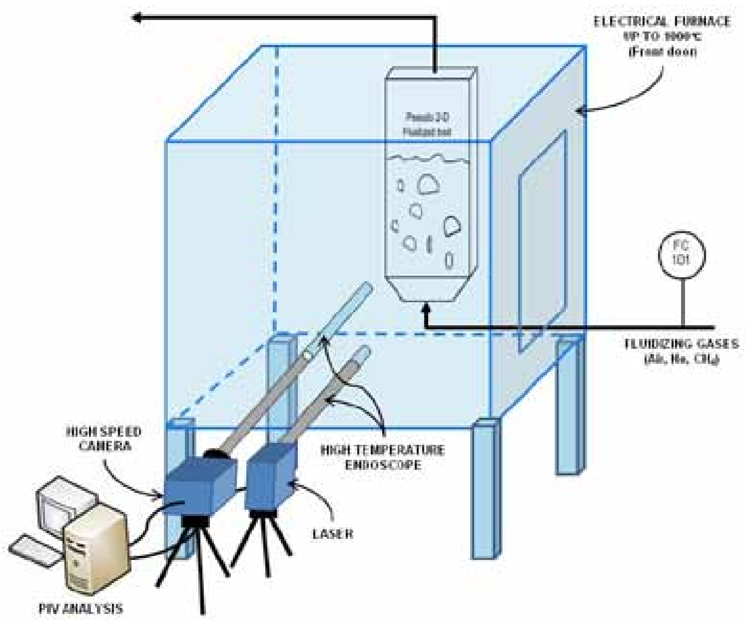
Construction of an experimental cold flow set up to investigate the effect of external solids circulation in the hydrodynamics of fluidized. In progress design and construction of a high temperature set up for endoscopic PIV/DIA of fluidized beds (Figure 1). Literature study to extend the existing bubble assemblage model to incorporate solid reaction and external circulation for two interlinked reactors.

Dissertations

-

Scientific Publications

-



Schematic representation of lab set up for high temperature endoscopic PIV/DIA

Fundamentals of reactive multi phase flows in chemical looping combustion

Project Aim

The study will contribute to fundamental knowledge on the intricately coupled multiphase hydrodynamics and reaction kinetics in the bubbling fluidized bed reactor employed in Chemical Looping Combustion (CLC) systems. CLC is one of the most promising technologies for CO2 capture. The work will generate and provide detailed experimental data for validation of Computational Fluid Dynamic (CFD).

Progress

Hydrodynamics study has been performed at cold conditions in order to determine solid velocity, bed porosity and bubble properties, using PIV/DIA.

Gas mixing study has been performed by injecting the CO2 at one position and measure its concentration at different positions.

Dissertations

-

Scientific Publications

-

Projectleaders

M van Sint Annaland, F Gallucci

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

A Zaabout, S Cloete, S Amini

Cooperations

SINTEF Materials and Chemistry

Funded

SINTEF Materials and Chemistry

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

Start of the project

2011

Information

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Prof.dr.ir. K Kopinga

Prof.dr.ir. OCG Adan

In the Transport in Permeable Media group, TPM, of the department of Applied Physics at the “Technische Universiteit van Eindhoven” research is carried out 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 innnovation institue (M2i), the European Community and various industrial partners. In our research Magnetic Resonance Imaging techniques is one of the major working horse.

Water transport in multilayer coatings

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

-

Scientific Publications

1. V. Baukh, H. P. Huinink, O. C. G. Adan, and S. J. F. Erich, "Water-Polymer Interaction during Water Uptake," Macromolecules, vol. 44, pp. 4863-4871, 2011.

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

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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
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Project Aim

The aim of the current project is to understand how compositions of multilayer coatings influence water transport. Different compositions imay nduce 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, and S. J. F. Erich, "Water-Polymer Interaction during Water Uptake," Macromolecules, vol. 44, pp. 4863-4871, 2011.

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 focussed 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

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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
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Project Aim

The aim of this project is to obtain knowledge on the physical an 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

-

Salt crystallization in porous materials

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 against NaCl damage. These results show that this inhibitor does work on bulk solutions and a supersaturation up to 2 was found. For porous materials it was found the inhibitor does not work within the material but is rather changing the boundary conditions. Therefore significant amount of salt can crystallize outside of a material. A start was made on the study of the effect of inhibitor on the mixture of salts, i.e., ternary mixtures of NaCl + KCl + water.

Dissertations

-

Scientific Publications

-

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

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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
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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. The aim is to develop a model which can give a better prediction of the chloride transport over a longer time. i.e., years.

Dissertations

-

Scientific Publications

-

Electrokinetic desalination of porous building materials

Project Aim

The objective of this project is to determine the effect of electrokinetics 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. However, these measurements showed thath at later stages the salt transport by electromigration 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

-

Scientific Publications

1. Kashif Kamran, Leo Pel, Alison Sawdy, Henk Huinink, Klaas Kopinga, Desalination of porous building materials by electrokinetics: an NMR study, Materials and Structures (2011).

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

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Chloride transport and monitoring in concrete

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

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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 developed a NMR setup which will be able to measure non-destructively 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 developed a NMR setup which will be able to measure non-destructively the transport in concrete.

Dissertations

-

Scientific Publications

-

Computational Biophysics

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.

Nanomechanical characterization of supermolecular protein structures using atomic force microscopy

Project Aim

The aim of this study is to gain a comprehensive understanding of the dynamics and material properties of suspensions and gels of fibrillar amyloid aggregates, in particular suspensions of β-lactoglobulin fibers. Significant insight into the dynamics will come from coarse grained simulations using Multiparticle Collision Dynamics (MPCD). This study will obtain experimental results from atomic force microscope (AFM) experiments. Results from simulation should provide considerable guidance in the choice of experiments and the final analysis of the results.

Progress

Using MPCD code we have simulated suspensions of semiflexible fibers in a hydrodynamic solvent. We have performed two main groups of simulations: In the first group of simulations we have fixed the flexibility of the fibres and performed simulations at a range of concentrations. In the second group of simulations we have fixed the concentration and varied the stiffness of the fibres. Following linear response theory we have calculated the viscoelastic properties of the fluid, the stress relaxation modulus G(t) and from it the storage and loss moduli Gß and Gß. From the second group of simulations, we have found that the stiffness of the fibers has a significant influence on the stress relaxation. In particular we find that two power-law regimes appear in the stress relaxation. Experimental works have reported liquid crystal phases in suspensions of ß-lactoglobulin and so modelling some aspects of these systems is of interest. However, the model as it stands describes chains as a series of beads connected by lines which are able to collide but do not cross. The lines do not have volume. At high chain concentration or in the liquid crystal phase this is unrealistic. We have extended the algorithm to take care of excluded volume between connecting rods and will use this to look at the dynamics at higher volume fractions. On the experimental component of this project Ramesh Subramani has done extensive AFM imaging of the β-lactoglobulin fibers from the gel we intend to simulate. We have analysing these images together and have been able to estimate the persistence length as well as the length distribution of the fibers in the sample. From this data we have also been able to estimate the fibre concentration of the sample. Some initial bulk rheology measurements have been performed. In addition, we have developed new periodic boundary conditions suitable for the simulation of uniaxial extensional flow (UEF). In the past the periodic boundary conditions of Kreynik and Reinelt (1992) had been used for the simulation of planar extensional flow, however similar suitable algorithms did not exist for uniaxial extensional flow and Kaynik and Reinelt had indicated that there were reasons why the method may not be extended to UEF. We have overcome these restrictions and we are currently testing our new technique through nonequilibrium molecular dynamics simulations of simple liquids. We expect to apply the technique to both MPCD and the Responsive Particle Dynamics (RaPiD) algorithm which has been developed in our group..

Dissertations

-

Scientific Publications

-

Projectleaders
WJ Briels, ML Bennink

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
TA Hunt, R Subramani, J Padding, WJ Briels, ML Bennink, V Subramaniam.

Cooperations
Bio-related materials materials network

Funded
FOM

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

Start of the project
2010

Information
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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
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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

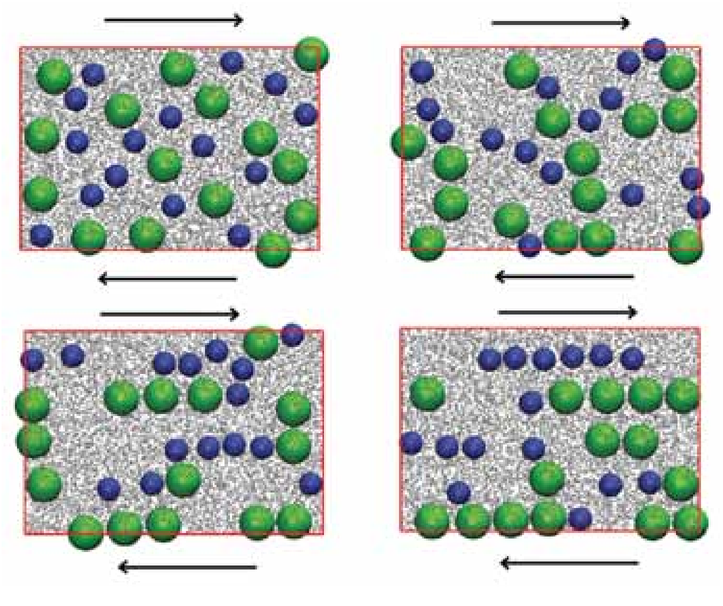
We carried out computer simulations using the Responsive Particle Dynamics (RaPiD) method to investigate dispersions of colloids in shear-thinning wormlike micellar and polymer solutions. The colloids distribute homogeneously in quiescent fluids, and remain randomly dispersed in sheared polymer solutions. In the sheared worm-like micellar solution, however, the colloids align to form strings along the flow direction. We also observed that bidisperse colloids segregate according to size, as illustrated in the figure blow, in agreement with experimental observations. We are currently exploring the physical origins of alignment and segregation, by systematically varying the parameters of the simulated fluids and by analyzing the flow-induced effective colloidal interactions.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. I.S. Santos de Oliveira, A. van den Noort, J.T. Padding, W.K. den Otter and W.J. Briels. Alignment of particles in sheared viscoelastic fluids, J. Chem. Phys. 135, 104902 (2011).



Project Aim

Topologically complex polymers, such as stars, combs and H-shaped polymers, exhibit complex dynamic and rheological properties, including hierarchical relaxation processes with many different time scales. The aim of this project is to study the flow behavior of branched polymers, which is a major issue in the industrial application of these polymers, by coarse-grained simulations.

Progress

The twentanglement code, an in-house developed technique that uses uncrossibility constraints to prevent the unrealistic bond crossings that occur in all coarse-grained polymer simulations, has over the last year been extended from linear to branched polymers. We have carried out the first coarse-grained simulations of H-branched polymer melts, and studied their dynamic and rheological properties. The center-of-mass diffusion, the relaxation dynamics of the arms and the stress autocorrelation function are all being compared against their counterparts for corresponding linear chains. We have also initiated simulations on other architecturally complex polymer melts, including symmetric and asymmetric stars. The simulation results will be compared against theoretical and experimental work.

Dissertations

-

Scientific Publications

-

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

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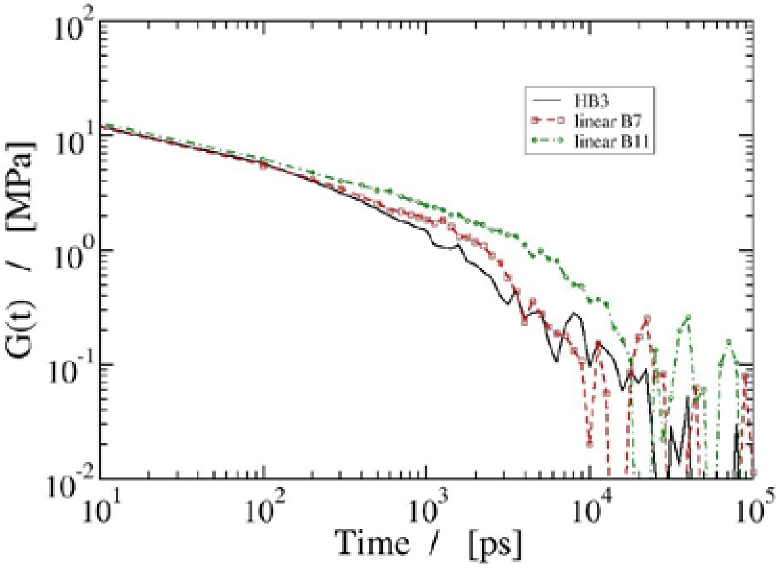
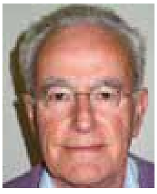


Physics of Fluids

Prof.dr. D Lohse

Prof.dr. A Prosperetti



Prof.dr.ir. L van Wijngaarden

Prof.dr. JF Dijksman

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

Turbulent convection under rotation about a vertical axis is a simple model system for industrial and geophysical systems. Examples include flow in the atmosphere, oceans, the inner core of the earth, giant gas planets and the outer layer of the sun. The aim of this research project is to investigate the effect of background rotation on Rayleigh-Bénard convection. With a cylindrical Rayleigh-Bénard cell, which is placed on a rotating table, we can accurately measure the heat transport in the system. These measurements are supplemented by numerical studies which give full access to the full flow domain to study changes in the flow structure.

Progress

Experimental measurements and results from direct numerical simulations show that there is a suddon increase in the heat transport in the system due to rotation. It turns out that this bifurcation is caused by the transition between two different turbulent states: One dominated by a large scale convection roll when there is no or very weak rotation, and one dominated by vertically-aligned vortices for strong rotation. In an aspect ratio Γ=D/L=1, where D is the diameter of the sample and L the height, the transition between the two different turbulent state is visible in temperature measurements of probes embedded in the sidewall. In contrast, in Γ=1/2 samples the transition is not obvious from these sidewall measurements as here a two-vortex state, in which one vortex extends vertically from the bottom into the sample interior and brings up warm fluid, while another vortex brings down cold fluid from the top, is formed and this flow field yields the same sidewall temperature-signature as a large scale circulation. The access to all 3D data in simulations allows us to quantify the transition between the two turbulent states, see figure 1.

Dissertations

1. Stevens, R.J.A.M.(June 30, 2011). Rayleigh-Bénard turbulence, Universiteit Twente, Enschede, The Netherlands. Promotor(en): Prof. Dr. D. Lohse en Prof. Dr. H.J.H. Clercx.

Scientific Publications

1. R.P.J. Kunnen, R.J.A.M. Stevens, J. Overkamp, C. Sun, G.J.F. van Heijst, H.J.H. Clercx, The role of Stewartson and Ekman layers in turbulent rotating Rayleigh-Bénard convection, J. Fluid Mech. 688, 422-442 (2011).
2. R.J.A.M. Stevens, J. Overkamp, D. Lohse, H.J.H. Clercx, Effect of aspect-ratio on vortex distribution and heat transfer in rotating Rayleigh-Bénard, Phys. Rev. E 84, 056313 (2011).
3. 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, Submitted to J. Fluid Mech., see also arXiv:1112.0411.
4. E.P. van der Poel, R.J.A.M. Stevens, D. Lohse, Connecting flow structures and heat flux in turbulent Rayleigh-Bénard convection, Phys. Rev. E 84, 045303(R) (2011).
5. Q. Zhou, K. Sugiyama, R.J.A.M. Stevens, S. Grossmann,D. Lohse, K.-Q. Xia, Horizontal structures of velocity and temperature boundary layers in 2D numerical turbulent Rayleigh-Bénard convection, Phys. Fluids 23, 125104 (2011).

Projectleaders
D Lohse, D van der Meer

Researchtheme
Complex dynamics of fluids

Participants
RJAM Stevens, D Lohse, EP van der Poel

Cooperations
H.J.H. Clercx (Eindhoven, Netherlands), G.J.F. van Heijst (Eindhoven, Netherlands),
S. Weiss (Santa Barbara, USA),
G. Ahlers (Santa Barbara, USA),
R. Verzicco (Tor Vergata, Italy)

Funded
FOM

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

Start of the project
2008

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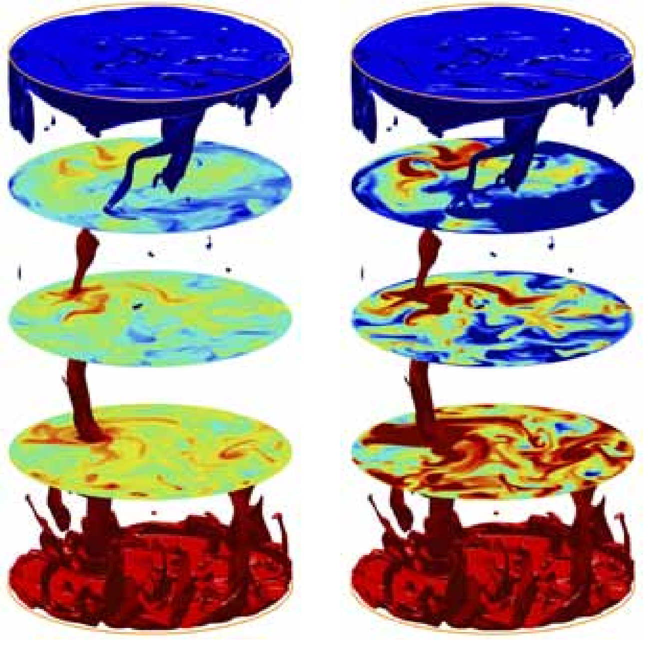
6. R.J.A.M. Stevens, H.J.H. Clercx, D. Lohse, Effect of plumes on measuring the large scale circulation in turbulent Rayleigh-Bénard convection, Phys. Fluids, 22, 085103 (2011).
7. R.J.A.M. Stevens, D. Lohse, R. Verzicco, Prandtl and Rayleigh number dependence of heat transport in high Rayleigh number thermal convection, J. Fluid Mech. 688, 31-43 (2011).
8. 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).
9. 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 Rayleigh-Bénard convection, Submitted to Phys. Rev. E., see also arXiv:1112.0454. Grossmann, S., & Lohse, D.

Flow visualization in an aspect ratio Γ=1/2 sample. The colormap for the horizontal planes is different in the left and right picture. The red and blue temperature isosurface indicates the up and down-going vortices.



PROJECT AIM

The aim of this project is to study the instabilities of advancing and receding contact lines, both theoretically and experimentally. Most work in the literature has focused on contact line dynamics in the viscosity dominated regime, neglecting outer flow effects or inertia. However in situations close to instabilities the latter two assumptions might be violated. This occurs, for example, in the context of immersion lithography, and therefore the project is in close collaboration with ASML. The main issues to be addressed in this project are: stability of contact lines over a broad range of velocities, bubble entrapment, high Reynolds number motion, constant acceleration and oscillations.

PROGRESS

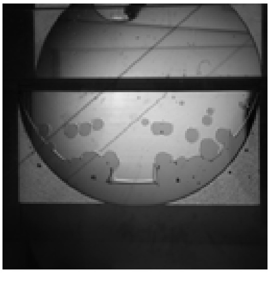
We have studied air entrainment close to the contact line for two cases: 1) by plunging a solid plate into a reservoir of silicone oil; 2) by collision of a sessile water droplet with a liquid bridge. In the first case, we experimentally observe the formation of an air film that subsequently destabilizes to form bubbles. The breakup of the air film occurs through the nucleation of ``rewetting'' holes, growing regions of liquid reestablishing contact with the surface — the inverse process of the classical dewetting holes. By varying the viscosity of the silicone oil, it is found that characteristic speeds depend, unexpectedly, strongly on air viscosity. For the second case, we experimentally reveal how bubbles are entrained into the liquid bridge during the process of coalescence. We characterize two mechanisms for entrainment and identify scaling relations for the size of the entrained bubbles in terms of impacting droplet size and velocity. Also progress is made in the study droplet spreading dynamics at very small timescales.

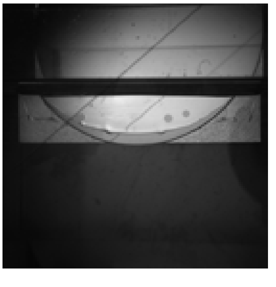
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. T.S. Chan, T. Gueudré and J.H. Snoeijer. "Maximum speed of dewetting on a fiber", Phys. Fluids 23, 112103 (2011).
2. K.G. Winkels, I.R. Peters, F. Evangelista, M. Riepen, A. Daerr, L. Limat and J.H. Snoeijer. "Receding contact lines: from sliding drops to immersion lithography", Eur. Phys. J. Special Topics 192, 195 (2011).
3. Weijs, J.H., Marchand, A., Andreotti, B., Lohse, D., & Snoeijer, J.H. Origin of line tension for a Lennard-Jones nanodroplet. Phys. Fluids 23, 022001 (2011).





PROJECTLEADERS

JH Snoeijer

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

TS Chan, KG Winkels, D Lohse

COOPERATIONS

ASML BV, Veldhoven

FUNDED

FOM, ASML and EU

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

START OF THE PROJECT

2008

INFORMATION

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PROJECTLEADERS
C Sun
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
N Oudalov, CW Visser, Y Tagawa, D Lohse, IR Peters, D van der Meer, A Prosperetti
COOPERATIONS
TimesLab
FUNDED
FOM

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

START OF THE PROJECT
2011
INFORMATION
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PROJECT AIM

By focusing a laser pulse into liquid in a micro-capillary, an ultra-high-speed (up to supersonic velocities, 640 m/s), ultra-sharp, focused liquid micro-jet emerges. The aim of this project is to understand the process of this remarkable jet in detail and investigate the dependence on the control parameter by use of our experimental setup and numerical method using the boundary integral method. Furthermore, we also study the impact of the microjet on solid (e.g. glass plate) and soft matter (e.g. gelatin and artificial human skins). Thanks to the supersonic microjets we can explore a totally new parameter regime.

PROGRESS

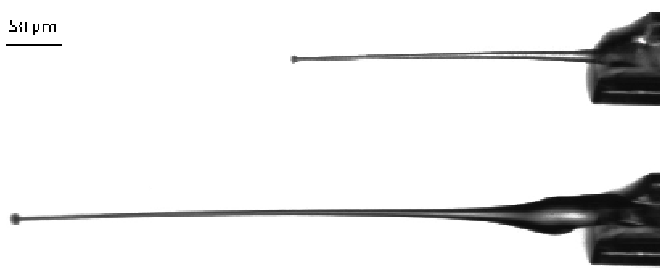
In the first year of the project the following progress was made:
Technical: Ultra high-speed imaging showed that the jetting device can provide consistent and reproducible jets up to 850 m/s. An example is shown in Fig.1. A paper of this work was published in ArXiv and submitted to a physical journal. In addition a thorough start was made with the study of micro-droplets at unprecedented velocities. Both results were presented at the APS-DFD meeting in Baltimore, USA. At present, these results are expanded with the aim to publish. Personal: A PhD. student (C.W.Visser) started working on the project since April, substantially speeding up output, and an MSc student (N.Oudalov) has finished an excellent master's assignment on the project, under the supervision of a Postdoc (Y.Tagawa) and academic staff. This very effective team aims to continue into 2012. Commercial: Together with Timeslab, a business development company, an ERC grant was successfully attracted to study of commercial application of the jet. This direct spin-off from the project is currently ongoing.

DISSERTATIONS

1. Nikolai Oudalov, "Supersonic microjet generation using laser-induced vapour bubbles", Master Thesis.

SCIENTIFIC PUBLICATIONS

1. Tagawa, Y., Oudalov, N., Visser, C., Peters, I., van der Meer, D., Sun, C., Prosperetti, A., and Lohse, D., 2011, "On highly focused supersonic microjets", 2011, submitted, http://arxiv.org/abs/1112.2517.



Supersonic and ultra-thin jet (~490 m/s, ~10 ≠ m in diameter)

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 experimental setup is fully operational and experiments in single bubble growth and interactive bubble growth are presently underway. A collaboration has been started with Dr. Edip Can, a former Ph.D student of the Physics of Fluids group to adapt a numerical code to simulate the interactive bubble growth by gas diffusion. The numerical code is being tested.

Dissertations

-

Scientific Publications

1. Enriquez, O.R., Peters. I.R., Gekle, S., Schmidt, L.E., Meer, D. van der & Lohse, D. Non-axisymmetric impact creates pineapple-shaped cavity. Phys. Fluids 23, 091106 (2011).

Carbon dioxide bubbles in water, growing from a line of 5 micro pits etched on a silicon wafer.

Projectleaders

D Lohse, A Prosperetti, D van der Meer, C Sun

Researchtheme

Complex dynamics of fluids

Participants

OR Enríquez

Cooperations

E Can

Funded

Shell/FOM

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

Start of the project

2010

Information

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PROJECTLEADERS
D Lohse, JH Snoeijer

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
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COOPERATIONS
Physics of Interfaces and Nanomaterials Group, University of Twente, Prof. Dr. Ir. H.J.W. Zandvliet Prof. Dr. Ir. B. Poelsema

FUNDED
UT, EU, FOM, m2i, TNO, NWO-nano/STW

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

START OF THE PROJECT
2004

INFORMATION
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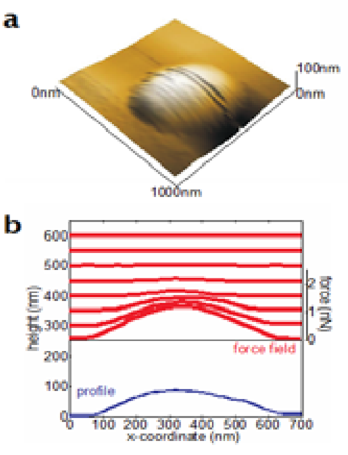

PROJECT AIM

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: Significant progress has been made in terms of understanding nucleation scenarios, as well as furthering the understanding of stability. Nucleation stability phase space (temperature/gas concentration) has been discovered, as well as the gas-type dependency. Dynamic equilibrium has been measured using atomic force microscopy (see Fig. 1).

Numerical: (molecular dynamics, MD) Better understanding of line tension and surface tension on the nanoscale. Transferral from Lennard-Jones fluids to real liquid, gas, and substrate potentials. Discovery of MD nanopancakes, matching the experimental micropancakes of densely adsorbed gas.

Theoretical: New model to describe how the dynamic equilibrium is driven (facilitated by the realisation that the internal nanobubble gas is of Knudsen type).

DISSERTATIONS

1. Sezer Caynak, “Surface nanobubbles phase space” Master’s thesis (March 2011).

SCIENTIFIC PUBLICATIONS

1. “Nanobubbles and micropancakes: gaseous domains on immersed substrates” J. R. T. Seddon and D. Lohse. J. Phys. Condens. Matter 23, 133001 (2011).
2. “Surface bubble nucleation stability”. J. R. T. Seddon, E. S. Kooij, B. Poelsema, H. J. W. Zandvliet, and D. Lohse. Phys. Rev. Lett. 106, 056101 (2011).
3. “Surface nanobubbles as a function of gas type”. M. A. J. van Limbeek and J. R. T. Seddon. Langmuir 27, 8694-8699 (2011).
4. “Knudsen gas provides nanobubble stability”. J. R. T. Seddon, H. J. W. Zandvliet, and D. Lohse. Phys. Rev. Lett. 107, 116101 (2011).
5. “Origin of line tension for a Lennard-Jones nanodroplet”. J. H. Weijs, A. Marchand, B. Andreotti, D. Lohse, and J. H. Snoeijer. Phys. Fluids 23, 022001 (2011).
6. “Why is surface tension a force parallel to the interface?”. A. Marchand, J. H. Weijs, J. H. Snoeijer, and B. Andreotti. Am. J. Phys. 79, 999-1008 (2011).

Evaporation of colloidal droplets: coffee stains and soccer balls

Project Aim

The aim of this project is to investigate time-dependent behaviour in the formation of coffee-stain rings, which occur when droplets with suspended particles evaporate, and to understand the structure of the remaining deposits. To understand the underlying mechanisms, 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 shown that the evaporation of droplets on a partially wetting substrate is completely governed by diffusive transport of vapor in air. We have shown that the velocity field inside an evaporating drop has a temporal divergence. This causes a rush-hour for the suspended particles in the drop: they all move towards the contact line at high speed at the end of evaporation. This also explains the order-to-disorder transition in the remaining stain: the outermost layers, formed before the rush-hour are ordered, whereas the layers formed during the rush-hour are disordered.

Dissertations

-

Scientific Publications

1. How water droplets evaporate on a superhydrophobic substrate, H. Gelderblom, A.G. Marin, H. Nair, A. van Houselt, L. Lefferts, J.H. Snoeijer, and D. Lohse, Phys Rev E 83 (2011).
2. Order-to-disorder transition in ring-shaped colloidal stains, A.G. Marin, H. Gelderblom, D. Lohse, and J. H. Snoeijer, Phys Rev Lett 107 (2011).
3. Rush-hour in evaporating coffee drops, A.G. Marin, H. Gelderblom, D. Lohse, and J.H. Snoeijer, Phys Fluids 23 (2011).

Projectleaders

D Lohse

Researchtheme

Complex dynamics of fluids

Participants

Á Gomez Marín, H Gelderblom, JH Snoeijer, D Lohse

Cooperations

L Lefferts (UT, TNW, CPM)

Funded

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

Start of the project

2010

Information

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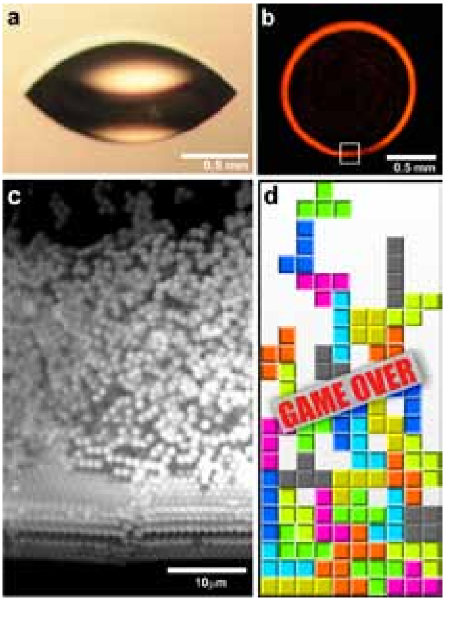

Air entrapment and drop formation in drop on demand inkjet printing

Projectleaders
D Lohse, M Versluis

Researchtheme
Complex dynamics of fluids

Participants
T Driessen, M van der Meulen,
E Staat

Cooperations
H. Reinten (Océ Technologies)
H. Wijshoff (Océ Technologies)
M. van den Berg (Océ Technologies)
A. van der bos (Océ Technologies)
R. Jeurissen (ACFD-consultancy)

Funded
Océ Technologies, Physics Of Fluids UT, NanoNextNL, FOM and HiPrins

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

Start of the project
2009 - T Driessen
2011 - M van der Meulen
2012 – E Staat

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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

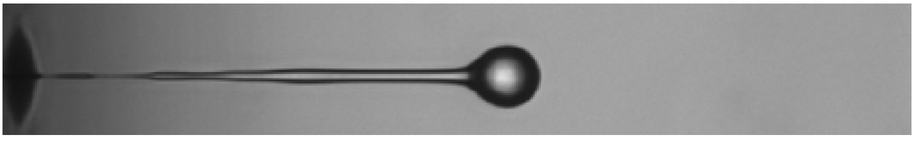
To find the relevant parameters for the droplet formation process, a second order accurate droplet formation model was developed, in which both droplet coalescence and separation can be simulated. Preliminary results from the comparison of detailed experiments with the model are shown in the figure below. 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

1. Bos, J.A. van der, Segers, T., Jeurissen, R.J.M., Berg, M van den, Reinten, H., Wijshoff, H., Versluis, M. & Lohse, D. Infrared imaging and acoustic sizing of a bubble inside a micro-electro-mechanical system piezo ink channel. JAP 110, 034503 (2011).
2. Driessen, T.W. & Jeurissen, R. A regularised one-dimensional drop formation and coalescence model using a total variation diminishing (TVD) scheme on a single Eulerian grid, iJCFD, Volume 25, Issue 6, Pages: 333-343 (2011).
3. Bos, J.A. van der, Zijlstra, A.G., Gelderblom, E.C. & Versluis, M. iLIF: illumination by Laser-Induced Fluorescence for single flash imaging on a nanoseconds timescale. Exp. Fluids 51, 1283 (2011).



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.

PROGRESS

Using the experimental data, a PRL paper was published, which was an Editor's Suggestion. More Experimental data was obtained for the publication of two more papers, one published January 2012 and one in the process of publication. The numerical code was validated, and data was obtained at low Reynolds number towards the publication of another paper. This code was also parallelized in large scale using MPI.

DISSERTATIONS

1. Gils, D.P.M. van (December16, 2011), Highly Turbulent Taylor-Couette Flow. Universiteit Twente (171 pag.) (Enschede, the Netherlands: Physics of Fluids group). Promotor: Prof. Dr. D. Lohse.

SCIENTIFIC PUBLICATIONS

1. Gils, D.P.M. van, Huisman, S.G., Bruggert, G.W.H., Sun, C. & Lohse, D. Torque Scaling in Turbulent Taylor-Couette Flow with Co- and Counterrotating Cylinders. PRL 106, 024502 (2011).
2. Gils, D.P.M. van, Bruggert, G.W.H., Lathrop, D.P., Sun, C. & Lohse, D. The Twente turbulent Taylor–Couette (T3C) facility: Strongly turbulent (multiphase) flow between two independently rotating cylinders. Rev. Sci. Instrum. 82, 025105 (2011).

PROJECTLEADERS

D Lohse, C Sun

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

SG Huisman, R Ostilla Monico, DPM Van Gils, R Verzicco (Tor Vergata, Rome), S Grossmann (Marburg)

COOPERATIONS

-

FUNDED

STW, University

University	33 %
FOM	-
STW	66 %
NWO Other	-
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

START OF THE PROJECT

2008

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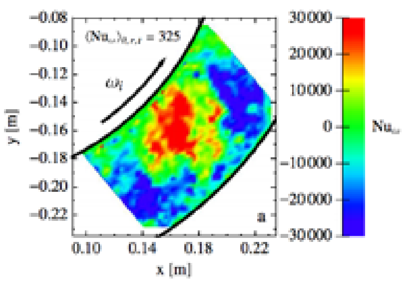

Inertial contact lines: how wetting affects large scale flows

Projectleaders
JH Snoeijer

Researchtheme
Complex dynamics of fluids

Participants
A Eddi, W Bouwhuis, K Winkels, JH Weijs

Cooperations
-

Funded

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

Start of the project
2011

Information
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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

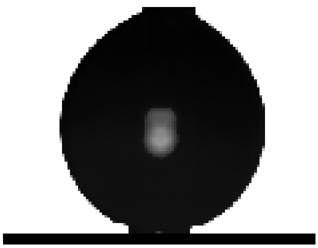
We investigated the very first stages of spreading of a water droplet on a partial wetting substrate, using Molecular Dynamics simulations and experimental measurements. In the experiments, we found that shortly after contact spreading exhibits universal behavior, dominated by inertia. These universal 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 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.

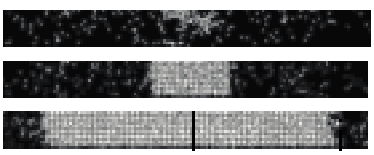
Dissertations

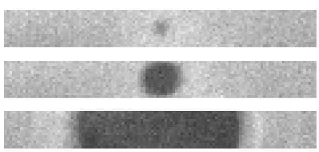
-

Scientific Publications

1. Weijs, J.H., Marchand, A., Andreotti, B., Lohse, D., & Snoeijer, J.H. Origin of line tension for a Lennard-Jones nanodroplet. Phys. Fluids 23, 022001 (2011).
2. Das, S., Marchand, A., Andreotti, B. & Snoeijer, J.H. Elastic deformation due to tangential capillary forces. Phys. Fluids 23, 072006 (2011).







PROJECT AIM

The aim of the project is to understand the dynamics of an impact on a liquid, including the resulting void collapse, splash and jet formation.

PROGRESS

The splash following disc impact has been investigated further, using numerical simulations and experiments. We have changed the viscosity of the fluid using glycerol-water mixtures, to see the influence of the Reynolds number on the transition to droplet ejection. We have performed an experimental study to disc impact on an oil layer covering the water surface. These experiments have given clear insight in the jet formation and the liquid behavior after the collapse of the cavity. In particular, we have shown experimentally that the jet is formed from the surface of the cavity. By pulling down a disc from an oil-water interface when we have a deep layer of oil covering a deep layer of water, we have found universal shapes of the entrained oil for high Froude numbers.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. O. R. Enríquez, I. R. Peters, S. Gekle, L. E. Schmidt, D. van der Meer and D. Lohse. Non-axisymmetric impact creates pineapple-shaped cavity. Phys. Fluids 23, 091106 (2011)

PROJECTLEADERS

D Lohse, D van der Meer

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

IR Peters, OR Enríquez, S Gekle, LE Schmidt

COOPERATIONS

University of Sevilla, Spain

FUNDED

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

START OF THE PROJECT

2006

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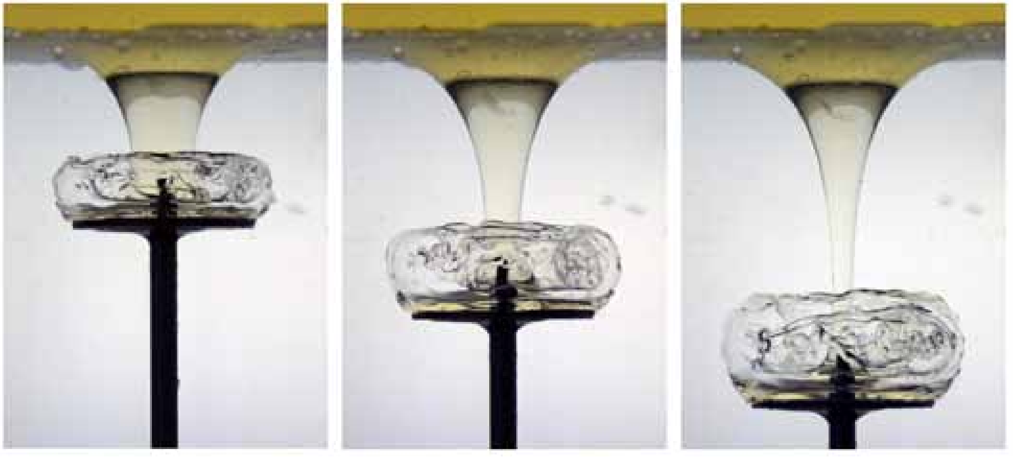

PROJECTLEADERS
D Lohse, D van der Meer
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
TAM Homan
COOPERATIONS
RF Mudde
FUNDED
FOM

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

START OF THE PROJECT
2009
INFORMATION
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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

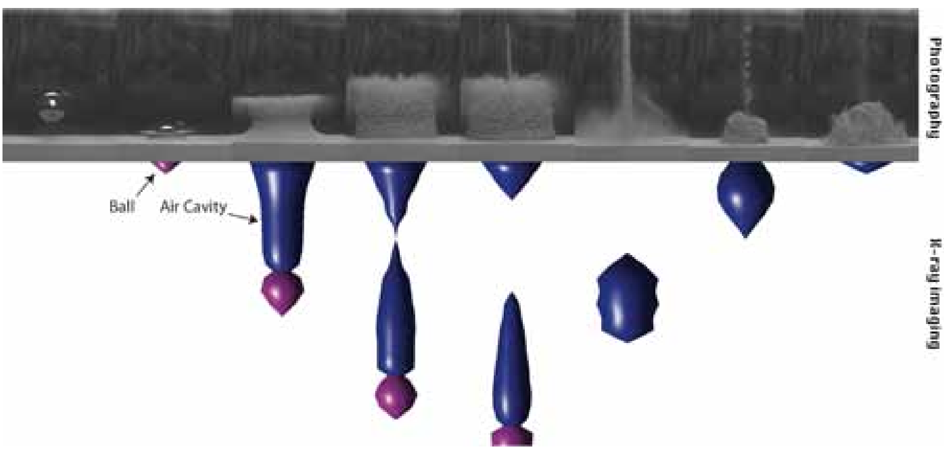
High-speed X-ray tomography experiments of a ball impacting on soft sand are carried out, in cooperation with the group of Rob Mudde. In these experiments the shape of air cavities in the sand bed are measured as a function of time. The results show the formation of the air cavity behind the penetrating ball, the collapse of the cavity and the shape of the bubble that is left below the pinch-off point. With this method it was even possible to retrieve the shape of the jet that is formed when the cavity walls hit eachother.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Bergmann, R., Tophoj, L., Homan, T.A.M., Hersen, P., Andersen, A. & Bohr, T. Polygon formation and surface flow on a rotating fluid surface. J. Fluid Mech. 679, 415 (2011).



PROJECT AIM

Floating particles form clusters on a surface wave in various ways. It is known that the physical properties of the floaters and the wave regime have effects on the clustering. However, it is not fully understood how the particle distribution and their dynamics depend on the particle concentration:

* Do the clusters disappear in higher concentrations?

* Do the particles move purely at random or do they move cooperatively?

In this study, we would like to answer these questions both by performing experiments and by using statistical analysis borrowed from the Lagrangian turbulence and colloidal physics. Our main interest is to understand the variations in the mobility and in the structral properties of the clusters by increasing the concentration and the relevant wave parameters, and in this way, to study physics near the jamming point.

PROGRESS

When macroscopic grains float on a water-air interface, they aggregate into a static cluster due to the attractive capillary interaction between the grains. Here, we study what happens when the grains in the cluster are excited using capillary Faraday waves with a wavelength comparable to the grain size. We observe very heterogeneous dynamics of the grains both in space and in time [see figure (a)]. Furthermore, the grains are found to exhibit cooperative motion in domains which tend to become slower as the grain concentration increases [see figure (b) and (c)]. To quantify the typical time scale of the heterogeneities, we apply two methods: Morphological analysis and the four-point dynamic susceptibility. We find that the morphological analysis [see figure (b)] is more sensitive than the four-point dynamic susceptibility [see figure (c)] in explaining the slowing down dynamics at moderate grain concentration.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS

D Lohse, D van der Meer

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

C Sanli

COOPERATIONS

-

FUNDED

FOM-program Rheophysics: Connecting Jamming and Rheology

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

START OF THE PROJECT

2008

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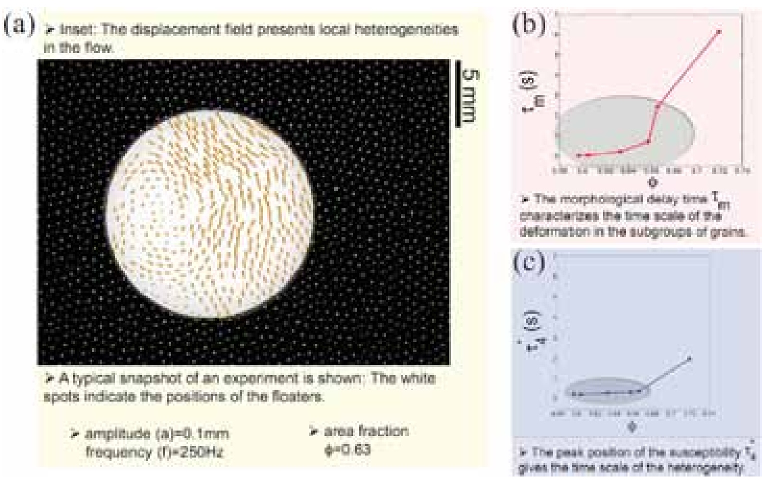

PROJECTLEADERS
M Versluis

RESEARCHTHEME
Complex dynamics of fluids

PARTICIPANTS
B Verhaagen, C Boutsioukis, L Heijnen, CP Sleutel, D Fernandez Rivas

COOPERATIONS
R Macedo, L-M Jiang, Paul Wesselink (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 Fellowship (EU)

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

START OF THE PROJECT
2007

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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 3D 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

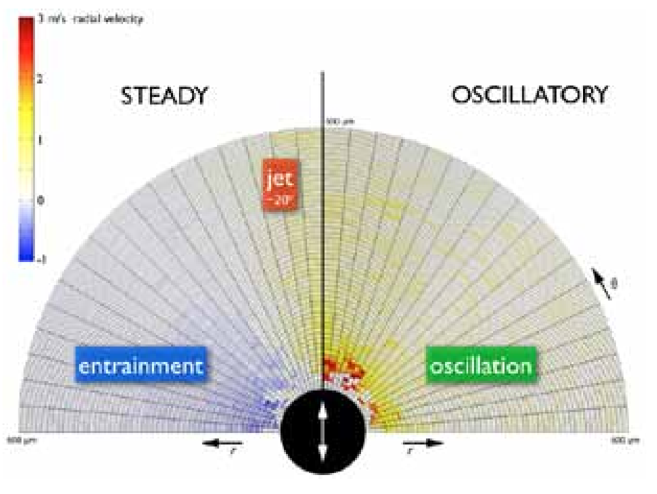
The oscillation characteristics of ultrasonically driven endodontic files have been investigated both experimentally and numerically, showing very good agreement. Also the effect of contact with the root canal wall has been studied, both in a lab setting and in a clinically realistic environment. The induced acoustic streaming has been measured using high-speed PIV, showing the influence of the confinement and curvature of the root canal on the flow.
The flow into the smallest microchannels present in the complex geometrical system of the root canal (dentinal tubules) has been studied using a fluorescent dye in silicon microchannels. The effect of the induced flow on a biofilm is now investigated using a hydrogel. Dosimetry and sonoluminescence techniques have been developed to determine the amount of cavitation that occurs.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. L-M Jiang, B Verhaagen, M Versluis, J Langedijk, PR Wesselink, LWM van der Sluis, 'The influence of the ultrasonic intensity on the cleaning efficacy of passive ultrasonic irrigation', Journal of Endodontics 37(5), 2011.



Measured radial velocity around an oscillating cylindrical endodontic file, showing both the steady and oscillatory component in one quadrant each

Project Aim

Sonochemistry is the use of cavitation for achieving a chemical conversion. Implosion of microbubbles (5-20 μm) can generate localized peaks of temperatures (10000 K) and pressures (up to 1000 bar), the conditions of the surrounding liquid remaining ambient. Therefore high temperature chemical conversions can occur at ambient conditions. The major objective of the project is to design, develop and test energy efficient sonochemical microreactors. A full understanding of the cavitation process and the development of methods to direct the energy towards the chemical are necessary to achieve this.

Progress

We achieved a more controllable and more efficient sonoreactor design using microfabrication techniques to modify the wall surface of a sonoreactor of the ultrasonic bath type. Simulations were carried on in order to estimate the radical production in different configurations. By fitting the PDF's of the radii from experiments and from simulations, an estimate of the effective forcing pressure felt by the bubble cloud was found. These values were much lower than the ones measured with the hydrophone. Simulations also allowed us to describe the temporal evolution of the small undetectable bubbles and to show that the most OH radical production came from them. We found that the calculated chemical rate raised monotonically with the effective pressure but not always with the applied power, as it also depended on the specific PDF's of the radii. Further comparison between predictive models for radical production were also carried on.

Dissertations

-

Projectleaders

D Lohse, JGE Gardeniers (MCS), JTF Keurentjes TUe (SPD)

Researchtheme

Complex dynamics of fluids

Participants

D Fernandez Rivas, L Stricker

Cooperations

A Prosperetti (Johns Hopkins University, Baltimore)

Funded

STW

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

Start of the project

2006

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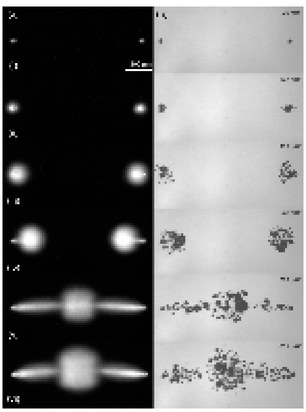
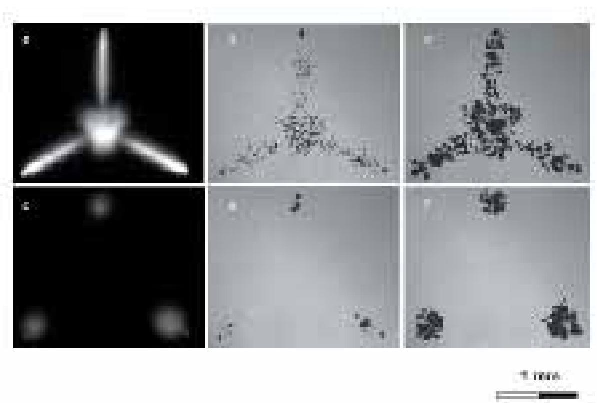
Scientific Publications

1. Stricker L, Prosperetti A, Lohse D.,"Validation of an approximate model for the thermal behavior in acoustically driven bubbles", J Acoust Soc Am., 2011 Nov.



Bubble clouds originating from a two-pits substrate. Each row corresponds to a progressive increase in acoustic amplitude. The left column illustrates the time averaged extent of the cavitation cloud imaged at normal speed. The right column are single snapshots of 7 ns exposure time.



Images of a substrate with three pits at different powers and at two selected points in the acoustic cycle. Visible with normal illumination conditions (a and d for high and low power) and short exposure. Corresponding images: b and e in the compression; c and f in the expansion phase of the acoustic cycle.

Nanocapsules and superheated nanodroplets for targeted contrast-enhanced imaging

Projectleaders
M Versluis, D Lohse

Researchtheme
Complex dynamics of fluids

Participants
E Gelderblom, O Shpak, G Lajoinie

Cooperations
B. Fowlkes, University of Michigan, Ann Arbor, USA; N. Reznik, University of Toronto, Toronto, Canada; N. de Jong, ErasmusMC, Rotterdam, The Netherlands

Funded
FOM, NanonextNL, UTwente

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

Start of the project
2010 + 2011

Information
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Project Aim

Microcapsules and nanodroplets are under investigation for their use as contrast agents in medical ultrasound imaging. The aim is to design and characterize various agents that are small enough for extravasation and display a strong acoustic backscatter for the applied ultrasound field. Functionalized liquid emulsion perfluorocarbon (PFC) nanodroplets also have great potential for molecular imaging and local drug delivery. Polymeric ultrasound agent microcapsules were found to be highly susceptible to laser irradiation, and may function as a multimodal contrast agent for photoacoustic imaging and ultrasound imaging alike.

Progress

The ultrasound-triggered vaporization of submicron and micron-sized droplets was visualized at frame rates up to 20Mfps providing new insights into the physical mechanisms of droplet vaporization. The dynamics of the vapor bubble demonstrates a combined contribution from thermal effects and inertia. Nucleation sites inside the droplets undergo vaporization/condensation cycles in phase with the applied ultrasound. Fluorescent dyed polymeric microcapsules were characterized for both pulsed and continuous laser irradiation, by combined acoustical and high-speed bright-field/fluorescence optical recordings. The underlying physical process was revealed and modeled which allows for future developments in optimization and further size reduction towards nanocapsules.

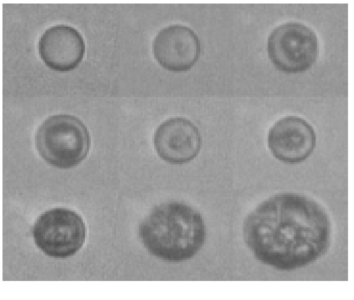
Dissertations

-

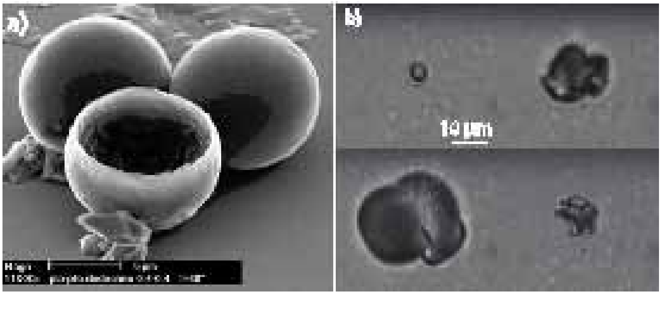
Scientific Publications

1. D. Lensen, E. Gelderblom, D. Vriezema, P. Marmottant, N. Verdonschot, M. Versluis, N. de Jong and J. van Hest, Biodegradable polymeric microcapsules for selective ultrasound-triggered drug release, Soft Matter 7, pp. 5417-5422 (2011).

From left to right and top to bottom: nucleation and vaporization of a 4 μm radius perfluoropentane droplet under ultrasound excitation imaged at 18.9 MHz frame rate



a) SEM image of the fluorescent microcapsules with a 600nm polymer shell; b) pulsed laser response showing the aporization/recondensation event occuring within 1μ



PROJECT AIM

Surface cleaning is accomplished by fluid mechanical forcing, often assisted by chemical and acoustical activation. Examples include the removal of nanoparticles from IC semiconductor substrates and the disruption of bacterial biofilms in dentistry. The presence of bubbles is known to greatly enhance the cleaning efficiency as it promotes mixing of the chemicals and it yields higher stresses through acoustic streaming and jetting following asymmetric collapse of the bubbles. With smaller nanofabricated structures and more delicate surgical therapies, there is a growing demand for precision cleaning with minimum damage to the surrounding media.

PROGRESS

Here we explore the concept of micro-machined cylindrical pits acting as cavitation nuclei for a continuous source of microbubbles, thereby localizing the cavitation phenomena and suppressing its inherent chaotic nature. The micropit bubble was found to be stable against dissolution, and the resonance behavior of surface mode vibrations of the cap was modeled with the unsteady Stokes equation combined with a Fourier-Bessel expansion. Above a pressure threshold, destabilization of the micromeniscus results in bubble pinch-off which was studied using high-speed imaging down to nanoseconds timescales. It was also found that the acoustic coupling and merging of cavitation clouds from neighboring micropits increasingly promote acoustic surface cleaning.

DISSERTATIONS

1. A.G. Zijlstra, “Acoustic Surface Cavitation”, PhD Thesis, University of Twente, Septeember 2, 2011. Promotor: D. Lohse.

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS

M Versluis, A Prosperetti, D Lohse

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

A Zijlstra

COOPERATIONS

P Mertens, D Fernandez- Rivas, H Gardeniers

FUNDED

IMEC

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

START OF THE PROJECT

2007

INFORMATION

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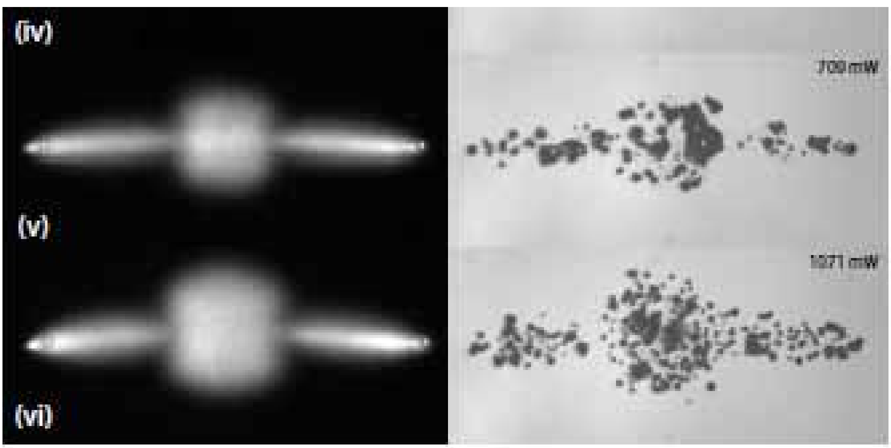

Projectleaders
M Versluis, D Lohse
Researchtheme
Complex dynamics of fluids
Participants
T Segers, W van Hoeve
Cooperations
Bracco, St. Antonius Ziekenhuis Nieuwegein
Funded
MicroNed, NanoNextNL

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

Start of the project
2011
Information
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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. The sorting approach can also be used to count bubbles to obtain in-line size distribution of microbubbles in the cardiopulmonary bypass machine during open heart surgery.

Progress

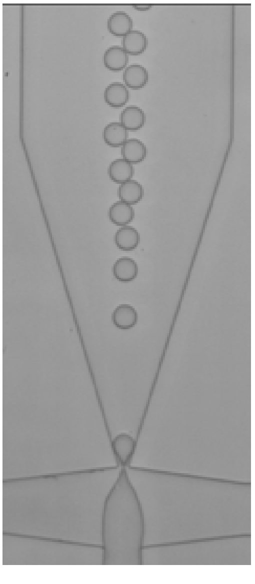
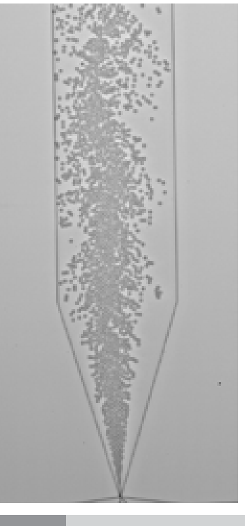
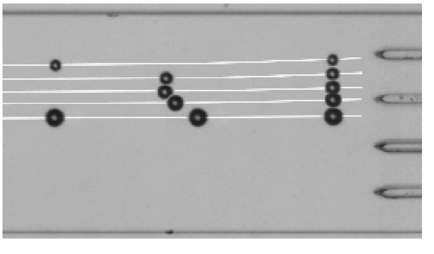
A lab-on-a-chip device capable of sorting microbubbles was developed. Bubbles are manipulated by primary radiation forces. The bubbles resonant to the applied ultrasound field are sorted from a suspension with a wide size distribution.

Dissertations

1. W. van Hoeve, “Fluid dynamics at a pinch: droplet and bubble formation in microfluidic devices”, PhD Thesis, University of Twente, 2011. Promotor; D. Lohse.

Scientific Publications

1. E. de Castro-Hernández, W. van Hoeve, D. Lohse, J. M. Gordillo, “Microbubble generation in a co-flow device operated in a new regime”, Lab on a Chip, 11, 2023-2029, 2011.
2. W. van Hoeve, B. Dollet, J. M. Gordillo, M. Versluis, L. Van Wijngaarden, D. Lohse, ”Bubble size prediction in co-flowing streams”, Europhysics Letters, 94, 64001, 2011.
3. W. van Hoeve, B. Dollet, M. Versluis, D. Lohse, “Microbubble formation and pinch-off scaling exponent in flow-focusing devices”, Physics of Fluids, 23, 092001, 2011.

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.

Viscosity of confined liquids

Project Aim

The goal of the project is to understand the dissipative properties of thin liquid films confined between two solid surfaces at a distance of order nanometer. We want to understand to what extent nano-effects alter the behavior of fluids as compared to simple downscaling of continuum hydrodynamic effects. This problem is studied using a combination of experiments (Atomic Force Microscopy) and numerical (Molecular Dynamics - MD) simulations. The focus will be on simple liquids, such as Lennard-Jones like fluids on chemically inert substrates.

Progress

Progress in 2011 was obtained on the numerical part of the project. Together with Prof. Briels and Dr. Wouter den Otter, MD simulations of confined Lennard-Jones fluids were carried out in a geometry mimicking the one of the AFM experiments. A novel method was developed in which we extracted the dissipation due to the fluid from the fluctuations of the force acting on the tip. In agreement with the experiments, we found pronounced maxima and minima of the dissipation as a function of gap width that correlate with the layered structure of the liquid. Gap widths leading to a more disordered structure displayed stronger damping. Our results suggest that below a thickness of 3-4 molecular layers the material can no longer be described in terms of continuum hydrodynamic picture.

Dissertations

1. SJA de Beer, Probing the properties of confined liquids, prom. F Mugele & HTM van den Ende, 187 pp, 2011.

Scientific Publications

1. Confinement-dependent damping in a layered liquid. SJA de Beer, HTM van den Ende, F Mugele, Cond. Matt. 23 (112206), 1-4, 2011. Small amplitude atomic force spectroscopy. SJA de Beer, HTM van den Ende, D Ebeling, F Mugele in Scanning Probe Microscopy in. Nanoscience and Nanotechnology 2, pp 39, Ed Bhushan Bharat, Springer Verlag.

Projectleaders

F Mugele

Researchtheme

Complex structures of fluids

Participants

SJA de Beer, HTM van den Ende, F Mugele

Cooperations

-

Funded

FOM

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

Start of the project

2007

Information

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PROJECTLEADERS
F Mugele
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
CU Murade, K Mishra, I Roghair, HTM van den Ende, MHG Duits, F Mugele
COOPERATIONS
BP
FUNDED
BP, STW

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

START OF THE PROJECT
2011
INFORMATION
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PROJECT AIM

The aim of this project is to explore manipulation of liquid to achieve optical phenomenon such as micro lens array, optical switch/aperture and tunable optical display using electrowetting. Electrowetting has unique advantage over other liquid manipulating techniques, which is, one can change the shape of the liquid without using any moving or mechanical parts.

PROGRESS

I. We developed an unique design for the optical switch and optical aperture. Where in electrowetting is used to manipulate the liquid-liquid interface formed by the clear water and dye mixed oil. One can precisely control the optical aperture diameter as function of applied voltage and frequency. Due to its unique design the liquid-liquid aperture is free of Fraunhofer Diffraction, this carried unique advantage in the field of microscopy where in removing Fraunhofer Diffraction due to sharp aperture is great problem.

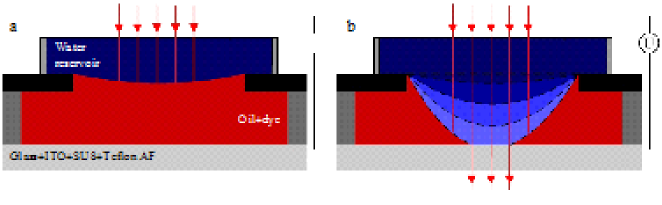
II. Development of high speed microlens array: With in this project we have developed unique fast microlens array using electrowetting and the pinned contact lines, microlenses can be modulated simultaneously up to 2 kHz and independently upto 20 kHz.

DISSERTATIONS

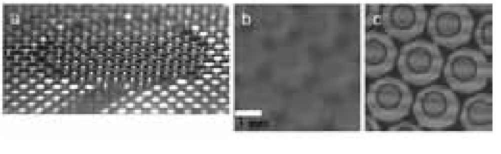
-

SCIENTIFIC PUBLICATIONS

1. Electrowetting driven optical switch and tunable aperture. CU Murade, JM Oh, HTM van den Ende, F Mugele, Optics Express, 19, 15525, 2011.
2. A microfluidic platform for on-demand formation and merging of microdroplets using electric control. H Gu, CU Murade, MHG Duits, F Mugele, Biomicrofluidics, 5(1), 011101, 2011.
3. Electrically assisted drop sliding on inclined planes. DJCM 't Mannetje, CU Murade, HMT van den Ende, F Mugele, Appl Phys Lett, 98(014102) 1-3, 2011.



Electrowetting Driven optical switch and aperture: Side View of the electrowetting driven optical switch and aperture. As the applied voltage between water reservoir and bottom electrode increases, water meniscus deflects towards the bottom electrode eventually touching the bottom electrode, which gives rise to a water tunnel through which light can pass.



High speed liquid microlens array: (a) presents a tilted view of the microlens array, (b-c) imaging ability of the microscles array upto 2 kHz.

PROJECT AIM

The aim of this (now concluded) project was is to explore the combination of ElectroWetting technology and droplet-based Two Phase Flow platform, which should bring the advantages of both worlds together: (i) high throughput (from pressure-driven channel-based TPF) and (ii) precise control over each individual droplet (from EW). To achieve this goal, different approaches and microfabrication technologies were to be explored. Also the (potential) functionalities of such chips had to be demonstrated.

PROGRESS

We developed a microfluidic chip capable of measuring interfacial tensions between two liquids, directly from a force balance. This was achieved using a tapered microchannel, which offers a range of possible interface curvatures. The mechanical equilibrium position along the channel , depends on the interfacial tension, the contact angles with the channel walls, and externally controllable pressures. Using a device of PDMS with a channel height of 50 μm and a width tapering from 300 to 20 μm, interfacial tensions (IFTs) could be measured between 3 and 38 mN/m. Quantitative agreement with macroscopic measurements was obtained, albeit that in the absence of surfactant, pinning forces played a role. We demonstrate of our device for measuring IFTs that change over time, due to a slow adsorption at the interface. Our device should be especially suitable for studying the formation of interfacial layers for different compositions of the continuous phase.

DISSERTATIONS

1. H. Gu, Controlling two-phase flow in microfluidic systems using electrowetting, pro. F. Mugele & MHG Duits, 128 pp., 2011.

SCIENTIFIC PUBLICATIONS

1. A microfluidic platform for on-demand formation and merging of microdroplets using electric Control. H Gu, CU Murade, MHG Duits, F Mugele, Biomicrofluidics, 5(1), 011101, 2011.
2. Droplets formation and merging in two-phase flow microfluidics. H. Gu, MHG Duits, F Mugele, Int J Mol. Sci, 12, 2572, 2011.
3. Interfacial tension measurements with microfluidic tapered channels. H Gu, MHG Duits, F Mugele, Coll. & Surf. A, 389(1-3), 3842, 2011.

PROJECTLEADERS

F Mugele

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

H Gu, MHG Duits, F Mugele

COOPERATIONS

-

FUNDED

MicroNed

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

START OF THE PROJECT

2006

INFORMATION

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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, OTB

Funded
HIPRINS

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

Start of the project
2009

Information
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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. This forms a so-called “dimple” that is expected to influence the subsequent impact of the droplet. We use nanometer- and microsecond resolved dual wavelength interferometry to quantitatively describe the complex evolution of the interface between the drop and the gas layer underneath. For intermediate impact speeds the layer thickness can develop one or two local minima – reproduced in numerical calculations – while the transition between these two regimes at We ~1 suggests that capillary forces play an important role in shaping the interface. Eventually, nucleation of solid-liquid contact is obtained at a local minimum, from a remarkably large film thickness > 200 nm. Solid-liquid contact spreads at a speed that is independent of time, and involves effects of both capillarity, liquid viscosity and inertia.

Dissertations

-

Scientific Publications

1. Drops on functional fibers: from barrels to clamshells and back, H.B. Eral, J. de Ruiter, R. de Ruiter,J.M. Oh, C. Semprebon, M. Brinkmann, F. Mugele. Soft Matter 7 (2011) 5138.

Formation and stability of (mono)layers under varying pH and salt concentration

Project Aim

We want to understand the effects of cations on the oil film adsorbed onto rock surface with the model of fatty acid, Silica/mica. This fundamental issue is critical in enhanced oil recovery and also have potential applications in biomedical areas. Formation and stability of fatty acids layer will be addressed with techniques such as Langmuir trough, ellipsometry. Besides, compositions of the layer will also be analyzed.

Progress

Pressure-area isotherms on subphases with varying salt concentrations and pH values were obtained from Langmuir trough. Fatty acids monolayers were transferred onto solid substrates. Thickness and homogeneity of the film were analyzed with Ellipsometry.

Dissertations

-

Scientific Publications

-

Projectleaders

F Mugele

Researchtheme

Complex structures of fluids

Participants

AM Brzozowska, L Wang, MHG Duits, F Mugele

Cooperations

BP

Funded

BP

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

Start of the project

2009

Information

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PROJECTLEADERS
F Mugele
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
D Ebeling, N Kumar, 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
2009
INFORMATION
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PROJECT AIM

To study the stability of Langmuir-Blodgett films of stearic acid transferred to silica and mica surfaces upon exposure to water having different salt concentrations. We want to study the role of divalent cations in stabilization of such LB films.

PROGRESS

We study the stability of Langmuir-Blodgett (LB) films of stearic acid transferred to silica surfaces upon exposure to water in ambient air and in ambient oil. LB films are transferred from an aqueous subphase of slightly elevated pH containing either NaCl, CaCl2 , and mixtures of both salts. Microscopic characterization using Atomic Force Microscopy reveals that LB films deposited in the presence of Na+ cations only are highly unstable and are easily removed from the surface upon exposure to water. In contrast, films transferred in the presence Ca2+ are more stable. Also, Electrostatic interactions forces were measured in aqueous salt solutions of variable concentration and valency. Dynamic force spectroscopy was employed which allowed the usage of sharp AFM tips and gives better lateral resolution than the standard techniques.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Electrostatic interaction forces in aqueous salt solutions of variable concentration and valency. D Ebeling, HTM van den Ende, F Mugele, Nanotechnology, 22, 305706, 2011.
2. Small amplitude atomic force spectroscopy. SJA de Beer, HTM van den Ende, D Ebeling, F Mugele in Scanning Probe Microscopy in Nanoscience and Nanotechnology 2, pp 39, Ed Bhushan Bharat, Springer Verlag.

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 use the Generalised Stokes Einstein relation to calculate the viscoelastic properties of the suspensions from the Mean Squared Displacement (MSD) of tracer particles around the jamming transition. We also probe the mobility of tracer particles using optical tweezers around the jamming transition. A ratio of Diffusivity (obtained from passive measurements) and Mobility (obtained from active measurements) yields an effective temperature(T_{eff}) which is analogous to the ´Granular Temperature´ in granular matter theory. We intend to check if this T_{eff} deviates from the thermodynamic temperature.

Progress

This year we spent on setting up the optical tweezer set-up. It involved modifications to the current setup like including a temperature controlling unit, re-designing the flow cell etc. Since our particles are thermosensitive, we control the volume fraction of our system by controlling the temperature. The original flow cell assembly on the opitical tweezer did not have the temperature control. We had to redesign the flow cell to mount it on the Delta-T temperature control dishes. We characterized the setup by measuring the trap stiffness of polystyrene particles trapped in a known surrounding medium i.e. water. We also measured the change in power spectral density (PSD) and the trap stiffness as a function of the laser power and the size of the trapped particle. We also synthesized the thermosensitive Poly N Isopropyl Acrylamide (PNIPAM) microgel particles which we use to make the suspensions.

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

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Contact line dynamics under electric fields

Projectleaders
F Mugele
Researchtheme
Complex dynamics of fluids
Participants
DJCM 't Mannetje, 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
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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 investigated the speed dependence of contact line motion in relation to contact angle hysteresis. We apply AC Electrowetting to suppress this hysteresis and pinning effects. At low velocities, the dynamics of the contact line behavior under AC Electrowetting is described as stick-slip motion, rather than a continuous movement. At high velocities a transition to a slipping regime is observed. The transition from stick-slip to sliding is described by a simple physical model.

Dissertations

-

Scientific Publications

1. Electrically assisted drop sliding on inclined planes. DJCM 't Mannetje, CU Murade, HTM van den Ende, F Mugele, Appl Phys Lett 98, 014102, 1-3, 2011.

PROJECT AIM

To develop an in situ microrheometer for lab on a chip purposes. This rheometer will be based on electroosmotic flow. By controlling the surface potential of opposite channel walls with external gate electrodes, a shear flow with variable strength can be created. The velocity gradient will be measured by particle tracking, while the driving shear stress can be calculated from the given surface potentials.

PROGRESS

In the first part of the project, the above mentioned device was realized, but the range of obtainable shear stresses was quite limited. Moreover the due to chemical equilibrium near the surfaces the resulting surface charge are hard to control, so in the second part of the project we concentrated on droplet based digital microfluidics. The motion and deformation of individual droplets under influence of AC electric fields was studied. For sandwiched drops this resulted in a new mixing scheme based on symmetry breaking due to contact line imperfections. This symmetry breaking was further studied for sessile drops by controlling the contact line imperfections via artificial pinning sites. These investigations resulted in an improved homogeneous drying of samples drops used in MALDI MS (matrix assisted laser desorption and ionization mass spectroscopy) analysis.

DISSERTATIONS

1. D Mampaillil Augustine, Microfluidic flow driven by electric fields, prom. F Mugele & HTM van den Ende, 175 pp, 2011.

SCIENTIFIC PUBLICATIONS

1. Controlling flow patterns in oscillating sessile drops by breaking azimuthal symmetry. D. Mampallil Augustine, HTM van den Ende, F Mugele, Appl. Phys. Lett, 99, 154102, 2011.
2. Suppressing the coffee stain effect: how to control colloidal self-assembly in evaporating drops using electrowetting. HB Eral, D. Mampallil Augustine, MHG Duits, F. Mugele, Soft Matter, 7, 4954, 2011.

PROJECTLEADERS

F Mugele

RESEARCHTHEME

Complex structures of fluids

PARTICIPANTS

D Mampallil Augustine, HTM van den Ende, F Mugele

COOPERATIONS

-

FUNDED

MicroNed network

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

START OF THE PROJECT

2007

INFORMATION

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PROJECTLEADERS
F Mugele, HTM van den Ende
RESEARCHTHEME
Complex structures of fluids
PARTICIPANTS
HTM van den Ende, O Deshmukh
COOPERATIONS
-
FUNDED
FOM

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

START OF THE PROJECT
2009
INFORMATION
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PROJECT AIM

We want to understand how confinement and wetting phenomenon alters the soft matter. This underexplored area in physical chemistry touches several fundamental issues and has potential for applications ranging from colloids in microfluidic chips to oil recovery. The question: How does transport and mechanical properties under confinement and under externally controlled wetting? will be addressed with techniques such as Confocal Microscopy, Particle tracking and microfluidic methods.

PROGRESS

We have shown that the geometry and contact angle play an important role in determining the mechanical stability of droplets on fibers. We have discovered a previously overlooked bistability regime in the classic drop on a fiber morphology. Furthermore, the developed technique allows for studying a unique set of wetting problems. In a development that branched out of the previously mentioned technique, PCF group developed a method to suppress undesirable pattern formation in evaporating droplets so called coffee stains.

DISSERTATIONS

1. HB Eral, Colloidal suspensions under external control, prom F Mugele & MHG Duits, 214 pp, 2011.

SCIENTIFIC PUBLICATIONS

1. Colloidal dynamics near a particle-covered surface. HB Eral, F Mugele, MHG Duits, Langmuir 27(20), 12297, 2011.
2. Drops on functional fibers: from barrels to clamshells and back. HB Eral, J de Ruiter, R de Ruiter, JM Oh, C Semprebon, M. Brinkmann, F Mugele, Soft Matter, 7(11), 5138, 2011.
3. Suppressing the coffee stain effect: how to control colloidal self-assembly in evaporating drops using electrowetting. HB Eral, D. Mampallil Augustine, MHG Duits, F. Mugele, Soft Matter, 7, 4954, 2011.
4. Wetting of a drop on a sphere. HB Eral, G Manukyan, JM Oh, Langmuir 27(9), 5340-5346, 2011.
5. Charge injection from carbon nanofibers into hexane under ambient conditions A Agiral, HTM van den Ende, HB Eral, JGE Gardeniers, IEEE electron device letters, 58(10) 3514, 2011.

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.

Progress

1) A chip consisting of nanochannels has been designed and fabricated. Our current focus is on instrumentation particularly on optimization of setup for studying the effect of confinement on phase equilibrium and evaporative processes.

2) A preliminary study on hydrophobization of flat Si-SiO2 terminated surfaces and 10's micron inner diameter capillaries has been conducted to test the hydrophobization procedure.

Dissertations

-

Scientific Publications

-

Projectleaders

F Mugele

Researchtheme

Complex structures of fluids

Participants

D Tiwari, MHG Duits, F Mugele

Cooperations

-

Funded

NWO CW

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

Start of the project

2010

Information

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Imbibition of water into oil-filled microchannels with complex wall properties

Projectleaders
F Mugele

Researchtheme
Complex structures of fluids

Participants
D Mampallil Augustine, HTM van den Ende

Cooperations
-

Funded
MicroNed network

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

Start of the project
2007

Information
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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. In this project, we will address these issues by generating 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 investigated the effect of gravity on the morphological transitions between the axisymmetric barrel and asymmetric clamshell states of drops on cylindrical fibers. As the capillary length is decreased, both transitions gradually shift to smaller contact angles. The clamshell regime is bounded at large drop volumes by the detachment criterion.
- We are developing a microfluidic trap in which drops are captured. The drops will be released on demand by application of electrowetting.
- We are designing microchannels with variable resistance by incorporation of (electrically) switchable superhydrophobic surfaces..

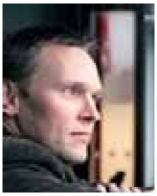
Dissertations

-

Scientific Publications

1. Influence of cationic composition and pH on the formation of metal stearates at oil-water interfaces. R. de Ruiter, R.W. Tjerkstra, M.H.G. Duits, F. Mugele, Langmuir 27 (2011) 8738-8747.
2. Drops on functional fibers: from barrels to clamshells and back. H.B. Eral, J. de Ruiter, R. de Ruiter, J.M. Oh, C. Semprebon, M. Brinkmann, F. Mugele, Soft Matter. 11 (2011), 5138-5143.

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.

New fabrication technologies for omniphobic surfaces

Project Aim

The industrial aim of this project is the development of new production techniques for the generation of omniphobic surfaces. Omniphobic surfaces are characterized by a strong degree of repellent behaviour towards all liquids, even low surface tension liquids like oils. Such surfaces have numerous possible applications, for example as self-cleaning surfaces or for the improvement of lubricated systems. To obtain such effect a special surface roughness is required in combination with very low surface tension solid materials. The required surface texture is characterized by relatively high aspect ratio structures on a micro and a nano scale.

Progress

To obtain omniphoic surface one should have a surface with re-entrant texture. We choose PDMS as a main material to make omniphobic surfaces. The advantage of our choice is that PDMS is highly flexible i.e. micro posts made of PDMS can easily bend. This property allows us to make re-entrant texture in one step: by only replicating the metal mould with deep (~100μm) micro pits. Replicated PDMS pillars bend creating overhanging features. Without additional surface treatment this surfaces already exhibit omniphobic properties. For Ethylene glycol we achieve contact angles ~1400 - 1450 whit contact angle hysteresis ~300. To improve the omniphobicity of the surface one should improve also the chemical composition of the microstructure i.e coating the PDMS pillars with low surface tension polymers or self-assembly monolayer. We used hydrophobized particles Al2O3 with ~35nm and ~800nm diameter) to reduce the surface tension of the microstructure.

Dissertations

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Scientific Publications

-

Projectleaders

RGH Lammertink

Researchtheme

Complex dynamics of fluids

Participants

-

Cooperations

LIghtmotif

Funded

M2i

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

Start of the project

2011

Information

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Meander reactor

Projectleaders
L Lefferts, JGE Gardeniers, RGH Lammertink

Researchtheme
Complex dynamics of fluids

Participants
Elif Karatay, Chris Reed

Cooperations
-

Funded
NWO / Poac

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

Start of the project
2009

Information
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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.

Progress

PVDF membrane integrated G/L contacting experiments with the produced glass chips is finished. Research on apparent slippage formation via micro-PIV experiments using the G/L contacting on a bubble mattress concept. For the removal of ionic species at over-limiting currents, the fabrication of glass-glass micro-devices are done using cleanroom facilities.

Dissertations

-

Scientific Publications

-

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

Using the Finite Element implementation of the Optimized Variational Bousinesq Model it was shown by comparison with MARIN experiments that uni-directional wind waves could be simulated accurately (publication accepted for 2012). For the 2D version, comparison with the Berkhoff experiment showed good shoaling properties. The practical use for harbor simulations was shown. The AB-model was extended to bi-directional waves in 1D and 2D. In the project on effective boundary conditions we prepared a publication on 1D simulations with a Variational Boussinesq Model.

Dissertations

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Scientific Publications

1. D. Adytia and E. van Groesen, The variational 2D Boussinesq model for wave propagation over a shoal, International Conference on Developments in Marine CFD, 18 - 19 November 2011, Chennai, India; RINA, ISBN No : 978-1-905040-92-6, p.25-29.
2. E. van Groesen, T. Bunnik & Andonowati, Surface wave modelling and simulation for wave tanks and coastal areas, International Conference on Developments in Marine CFD, 18 - 19 November 2011, Chennai, India, RINA, ISBN: 978-1-905040-92-6, p. 59-63.

Projectleaders

EWC van Groesen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

I Lakhturov, D Adytia, W Kristina, Andonowati

Cooperations

LabMath-Indonesia, Bandung Indonesia, MARIN Wageningen

Funded

UT, STW, NWO-ALW

University	25 %
FOM	-
STW	20 %
NWO Other	50 %
Industry	-
TNO	-
GTI	5 %
EU	-
Scholarships	-

Start of the project

2003

Information

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Generation of deterministic extreme waves in hydrodynamic laboratories

Projectleaders
EWC van Groesen
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
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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
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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

Third and fourth order AB equations in 1D have been derived; the 3th order code gives improved results, but not 4th order. The numerical implementation of the linear 2D Hamiltonian AB-equation has finished; hard walls (in a spectral implementation) are now being tested. Research on the characterization and prediction of freak waves using phase information has led to the unexpected discovery of freak waves in wind-wave experiments of MARIN. Not nonlinear effects modeled by the Benjamin-Feir instability but linear interference is found to be responsible for the extreme waves of more than 2.5 times the significant wave height. This leads to good results for prediction with a linear method over many wavelengths. Additional freak wave experiments were performed in a TUD-wave tank.

Dissertations

-

Scientific Publications

1. E. van Groesen & Andonowati, Fully dispersive dynamic models for surface water waves above varying bottom, Part 1: Model equations, Wave Motion 48 (2011) 657-666.
2. I. Lakhturov & E. van Groesen. Optimized Variational 1D Boussineq modelling for broad-band waves over flat bottom, Wave Motion, http://dx.doi.org/10.1016/j.wavemoti.2011.11.004.
3. E. van Groesen & Andonowati, Time-accurate AB-simulations of irregular coastal waves above bathymetry, Proceedings of the Sixth International Conference on Asian and Pacific Coasts (APAC 2011) December 14 – 16, 2011, Hong Kong, China, World Scientific ISBN: 978-981-4366-47-2, pp.1854-1864.

Numerical Analysis and Computational Mechanics

Prof.dr.ir. JWW van der Vegt

Prof.dr. HJH Clercx

Prof.dr.ir. BJ Geurts

Prof.dr.ir. JGM Kuerten

The research in the Numerical Analysis and Computational Mechanics (NACM) 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 a novel space-time (dis)continuous Galerkin method 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 (fig.1).

Progress

A variational finite element method based on Miles' variational principle has been developed for nonlinear free-surface waves. The method gives a space-time discretization. Resulting numerical scheme conserves discrete energy and shows no amplitude decay. The method is accommodated with the wave maker movement and validated against experimental data. We are extending this numerical model to incorporate a discretization of Luke's variational principle. Consequently, more versatile nodal movement is required. Also this year we perform the BSS experiment, which consists of the following. Opening a sluice gate in an initially still wave channel creates two solitons. The front soliton breaks and becomes a bore shortly. When the bore and soliton interact in the converging V-shaped channel end a large splash is generated (fig1). We have compared the experiment to SPH simulations (fig 2).

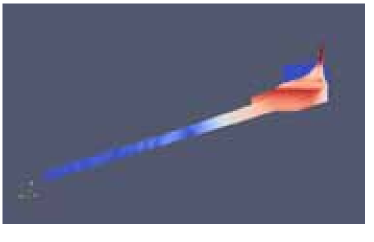
Dissertations

-

Scientific Publications

1. Onno Bokhove, Elena Gagarina, Wout Zweers, Anthony Thornton (2011): Bore Soliton Splash - van spektakel tot oceaangolf? Ned. Tijdschrift voor Natuurkunde. Popular science version in Dutch. 77/12, 446-450.

The Bore–Soliton–Splash experiment. The height of the jet is 3.5 – 4 m.



Smooth particle hydrodynamics (SPH) simulation of the BSS. The initial section is a 2D periodic channel coupled with 3D V-shaped contraction. The vertical jet appears at the converging border.

Projectleaders

O Bokhove, JJW van der Vegt

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Nurijanyan, E Gagarina, VR Ambati

Cooperations

A Thornton, M Robinson
MARIN, NIOZ, Delft Hydraulics, Alkyon Hydraulic Consultancy & Research, and TU Delft Marine Technology

Funded

STW

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

Start of the project

2008

Information

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BSS
www.woutzweers.nl/text%202010/2010%20soliton%20splash.html
or see youtube channel
http://www.youtube.com/user/BoreSolitonSplash

Aerosol particle motion in porous media

Projectleaders
BJ Geurts

Researchtheme
Mathematical and computational methods for fluid flow analysis

Participants
L Ghazaryan

Cooperations
Philip Morris International – Dr. Arkadiusz Kuzcaj
University of Twente – Dr. Steffen Stolz

Funded
Philip Morris International

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

Start of the project
2008

Information
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Project Aim

The target of the project is to understand aerosol particle dynamics in porous media. This is to be done by performing numerical simulations and analysis of aersol property evolution in complex geometry due to evaporation, condensation and (possible) collision.

Progress

A model for filtration of aerosol droplets by porous media due to impaction and diffusion was studied. This was done in the framework of Lagrangian particle tracking in a gas flow through porous media. The model was applied for structured porous media as well as for realistic porous filters, consisting of a bundle of slender fibers with rectangular cross-section. Filtration characteristics due to inertial and diffusive forces were studied and the filtration efficiency as a function of particle size and gas temperature was quantified. As a next step, removal efficiencies of several porous filters computed from our numerical simulations are being compared to available experimental data. Nucleation of aerosol droplets is to be included in the existing model.

Dissertations

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Scientific Publications

1. L. Ghazaryan , D.J. Lopez Penha, B.J. Geurts and S. Stolz. (2011) Physically consistent simulation of transport of inertial particles in porous media. In: Proceedings of the 4-th International Conference on Approximation Methods and Numerical Modelling in environment and Natural resources (MAMERN'11), 23-26 May 2011, Saidia, Morocco, p.393-396. ISBN 978-84-338-5230-4.

Clustering in turbulent droplet ensembles: the role of phase transitions

Project Aim

The main target of this project is to look at the influence of the presence of evaporating and condensating droplets on the properties of turbulent particle-laden channel flow, in particular, on the heat transfer within the channel. Moreover, the behaviour of the droplets themselves wll be studied, in particular, the effect of turbophoresis in case of phase transitions.

Progress

Firstly, the literature on turbulent channel flows with evaporating droplets was studied in order to choose the appropriate mathematical model. The model was formulated and implemented in an existing parallel DNS code for the turbulent flow. The next step is the influence of phase transitions on the flow and heat transfer properties.

Dissertations

-

Scientific Publications

-

Projectleaders

BJ Geurts

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Bukhvostova Anastasia

Cooperations

-

Funded

FOM

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

Start of the project

2011

Information

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PROJECTLEADERS
BJ Geurts

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
DJ Lopez Penha, BJ Geurts

COOPERATIONS
Philip Morris International R&D

FUNDED
Philip Morris International R&D

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

START OF THE PROJECT
2008

INFORMATION
DJ Lopez Penha
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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

A volume-penalizing IB method has been implemented to simulate the flow around arbitrarily shaped porous media extracted from computed-tomography imagery. The method has been extended for conjugate heat transfer predictions. Results are being processed for scientific publications.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

1. D.J. Lopez Penha, B.J. Geurts, S. Stolz, and M. Nordlund, Computing the apparent permeability of an array of staggered square rods using volume-penalization, Comput. Fluids 51 (2011) 157-173.

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 the 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 new 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

The numerical simulation of phase transitional flows is very challenging. It requires an accurate description of the physical phenomena at the interface between the 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 new 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.

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. J.G.M. Kuerten, Prof.dr.ir B.J. Geurts

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

2002

Information

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Mathematical analysis and classification of flow topologies in cerebral aneurysms

Projectleaders
BJ Geurts
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
J Mikhal
Cooperations
Prof. Dr. Ir. C. H. Slump
SAS Group, EEMCS Department, University of Twente
Funded
UT

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

Start of the project
2008
Information
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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. The whole process from medical imagery to the flow and stresses inside cerebral aneurysms is a long-term goal.

Progress

Work was focused on pulsatile flow in realistic cerebral aneurysms. In the immersed boundary method the geometry of an aneurysm and related vessels is represented by the so-called 'masking function', for which several strategies were considered: slightly bigger and slightly smaller 3d-geometries, which bound the original one from both sides. This results into a range of possible solutions, which gives an impression about the sensitivity of flow characteristics to uncertainties in the medical imagery. The paper about bounding solutions was published in NAW, as an invited publication after winning the Philips Wiskunde Prize 2011. Current attention is devoted to writing papers about the whole process: from medical images to the flow and stresses inside vessels. The pulsatile inflow was implemented and transitions in shear stress predictions are obtained as a function of Reynolds number. On the basis of these papers the PhD thesis will be completed in 2012.

Dissertations

-

Scientific Publications

1. Julia Mikhal, Bernard J. Geurts (2011). 'Bounding solutions for cerebral aneurysms' Nieuw Archief voor Wiskunde, 12(3). pp. 163-168.
2. Julia Mikhal, Bernard J. Geurts (2011). 'Pulsatile flow in model cerebral aneurysms'. In Proceedings of the International Conference on Computational Science, ICCS 2011. Singapore, 1-3 June 2011. pp.811 - 820. Procedia Computer Science 4. Elsevier.

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

During the first stage of the project a one-dimensional lubrication model was investigated for which a higher order accurate discontinuous Galerkin discretization was developed. This model was tested on a number of inkjet simulations, including breakup into droplets. The results look promising but further work is needed to improve the robustness of algorithm, in particular at the droplet boundaries.

Dissertations

-

Scientific Publications

1. W.E.H. Sollie, O. Bokhove, O. and J.J.W. van der Vegt, Space-time discontinuous Galerkin finite element method for two-fluid flows. Journal of computational physics, 230 (3). pp. 789-817, 2011.

Projectleaders

JJW van der Vegt

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

T Medvedeva, WEH Sollie, O Bokhove

Cooperations

-

Funded

HIPRINS

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

Start of the project

2011

Information

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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, O Bokhove

COOPERATIONS

Dr.ir. S. Rhebergen University of Minnesota, Mineapolis, USA

FUNDED

DIKTI Fellowship

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

START OF THE PROJECT

2009

INFORMATION

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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.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Multi-scale discrete and discontinuous Galerkin FEM for granular flows

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. 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

A shallow-layer model for granular flows on rough inclined channel with local contaction is now completed with macro-scale closure relations obtained from micro-scale DPM simulations of steady uniform flow. A thorough investigation was undertaken by Weihart et. al. to study the dependence of the closure laws on micro-scale parameters such as botton roughness and bottom friction. Validation of results using 2D shallow layer granular equations (DGFEM) and using micro-scale (DPM) model is in progress.

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, submitted August 2011.

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

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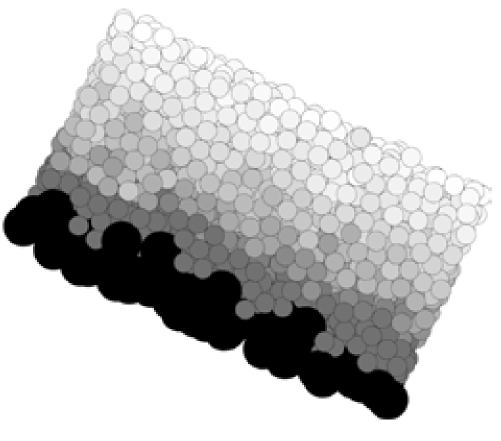
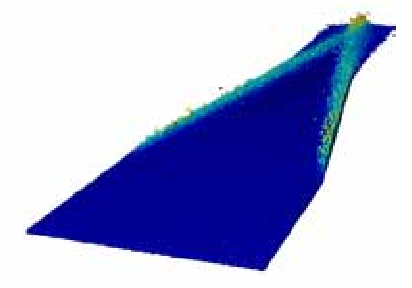
Steady uniform flow over a rough surface at inclination 25°. Shading indicated speed.





Steady flow through a contraction at inclination 19°, 400 000 particles. Shading indicated flow thickness..

Prof.dr.ir. HWM Hoeijmakers

Prof.dr.ir. A Hirschberg

Engineering Fluid Dynamics

Research within the group Engineering Fluid Dynamics deals with theoretical, numerical and experimental 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 methods 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 analytically.
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-swirling, condensing flows of mixtures of gases and liquids in complex geometries. Topics of interest are slipping 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 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. Flow control is developed for application to wind turbine blades and diffusors, 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 Lubrication. The theoretical research involves modeling, development of efficient numerical solution algorithms 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 aa well as the study of grease lubrication 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 therapeutic 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
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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

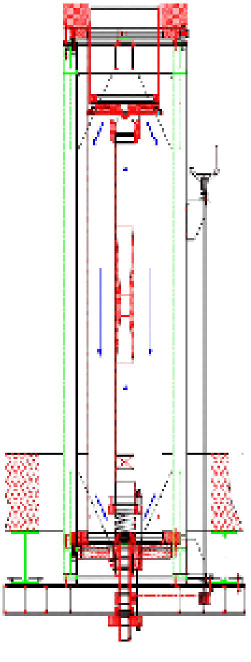
In 2011 further work has been carried out and publication of results has been realized. The Rotating Flow facility is being redesigned so that higher rotational speeds become possible.

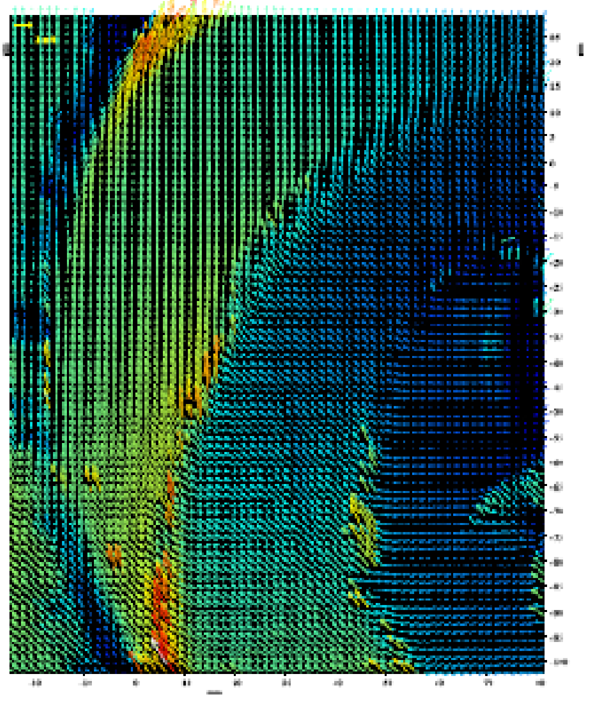
Dissertations

-

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

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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
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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

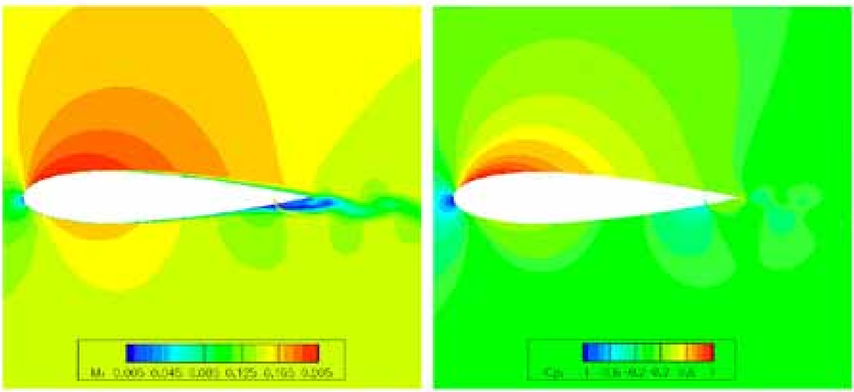
In 2011 the research into the application of flow control devices, such as synthetic jets as well as plasma actuators, on wind turbine rotor blades has continued, both experimentally and computationally. On the computational side of the research, the Unsteady Reynolds-averaged Navier-Stokes (URANS) method, 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 discretizations 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 prleminary investigation into plasma actuators has been performed.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. JAW Meijerink, HWM Hoeijmakers: Plasma Acr=tuators for Active Flow Control on Wind Turbine Blades. AIAA Paper 2011-3353, 18 pages.



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

The implementation of the overset block connectivity has been modified to improve the block connectivity in regions near curved surfaces. This was done by performing a correction of the interpolation point based on the wall distance considered from a different discretization of the same surface. Furthermore, a method for the construction of the Jacobian matrix has been implemented. This Jacobian matrix is required for solving the adjoint equations, which are used to compute the gradients of the objective function. Moreover, this Jacobian matrix is used in to obtain a steady flow solution, by applying Newton's method.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. J. A. Fike, S. H. Jongsma, J. J. Alonso, E. T. A. van der Weide, Optimization with gradient and Hessian Information Calculated using Hyper-Dual Numbers, 29th AIAA Applied Aerodynamics Conference, Honolulu, 2011.

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

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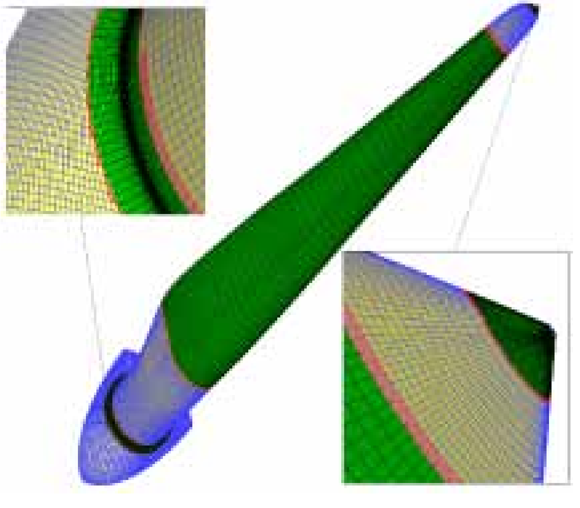

Surface grid on one blade and part of the nose cone, including zipper grid.

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
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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

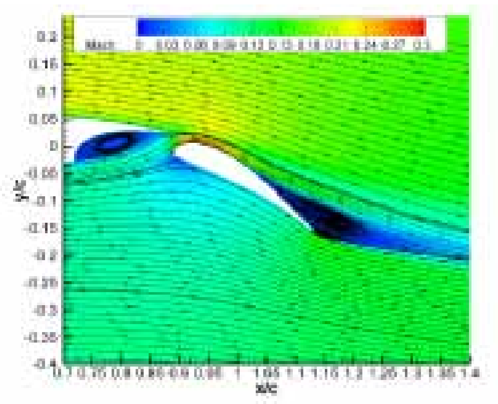
Surface boundary conditions representing the effect of the synthetic jet have been developed and applied to a NACA-0018 test case. The advantage of the surface boundary condition is that it is not required to model of the details of the synthetic jet itself, which reduces the computational complexity of the problem. Moreover an optimization for the position of the synthetic jets can be carried out much more easily. Furthermore, it was agreed that with the Dutch consortium a demonstrator will be built, for which such an optimization process is essential.

DISSERTATIONS

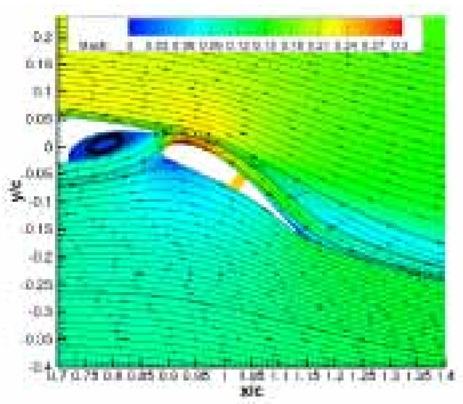
-

SCIENTIFIC PUBLICATIONS

-



Without flow control



With flow control

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

SNGR methods for the prediction of broad band noise of obstructions in a duct are considered. PIV experiments have been carried out at the LEA for verification of theoretical predictions. Publication of results is in prepoaration.

DISSERTATIONS

1. HCJ van Wijngaarden: Prediction of Propeller-Induced Hull-Pressure Fluctuations, Delft University of Technology. Supervisors: Prof.dr.ir. T.J.C. van der Terwisga and Prof.dr.ir. H.W.M. Hoeijmakers. ISBN 978-90-75757-00-2, November 25, 2011, 210 pages.

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS

HWM Hoeijmakers, A Hirschberg

RESEARCHTHEME

Complex dynamics of fluids

PARTICIPANTS

CH Venner, A Hirschberg HWM Hoeijmakers, ETA v.d. 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

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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
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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

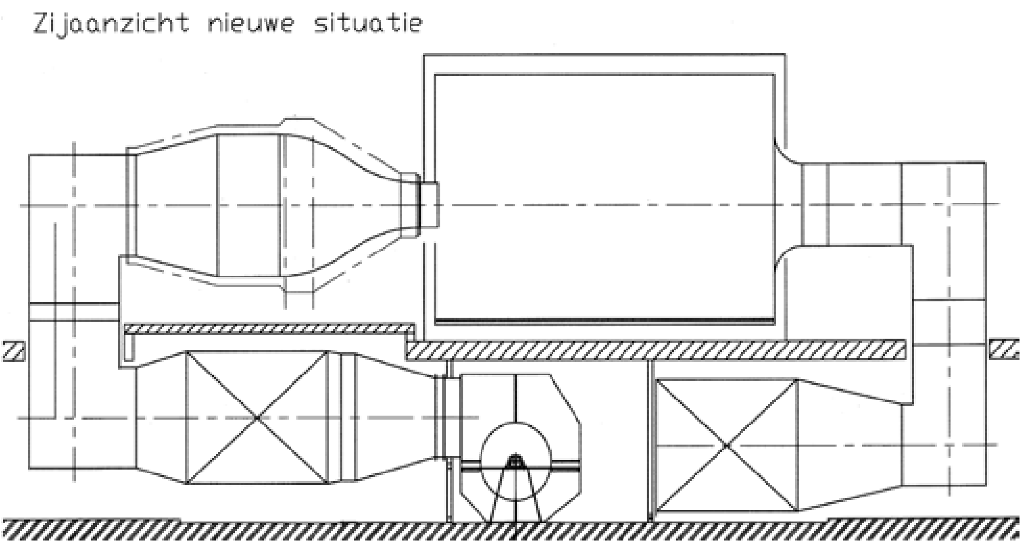
A. Mueller has finalized her PhD thesis (defense 20-1-2012). Publication of results is in preparation.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. G Nakiboglu, SPC Belfroid, J Golliard, A Hirschberg: On the Whistling of Corrugated Pipes: Effect of Pipe Lengt and Flow Profile. JFM, 2011, Vol. 672,b pp. 78-108.
2. WFJ Olsman, JFH Willems, A Hirschberg, T Colonius, RR Trieling: Flow around a NACA0018 Airfoil with a Cavity and its Dynamical Response to Acoustic Forcing. Exp. Fluids, 2011, Vol. 52, No. 2, pp. 493-509.
3. D Tonon, A Hirschberg, J Golliard, S Ziada: Aeroacoustics of Pipe Systems with closed Side Branches. Int. J. Aeroacoustics, 2011, Vol. 10, No. 2, pp. 201-276.



Efficient solution methods for N-component condensation

Project Aim

The project aimes at improving and advancing the modeling of flows with condensation, in view of gas conditioning by selective condensation. On the one hand the most accurate model based on the Becker-Doring equations is solved for reference purposes, and on the ather hand reduced models based on the Fokker-Planck equation are investigated to develop fast and yet accurate methods to be used in applications. The investigation addresses both single component as well as multi-component condensation. In addition a so-called flash model for equilibrium condition has been developed.

Progress

The project has been completed on 14 October 2011, and led to three scientific publications in J. Chem. Phys., and a fourth manuscript will be submitted shortly.

Dissertations

1. D.S. van Putten, "Efficient Solution Methods for N-Component Condensation", PhD-thesis, University of Twente, 14 October 2011.

Scientific Publications

1. D.S. van Putten, S.P. Glazenborg, R. Hagmeijer, C.H. Venner, A multigrid method for N-component nucleation, J. Chem. Phys. 135 (2011).

Projectleaders

R Hagmeijer

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

DS van Putten, R Hagmeijer, HWM Hoeijmakers

Cooperations

Twister BV

Funded

Twister BV

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

Start of the project

2008

Information

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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
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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

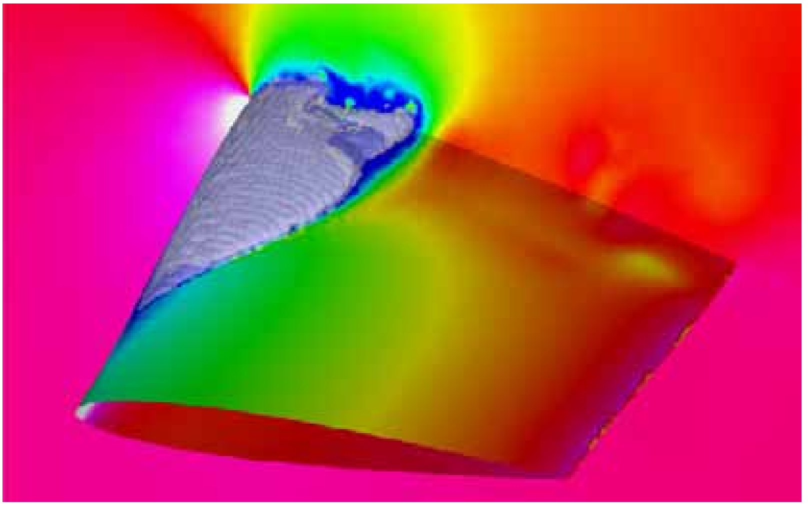
An unstructured-grid Euler method for compressible flow has developed for flows with cavitation. The method assumed the liquid and the vapor to be compressible and the liquid-vapor mixture to be in mechanical and thermal equilibrium. Various upwind schemes have been implemented. Results show that the 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 2010 a new project has been defined (MIP-IOP) on vortex cavitation that has been granted. It will start in 2011.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-



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

A thorough analysis of the earlier work carried out by AH Koop showed a severe computational bottleneck in the computation of the thermodynamic relations, needed to close the set of governing equations. It was decided to use thermodynamic tables instead, which can speed up the computation by a factor of 10. Furthermore, the low dissipation numerical schemes (needed for the accurate solution of LES), were used for a couple of test cases defined by the AIAA workshop. The results of these computations were presented at this workshop and showed that the schemes behave as designed for these cases.

Dissertations

-

Scientific Publications

-

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

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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
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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.

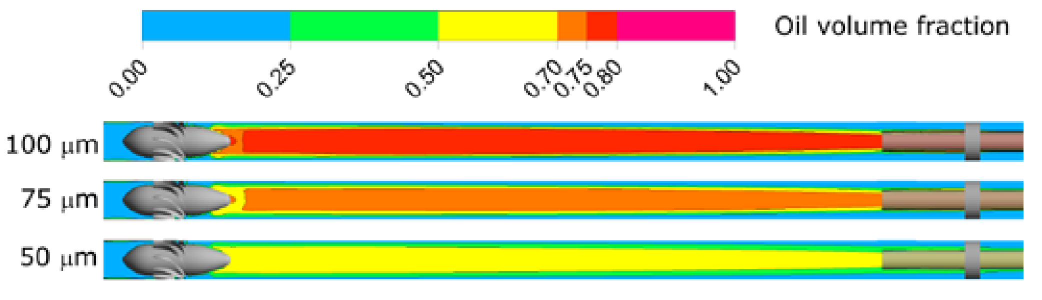
Dissertations

-

Scientific Publications

1. JJ. Slot, LJAM van Campen, HWM Hoeijmakers, RF Mudde, Inline Oil-Water Separation in Swirling Flow. Proc 8th Int. Conf. CFD in Oil & Gas, Metallurgical and Process Industries, Trondheim, June 2011, Norway. Paper 121, 10 pages. ISBN 978-82-519-2811-3.
2. LJAM van Campen, JJ Slot, RF Mudde, HWM Hoeijmakers: An Axial Cyclone for Oil/Water Separation, (USB stick). In F. Remni (Ed.), Proceedings of 12th International Conference on Multiphase Flow in Industrial Plants, September 21-23, 2011, Milano, Italy, (pp. 1.1-1.12). ISBN 978-88-89677-22-3.

Distribution of oil volume fraction as function of inlet droplet size in design of inline separator



Multiphase flow effects in compact produced-water treatment equipment

Project Aim

The physical phenomena occuring during produced-water treatment are studied numerically. Oil droplet, and gas bubble trajectories will be predicted for both swirling flow and settling conditions. Influence of effects such as a history term are required for prediction of trajectories. Collision and coelescence 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 extend existing Reynolds dependent kernel. A Lattice Boltzmann Method code for gas, with extension to fluids via body force, has been developed to investigate influences on 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 Drag Correlation in a Lagrangian Method Applied to Oil-Water Separation, (USB stick). In S.T. Johansen (Ed.), Proceedings of 8th International Conference on CFD in Oil & Gas, Metallurgical and Process Industries, Trondheim, Norway, June 21 – June 23, 2011. Paper 111, 10 pages. ISBN 978-82-519-2811-3.

Projectleaders

HWM Hoeijmakers

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

DF van Eijkeren, HWM Hoeijmakers

Cooperations

FMC Technologies/CDS Separation Systems.

Funded

FMC Technologies/CDS Separation Systems

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

Start of the project

2009

Information

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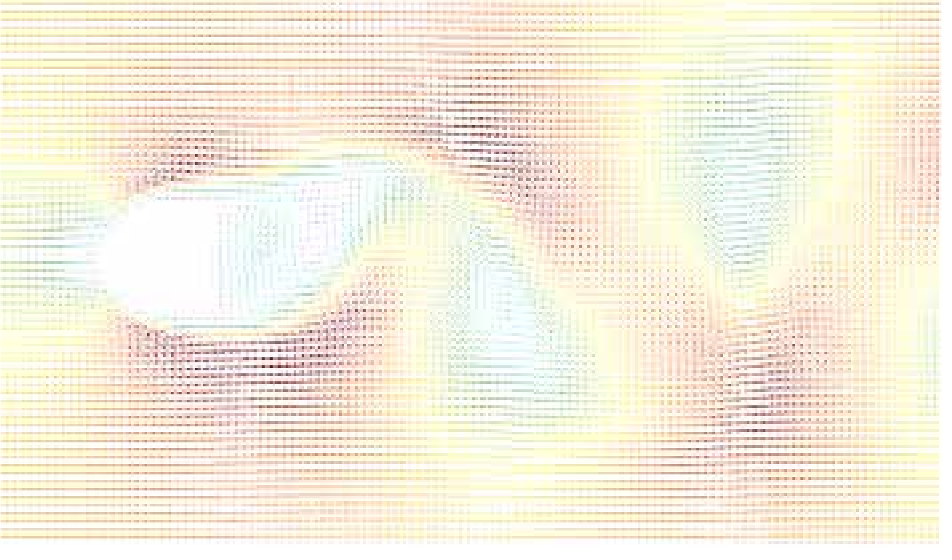

PROJECTLEADERS
HWM Hoeijmakers, CH Venner

RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis

PARTICIPANTS
CH Venner, HWM Hoeijmakers, M van Zoelen (SKF) PM Lugt (SKF), J Snoeijer (PoF, UT)

COOPERATIONS
INSA-de Lyon France, SKF ERC, VOJA

FUNDED

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

START OF THE PROJECT
2007

INFORMATION
CH Venner
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PROJECT AIM

Development of accurate thin film/layer flow models and numerical simulation algorithms for the prediction of lubricant film formation capacity and lubrication life in rolling element bearing contacts in relation to operating conditions, lubricant rheology (oil-grease), and supply conditions (starved-flooded).

PROGRESS

The general 'inlet length" mechanism governing the film formation and response to dynamic variations in EHL contacts has been re-investigated and shown to imply self similarity in the solution in a similar way as found in the so-called "Bretherton problem" of droplet flow in a narrow tube. Using developed models and computational methods narrow elliptic contacts have been studied. The results have revealed that the ratio central to minimum film in such conacts is a function of the same single non-dimensional parameter reflecting 'inlet control'. The results imply a major step forward to generalized film thickness formula valid for all point contacts. Free surface thin layer flow models have been used to optimize rolling element shape to minimize lubricant loss by pressure ejection to extend lubrication life of bearings. Film formation of grease in a model ElastoHydrodynamic lubrication has been studied in the contact between a steel ball and a coated glass disc using optical interferometry. Grease exhibits complex rheological behavior which provides challenging possibilities for film optimization in bearings by "smart grease composition" and "active local redistribution" The results have shown that grease lubricated contacts operate in a heavily starved regime and film thickness is mostly very insensitive to speed unless local resupply by low viscous material (base-oil) occurs.

DISSERTATIONS

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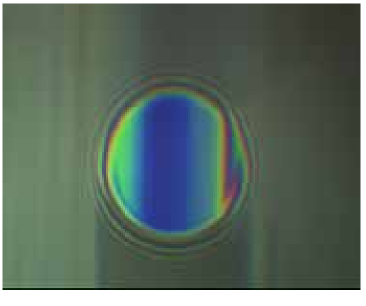
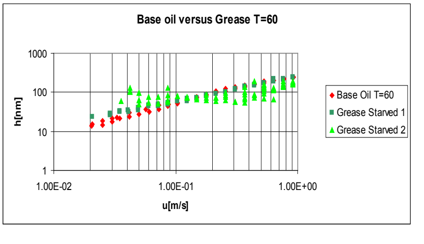
SCIENTIFIC PUBLICATIONS

1. J Wang, CH Venner AA Lubrecht: Amplitude reduction in EHL line contacts under rolling sliding conditions (online). Tribol. int., (ISSN 0301-679X), 2011, 44(12), 1997-2001.





Interferometric image of the film thickness in a grease lubricated contact between a steel ball and glass disc (left).
Central film thickness versus rolling speed for grease lubrication compared to base oil lubrication.

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. The pressure in dynamic pockets or dents filled with fluid (oil) is generated by fluid behaviour. As a first step a dry contact with a single dent in which a volumetric compression law is used has been used as a model problem. The next step is to assume more relastic flow equations in the pockets and to model multiple pockets or islands. To be able to identify pockets and contact regions from actually measured results image analysis methods will be used from the field of “vision”. In particular emphasis will be on multiscale image segmentation. Experiments will be carried out in a controlled single contact setting using optical interferometry and high speed camera equipment to generate data to validate and guide further model development.

DISSERTATIONS

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SCIENTIFIC PUBLICATIONS

-

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

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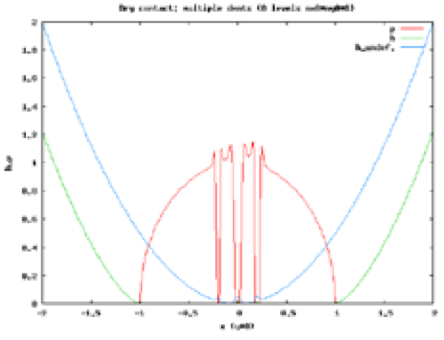

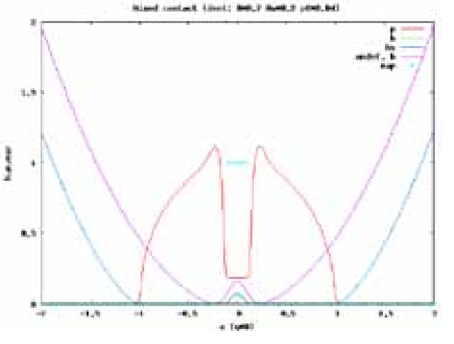

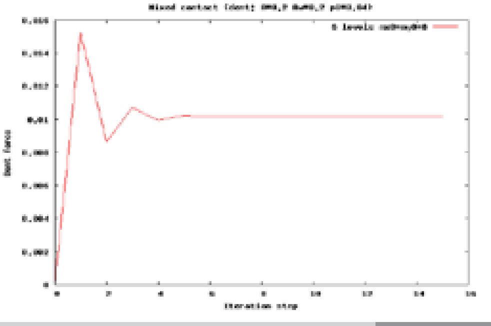

PROJECTLEADERS
NP Kruyt
RESEARCHTHEME
Mathematical and computational methods for fluid flow analysis
PARTICIPANTS
NP Kruyt
COOPERATIONS
University of Waterloo, Canada, University of Leeds, Université Joseph Fourier, Grenoble, France
FUNDED
UT

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

START OF THE PROJECT
2003
INFORMATION
NP Kruyt
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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

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SCIENTIFIC PUBLICATIONS

-

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, H Nieland, JAM van der Palen, WMC van Aalderen, BJ Thio, FHC de Jongh: Effects of a Single Dose Inhaled Corticosteroid on the Dynamics of Airway Obstruction after Exercise. Pediatr. pulmonol., (ISSN 8755-6863), 46(9), 849-856.
2. BL Laube, HM Janssens, FHC de Jongh, SG Devadason, P Diot, R Dhand, ML Everard, I Horvath, P Navalesi, T Voshaar, H Chrystyn: hat the Pulmonary Specialist should know about the new Inhalation Therapies. Eur. respir. j., (ISSN 0903-1936), 37(6), 1308-1331.

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

Start of the project
2011

Information
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Project Aim

Aim of the project is to develop a CFD method for the modeling of dense-phase fluid-particulate flow. Firstly, experiments 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.

Dissertations

-

Scientific Publications

-

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.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. JM Hospers, HWM Hoeijmakers: Numerical Simulation of SLD Ice Accretions. SAE Paper 2011-38-0071, 18 pages.

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

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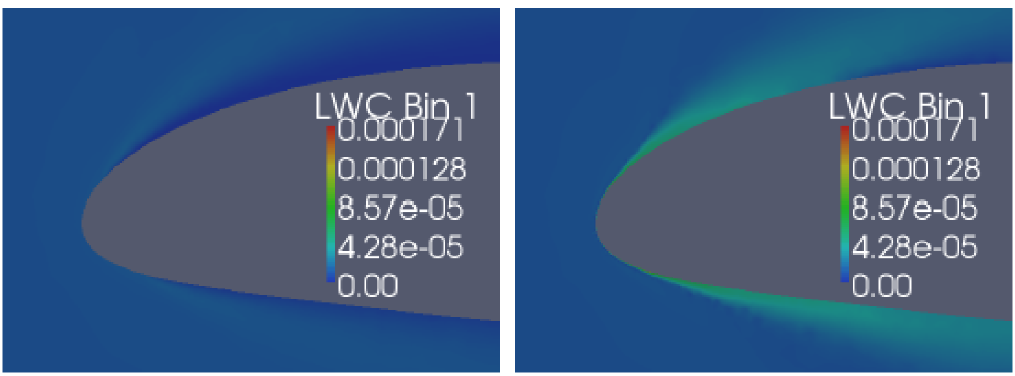

(a) Without splashing model

(b) With splashing model

Calculated droplet distributions [kg/m3], region near the leading edge, 236 μm MVD, bin 1 (16 μm)

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 novel heat 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 the novel engine generator for application within a micro-CHP appliance.

Progress

Benchmark cases for thermoacoustic CFD simulations are developed. During a literature survey it was found out that only a few benchmark cases for thermoacoustic simulations with full CFD exist. However, these benchmark cases are necessary in order to provide a good estimate of the numerical error made within a numerical simulation. The next steps are to further investigate these cases and make a well-founded choice for the software package and numerical parameters.

Dissertations

-

Scientific Publications

-

Projectleaders

TH van der Meer

Researchtheme

Complex dynamics of fluids

Participants

S Bühler, JP Oosterhuis

Cooperations

-

Funded

Agentschap NL

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

Start of the project

2011

Information

TH van der Meer
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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
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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 the NIST flame is further investigated. The predicted mean velocity components of the air flow at various downstream elevations show good agreements with the experiment. For the spray and combustion, the Euler-Lagrange method and the steady flamelet model with detailed reaction mechanism of methanol are employed. The droplet number density, SMD, and the mean axial and radial velocities of the droplets are compared to the measured data and resemble the experiment well. For the simulation of the Delft flame, the influences of the open system on the simulation of the Delft flame have been investigated. Both the Eddy dissipation model with global reaction mechanism and the steady laminar flamelet model with detailed reaction mechanism of ethanol are employed. The latter seems to perform better in the inner part of the flame near the nozzle. A modified Eddy dissipation model is proposed and the results show more agreements with the flamelet model. The 3D simulation of the boiler at Stork with the existing burner has commenced. The standard k- model, the Eddy dissipation model and an empirical droplet distribution are used. Preliminary results show that the influence of the steam should be taken into account in the simulation, and the temperature and oxygen concentration have influences on the combustion characteristics.

Dissertations

-

Scientific Publications

1. Numerical study of a methanol spray flame, Shanglong Zhu, Dirk Roekaerts, Theo van der Meer, The Fifth European Combustion Meeting, Cardiff, UK, 28th June - 1st July 2011.
2. Numerical simulation of a turbulent methanol spray flame using the Euler-Lagrange method and the steady laminar flamelet model, Shanglong Zhu, Dirk Roekaerts, Theo van der Meer, The Seventh Mediterranean Combustion Symposium, Sardinia, Italy, September 11-15, 2011.

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 all physical effects is a new challenge and the overall scientific objective of the COPA-GT project.
In the project 13 PhD students and 5 Post Docs work under coordination of CERFACS in Toulouse. At the UT 3 PhD students will be active. Full engine computations will be performed of Rolls Royce, Siemens and TurboMeca engines. These computations will be performed on 100,000 cores at the computational centers in Julich and Barcelona. This is about 30x the capacity of the Dutch center SARA. The project task of S. Gövert focuses on computationally efficiently modelling fluid structure interaction of the combustor as embedded in full engine computations.

Progress

The project has started 1 december 2011.

Dissertations

-

Scientific Publications

-

Projectleaders

JBW Kok

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

G Giangaspero, S Gövert, JBW Kok, ETA van der Weide

Cooperations

CERFACS, RWTH Aachen University, Von Karman Institute, Loughborough University, Turbomeca, Siemens, Barcelona Supercomputing Center, Julich 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

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LIMOUSINE : Limit cycles of pressure oscillations in gas turbine combustors

Projectleaders
JBW Kok

Researchtheme
Mathematical and computational methods for fluid flow analysis

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
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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. An acoustic network model has been brought to very accurate prediction in the stable operating case. To explore the behavior at a point of instability at 430 Hz a siren has been built. This is used to measure the Flame Deriving Function. The boundary conditions depend on the flow condition and have been shown to be very important.

Dissertations

-

Scientific Publications

1. Measurement and Modeling of the Acoustic Response in a High Pressure Combustor, M. Kapucu, P. R. Alemela, J.B.W. Kok and A.K. Pozarlik, European Combustion Meeting (ECM2011), 28th June - 1st July 2011, Cardiff, U.K.,6 pages.
2. Characterization of acoustic oscillations in fuel supply lines ,Mehmet Kapucu, Jim Kok, Reddy Alemela., The 18th International Congress on Sound and Vibration (ICSV 18), 10-14 july 2011, Rio de Janeiro, Brazil.

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 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.

Dissertations

-

Scientific Publications

1. T. V. Santosh Kumar* P. R. Alemela J. B. W Kok, DYNAMICS OF FLAME STABILIZED BY TRIANGULAR BLUFF BODY IN PARTIALLY PREMIXED METHANE-AIR COMBUSTION, GT2011- 46241, Proceedings ASME Turbo Expo 2011, Vancouver, Canada, 2011.

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

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LIMOUSINE : Limit cycles of pressure oscillations in gas turbine combustors

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
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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

-

LIMOUSINE : Limit cycles of pressure oscillations in gas turbine combustors

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. With a view to acoustic modeling, the acoustic impedance was measured in the inlet, outlet and burner. In the last part of the year, a siren unit was added to measure Flame Describing Functions, taking into account non linear behavior. During this year, the original design of the burner was modified and limit cycles were observed around 240 Hz at 160 dB saturated SPL.

Dissertations

-

Scientific Publications

1. LES and acoustic analysis of thermo-acoustic instabilities in a partially premixed model combustor. I. Hernandez, G. Staffelbach, T. Poinsot b, J.C. Roman Casado, J.B. W. Kok, INCA Coll. 2011.
2. Experimental and numerical study of the effect of acoustic time delays on combustion stability. Juan Carlos Roman Casado, Panduranga Reddy Alemela and Jim B.W. Kok, Ignacio Hernández Vera. Proceedings of the ICSV 18 IBSN 978-85-63243-01-0.

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

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PROJECTLEADERS
ThH van der Meer
RESEARCHTHEME
Complex dynamics of fluids
PARTICIPANTS
N Pelevic
COOPERATIONS
-
FUNDED
Agentschap-nl, ATAG.

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

START OF THE PROJECT
2008
INFORMATION
ThH van der Meer
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PROJECT AIM

A numerical study investigates a new heat exchanger material existing of a fine metallic structure, e.g. a metallic foam. The surface of this material carbon is covered with carbon nano fibers (CNF's). These fibers influence the fluid flow, and enlarge the heat exchanging surface. Preliminary experimental research has shown that the presence of these CNF's can enhance heat transfer by 40%. This depends very much on the CNF density and on the structure of the CNF itself. This numerical study gives directions in optimizing this new material.

PROGRESS

A stochastic model for three-dimensional CNF's structural description is developed. This model takes into account concentration, diameter, orientation angle and length of the fibers, for a each fiber independently. A three-dimensional fluid-dynamic and thermal-dynamic numerical code including heat transfer has been developed for the prediction of the thermal behavior of the CNF's attached to a wall using the lattice Boltzmann equation. The predicted thermal behavior of the CNF's shows that there is a high heat transfer enhancement through the CNF's layer. The results show substantial heat transfer enhancement for a densely covered surface with CNFs of varying length. Stagnation flow, boundary layer flow and flow in micro-channels have been studied.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. N. Pelevic, Th. H. van der Meer, Numerical investigation of the heat transfer enhancement by carbon nano fibers, " 8th International Conference for Mesoscopic Methods in Engineering, Lyon, France, 2011.
2. N. Pelevic, Th. H. van der Meer, Numerical investigation of the effective thermal conductivity of nano-fluids using the lattice Boltzmann mode, International Journal of Thermal Sciences, 2011.

Heat transfer to micro- and nanostructures surfaces

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 but parameter adjustments for different morphologies and topologies of the carbon nano-fibers are still under investigation. Heat transfer measurement setup was constructed and tuned to highest accuracy possible. Preliminary experimental investigation was done for both pure nickel wire and nickel with CNF deposit. Results shows that the amount of carbon deposit and surface structure have an influence on heat transfer from the surfaces. As a result, further investigation will be carried out for the optimization process. After optimization, the performance test of the new material on regenerator material will be determined on another heat transfer setup which is currently under design.

Dissertations

-

Scientific Publications

-

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
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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
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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 generation of modulated turbulence by means of a rotating perforated plate has extensively been studied with hotwire anemometry. Six different sets of grids were tested and the main conclusion are that it is possible to introduce turbulent fluctuations with a distinct frequency in the energy containing range and only a little in the inertial subrange. This concept has been adapted such that this grid can be used in a Low Swirl Burner where it replaces the central blocking grid. This is done to study the effect of the modified turbulence on the premixed flame. An experimental method for measuring the flame surface density and curvature is has been beeing developed. This consists of an OH-LIF setup to capture the OH distribution and an image postprocessing algorithm to calculate the length and the curvature of the flame front.

Dissertations

-

Scientific Publications

1. Verbeek, A.A. and Pos, R.C. and Stoffels, G.G.M. and Meer van der, Th.H. (2011) Resonant Turbulence applied to a Low Swirl Burner. In: 5th European Combustion Meeting, ECM 2011, 28th June - 1st July 2011, Cardiff, UK.
2. Verbeek, A.A. and Stoffels, G.G.M. and Bastiaans, R.J.M. and Meer van der, Th.H. (2011) Optimization of combustion in gas turbines by applying resonant turbulance. In: International Gas Union Research Conference, IGRC 2011, October 19-21, 2011, Seoul, South Korea.

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

The design, manufacturing, assembly and validation of a sample and dilution system for flue gases with soot has been completed. This system is able to take sample and dilute these with a factor of 10,000 in less than 10 ms from a reactor operating at temperatures up to 1400° Celsius and pressures up to 6 bar. A custom soot model describing the processes of nucleation, surface growth, agglomeration and oxidation has been coupled to ANSYS CFX's turbulence and combustion models. Simulations of the experimental setup with this soot model have been performed for several pressures and fuel/oxidizer ratios.

Dissertations

1. Flame Soot Sampling System for an Ultra-Rich Combustion Setup: Design and Experimental Validation. University of Twente, Master's Thesis, J.A. de Jong, June 1, 2011.

Scientific Publications

1. M.H.F. Woolderink, J.B.W. Kok. Modeling ultra rich combustion of natural gas using a reaction progress variable. Extended abstract for the 3rd International Workshop on Model Reduction in Reacting Flows, April 27-29 2011, Corfu, Greece.
2. M.H.F. Woolderink, J.B.W. Kok. Ultra rich combustion of natural gas to syngas (GT2011-46386). Proceedings of ASME Turbo Expo 2011, GT2011, June 6-10, 2011, Vancouver, Canada.
3. M.H.F. Woolderink, J.B.W. Kok. Ultra rich combustion of natural gas to syngas. Proceedings of European Combustion Meeting 2011, June 28 – July 1, 2011, Cardiff, Wales.

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

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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. The group studies the static and dynamic properties of dry and wet granular materials, i.e., particulate and atomic fluids and solids. Examples include segregation versus mixing; sticky powders; 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 contacts on the nano-meter scale determines the interactions between the particles. The mesocopic level sees the collective motions of the individual granules involving e.g. shear localization. Finally, on the macroscopic level, a granular material behaves as a fluid with complex flow behavior. 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. The advanced numerical simulations by the MSM group are aimed at understanding the various 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. These 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. We focus on long-range interactions and the effect of size in the particles' dynamics. The aim is both to model attractive/ repulsive interactions in homogeneous systems and size driven segregation in granular flows, and compare the results with theoretical work.

Progress

In the last year, we focused mainly in the study of segregation in dense flows of polydisperse granular matter, both numerically and experimentally (see figure). Our current goal is to understand the mechanism of segregation in more realistic systems, considering size ratios up to ten. On the other hand, we found that the ED simulation of long-range potentials, for small dissipation and density, follows exactly the mean field theory. Thanks to this, we understood that the homogeneous cooling shows an universal behavior once normalized the temperature for either attractive or repulsive forces.

Dissertations

-

Scientific Publications

1. M. K. Müller and S. Luding, Homogeneous Cooling with Repulsive and Attractive Long-Range Potentials, [Math. Model. Nat. Phenom. 6(4), 118-150, 2011]

Projectleaders

S Luding

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Gonzalez, A Thornton, S Luding

Cooperations

T Pöschel, Erlangen (Germany)

Funded

FOM

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

Start of the project

2009

Information

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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).
FUNDED
MicroNed

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

START OF THE PROJECT
2006
INFORMATION
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PROJECT AIM

During the past few years molecular dynamics has been a widely applied tool to simulate fluid confined in micro/nano geometries. What makes interfacial fluids fundamentally different from the bulk fluid is the fact that their density varies considerably over microscopic distances. A class of such strongly inhomogeneous fluids are those confined in very narrow spaces by solid boundaries. In the present project the goal is to study the transport properties of such fluids, investigate the effect of wall-fluid interaction, surface roughness and wall-morphology on the flow behavior.

PROGRESS

In this project we simulate planar Poiseuille flow of a Lennard-Jones fluid in channels of various widths in the nanoscale regime. We obtain average stress and strain rate profiles across the channel and the local viscosity can be estimated from stress-strain-rate relations and as a function of density. Atoms arrange in layers parallel to the channel walls and anisotropic 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 in order to quantify the relation between the 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, to appear in J. Chem. Phys.
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, submitted to J. Chem. Phys.
3. R. Hartkamp, A. Ghosh, T. Weinhart and S. Luding, A study of the anisotropy of stress in a fluid confined in a nanochannel, submitted to J. Chem. Phys.

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 and relate the behavior to localization effects. 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 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

-

Scientific Publications

-

Projectleaders

S Luding

Researchtheme

Complex dynamics of fluids

Participants

BP Lawney

Cooperations

-

Funded

VICI Project No. 10828

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

Start of the project

2011

Information

BP Lawney
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Micro-macro modeling for critical state and flowing of dense granular materials

Projectleaders
S Luding
Researchtheme
Complex structures of fluids
Participants
V Magnanimo
Cooperations
-
Funded

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

Start of the project
2010
Information
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Project Aim

Dense granular materials behave differently from fluids or solids. Classical continuum theories fail in describing granular matter when the onset of flowing is approached, and his properties, as dilatancy, yield limit, anisotropy and ratcheting. In fact, the behavior at macro-scale is strongly related to smaller-scale field variables and kinetic processes. Our goal is to solve this lack with a multiscale approach, coupling discrete and continuum. Getting insights from Discrete Element Method (DEM) simulations a continuum in-homogeneous model will be developed and implemented to describe the macroscopic behavior of the material in terms of homogeneous local properties.

Progress

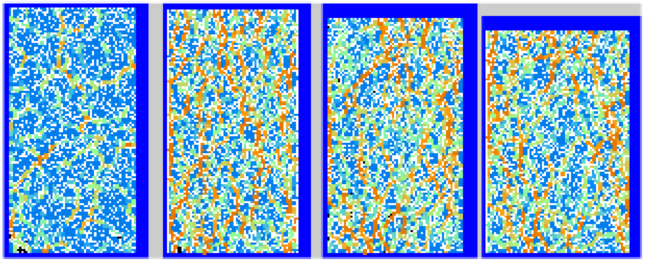
In the last year a constitutive model has been formulated for two-dimensional stress-strain behaviour of anisotropic granular materials, based on non-linear tensorial functions. The history dependence is represented by a symmetric 2nd-rank fabric tensor, which characterizes the geometric arrangement of the material microstructure. Non-linear constitutive evolution equations relate the stress and the fabric to the strain as they approach their critical-state and the limit of flowing failure. At the same time the relation between macroscopic observable anisotropy and fabric anisotropy has been investigated by means of discrete element simulations. Numerical samples characterized by stress isotropy and anisotropic distribution of contacts have been created. The dependence of the material response on the strain direction resulted to be proportional to the value of deviatoric fabric in the system. The step now in progress is the formulation of the model in three dimensions.

Dissertations

-

Scientific Publications

1. V. Magnanimo and S. Luding, "A local constitutive model with anisotropy for ratcheting under 2D axial-symmetric isobaric deformation", Granular Matter, 13(3), 225-232 (2011).
2. V. Magnanimo and S. Luding, "A 2D non-linear constitutive model with anisotropy for granular materials", submitted to Philosophical Magazine – special issue for the conference Instability across the scales 2011 (2011).
3. L. La Ragione and V. Magnanimo, "Contact anisotropy and coordination number for a granular assembly: a comparison between DEM simulation and theory", under review in PRE (2011).
4. A. Sollazzo and V. Magnanimo, "Origine ed Evoluzione dell'Ingegneria Sismica in Italia", chapter in book Edifici antisismici in cemento armato (ed. M. Mezzina et al.), Città Studi Ed. – De Agostini Scuola S.p.A.: Novara, (2011).



Bridging the gap between particulate systems and continuum theory

Project Aim

Two general approaches are used to model granular materials: microscopic, where information is taken from individual particles, or macroscopic, where continuum fields are considered. In this project we apply and compare both approaches for a driven granular system, consisting of a vertically shaken box containing grains. This system presents many different stable states as the parameters of energy injection, geometry, and grain properties and number are varied. Studying the stability of the states and the transition 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), in order to see the limits and advantages of each approach in different scenarios.

Progress

Last year was devoted mainly to the correct reproduction of previous known results with new simulation approaches. Event-driven molecular dynamics simulations where seen to correctly capture all known states, with a good quantitative agreement. The considerably higher speed of these simulations made feasible the exploration of new regions of phase space. Segregation was observed when binary mixtures were considered, for both mass and size differences. Also, the transition between the horizontally symmetric and density inverted Leidenfrost state to a convective state was studied in detail, looking for hysteresis as the frequency of oscillation was increased or decreased. The comparison between finite element and event-driven methods was started, as also work was done to solve the continuum granular-hydrodynamic equations.

Dissertations

-

Scientific Publications

-

Projectleaders

S Luding

Researchtheme

Complex dynamics of fluids

Participants

A Thornton, A Meheboob, D van der Meer

Cooperations

-

Funded

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

Start of the project

2011

Information

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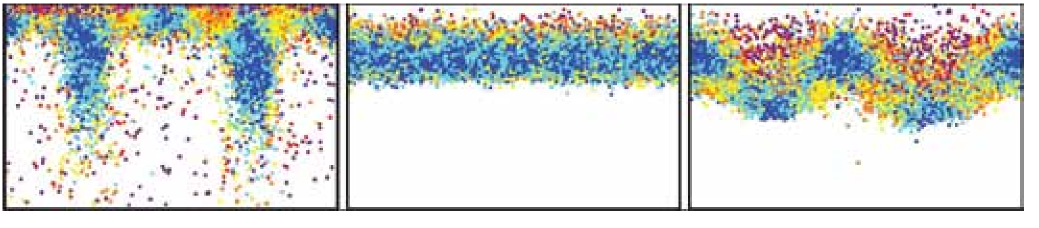

Different states observed in the ED simulations.

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
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PROJECT AIM

A validated CFD-DEM simulation will be 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). We wish to determine which operating conditions give 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 (eg. 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.

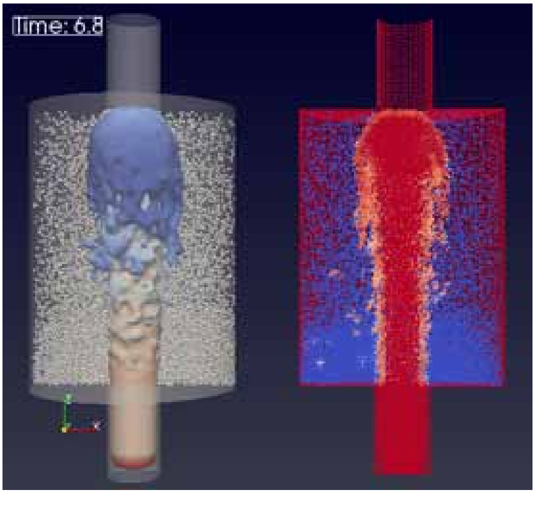
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Martin Robinson, Marco Ramaoli, (2011). Mesoscale fluid-particle interaction using two-way coupled SPH and the Discrete Element Method, SPH European Research Interest Community (SPHERIC) workshop.

SPH-DEM simulation of a water jet impacting on a granular bed. Constant velocity fluid inlet from the bottom of the cell. Left: water free surface coloured by velocity. Right: SPH and DEM particles coloured by porosity



Bridging the gap between particulate systems and continuum theory

Project Aim

Particulate systems (granular materials) consist of discrete particles and show a broad range of not yet understood phenomena like segregation, structure formation, or failure of structures due to (granular) flow. Generations of scientists and engineers have developed a basic, practical understanding and have provided applicable recipes for the solution of material-transport and processing issues. In the last 20 years, also theoretical physics and computer simulations have significantly contributed by explaining many topics in particulate systems. The goal of the project is to bridge the big gap between discrete and continuum concepts and methods.

Progress

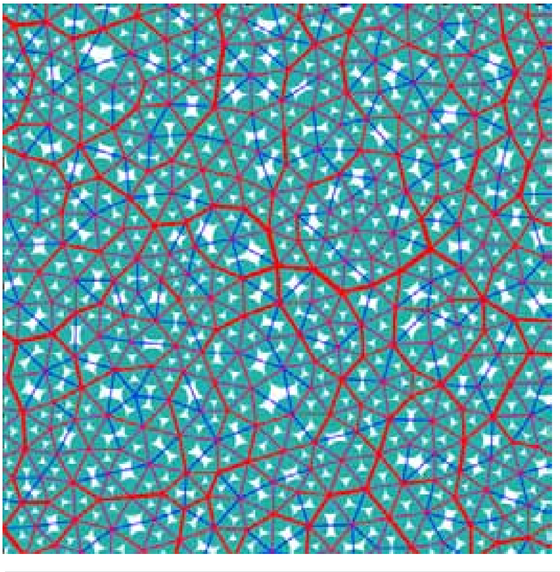
Jamming is one of universal features of vast ranged materials including both thermal and athermal systems, where constituents are arrested in disordered states so as to obtain rigidities. The jamming transition of athermal systems, for instance, granular particles, is governed by the density and one can see various critical behaviors of some physical quantities near the critical density, i.e., the jamming point. We investigate the jamming transition of two dimensional bidisperse granular particles by the discrete element method (DEM). Above the jamming point, the interparticle forces are distributed on the force chain network as shown in the below figure (left), and the excess coordination number and the pressure are scaled by the power laws of the distance from the jamming point. We also find the critical slowing down of energy as shown in the below figure (right), where the relaxation time diverges as approaching to the jamming.

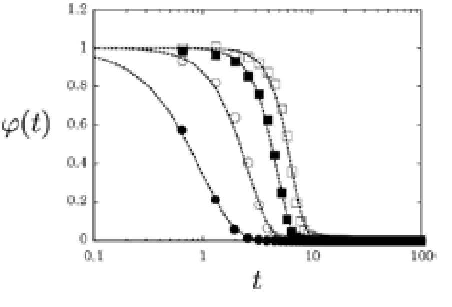
Dissertations

1. Saitoh K. “Studies of Nanoclusters’ collisions”, PhD thesis, Kyoto University, 2011.

Scientific Publications

1. Saitoh, K. and Hayakawa, H Weakly nonlinear analysis of two dimensional sheared granular flow, Granular Matter, 13 (5) 697-711, 2011.





Projectleaders

S Luding

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

Kuniyasu Saitoh

Cooperations

-

Funded

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

Start of the project

2011

Information

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Projectleaders

S Luding

Researchtheme

Complex dynamics of fluids

Participants

A Singh, V Magnanimo, A Thornton

Cooperations

-

Funded

FOM

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

Start of the project

2009

Information

A Singh
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Project Aim

To probe the connections between jamming, shear banding and microstructures in numerical simulations of Brownian and non-Brownian systems with various interaction forces, shear rates, stress regimes. Discrete element simulations will be used to study the shear banding in “split bottom ring shear cell” where a slow, quasi-static deformation leads to wide shear bands that are formed away from side walls.

Progress

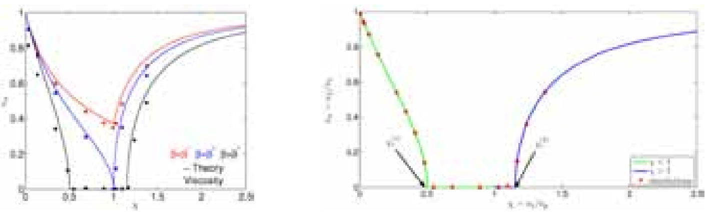
This year from we have from a single simulation, by applying averaging techniques, computed continuum quantities. The typical characteristic of quasi-static system is rate-independence of the continuum quantities. Yield locus for slower driving rates are found to collapse on top of each other. Increasing contact-cohesion is found to induce non-linearity in the termination locus at continuum level. The effect of particle velocity on coefficient of restitution is also studied. Based on a given contact-cohesion, a range of particle velocity can be analytically predicted for which particles are found to stick together. This range is also found to be dependent of contact-cohesion. Additionally, in a side project, a linear stability analysis of 2D depth-averaged segregation equation was done to shed light on finger and levee formation in granular avalanches.

Dissertations

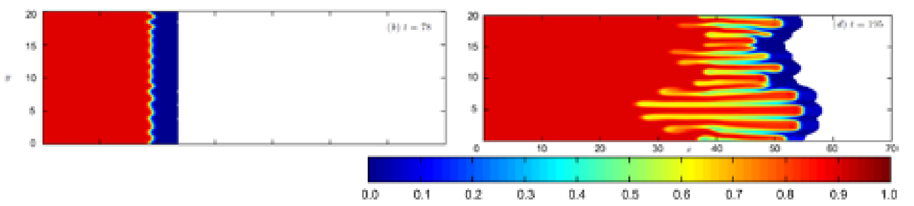
-

Scientific Publications

1. A. Singh, V. Magnanimo S. Luding, Sticking of cohesive particles in elasto-plastic collisions. Submitted (Granular Matter).
2. A. Singh, V. Magnanimo and S. Luding, Microstructure analysis in shear bands for cohesive-frictional powders, Physics@FOM Veldhoven. (Poster)
3. A. Singh, A. Thornton and S. Luding, Linear stability analysis of fully coupled segregation equations in granular avalanches. 2nd International Conference on Material Modeling, Paris (Oral presentation)



Dependence of coefficient of restitution on scaled particle velocity for a given cohesive-strength (Left), and dependence of coefficient of restitution on scaled particle velocity for different cohesive-strengths)



Time evolution of contours of depth-averaged volume fraction of smaller particles in a granular avlanche, showing the create of ‘segregation fingers’)

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. Delaunay triangulation is a efficient tool for detecting contact in granular media simulations using the Discrete Element Method (DEM). We utilize this triangulation for simultaneously solving the continuum equations of fluid dynamics using finite element Method (FEM) on a moving mesh. To this end we have developed coupled computational framework based on a stabilized higher order FEM for fluid dynamics and DEM for particle dynamics. A salient computational feature of our methodology is that both fluid and particles data are stored in a single data structure (i.e. the triangulation). 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

-

Scientific Publications

1. K. Yazdchi, S. Srivastava and S. Luding, Microstructure effects on the permeability of periodic fibrous porous media, Int. J. Multiphase Flow Vol. 37 (8) 956-966.
2. S. Srivastava and A. Patra Interior penalty and mixed discontinuous Galerkin methods for elasticity, Proceeding of the ACOMEN 2011 conference Liège, Belgium, CD ISBN-978-2-9601143-1-7.

Projectleaders

S Luding

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

S Srivastava, K Yazdchi, V Ogarko

Cooperations

Prof. Dr. Hans Kuipers, DEM solutions (Dr. John Favier), CeParTec GmbH (Dr. Torsten Gröger), CSIRO (Dr. Paul Cleary)

Funded

STW, Industry

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

Start of the project

2008

Information

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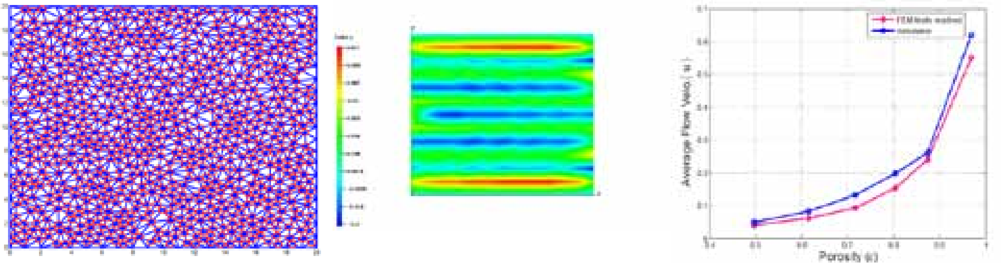

(a) Triangulation (Mesh) based on particle locations. (b) Flow computed through an ordered packing. (c) Comparison with fully resolved flow from Ansys.

PROJECTLEADERS
S Luding
RESEARCHTHEME
Complex structures of fluids
PARTICIPANTS
V Ogarko, K Yazdchi, S Srivastava
COOPERATIONS
Prof. Dr. Hans Kuipers, DEM solutions (Dr. John Favier), CeParTec GmbH (Dr. Torsten Gröger), CSIRO (Dr. Paul Cleary)
FUNDED
STW, Industry

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

START OF THE PROJECT
2008
INFORMATION
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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

A novel method for contact detection for arbitrary particle size distributions has been developed and confirmed by discrete element simulations. It has application in computer simulations of widely distributed in particle size materials, like for example, concrete, powders, mixtures. With proposed contact detection method we investigate numerically the effect of polydispersity on the system pressure. We show that there is a close relationship between many-component hard sphere fluids mixtures and their binary, two-component equivalents, even in metastable states. Equations for the jamming density as functions of the extreme size ratio are obtained.

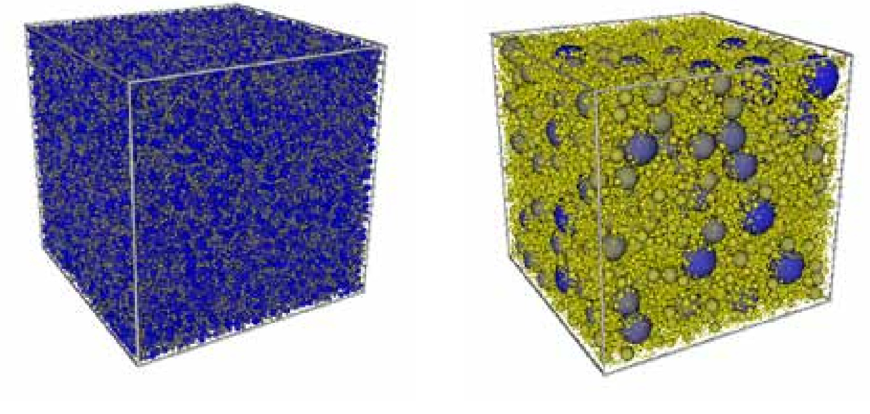
DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. V. Ogarko, S. Luding, A fast multilevel algorithm for contact detection of arbitrarily polydisperse objects, Computer Physics Communications, 183(4), 2012, 931–936.

Systems with 40% volume fraction, 125001 particles, and a) uniform size distribution, b) uniform volume distribution. Color is by relative size.



Project Aim

The primary propose of the project is to develop a new multiscale-method (HMM) model for granular flow, coupling a micro-scale discrete element model to the macro-scale continuum granular flow model. In regions where the flow is smooth, a shallow-layer model is used with macro-scale closure relations obtained from micro-scale Discrete Particle Method (DPM) simulations of steady uniform flow (fig. 1). The new model will be verified through some test cases where closures are known experimentally or theoretically, such as for dry granular flows in a uniform channel with a rough bottom, and for flow through a contraction (fig. 2). Additionally, an investigation of segregation in granular flows will be undertaken.

Progress

Both micro- and macroscale models for granular flows have been developed and implemented. The microscale model consists of a Discrete Particle Method (DPM) governed by Newtonian mechanics, whereas the macroscale model is a Discontinuous Galerkin finite element solver built using the in-house HPGEM package. A shallow-layer model for granular flows is now completed with macro-scale closure relations obtained from micro-scale DPM simulations of steady uniform flow [1]. A thorough investigation was undertaken to study the dependence of the closure laws on micro-scale parameters such as botton roughness [1] and bottom friction [2]. The closures have been obtained using an novel coarse graining method that is able to accurately define the stress fields near external boundaries [3]. We further investigated segregation rates in bidisperse granular flows [4].

Dissertations

-

Scientific Publications

1. Thornton, A.R. and Weinhart, T. and Luding, S. and Bokhove, O. Friction dependence of shallow granular flows from discrete particle simulations, EPL, submitted October 2011.
2. Thornton, A.R. and Weinhart, T. and Luding, S. and Bokhove, O. Modeling of particle size segregation: Calibration using the discrete particle method Modern Physics letter, submitted October 2011.

Projectleaders

O Bokhove, S Luding

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

T Weinhart, AR Thornton

Cooperations

-

Funded

Institute of Mechanics, Processes and Control, Twente (IMPACT)
Since August 2011 funded by DFG SPP 1486 Piko – B12

University	58 %
FOM	-
STW	-
NWO Other	42 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project

2009

Information

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Fig 1 Steady uniform flow over a rough surface at inclination 25°. Shading indicates speed.

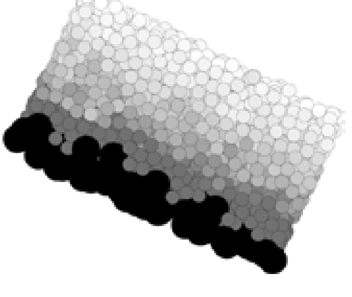
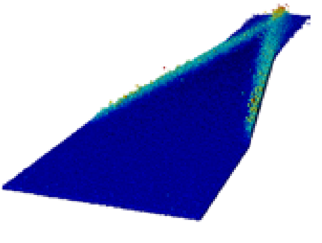


Fig 2 Steady flow through a contraction at inclination 19°, 400 000 particles. Shading indicates flow thickness..



Prof.dr. SJMH Hulscher

The work of the “Water Engineering and Management (WEM) group was originally mainly devoted to the modelling of sand waves on the seabed. First it was shown, that the seabed patterns in the North Sea can be explained as free instabilities of the seabed. Subsequently, the modelling of sand waves was extended and refined. The group has worked on a scientific and practical tool for fully nonlinear modelling of sand waves. Over the last five years, the offshore morphodynamic work has broadened to rivers, coasts and blue-ice. Alternate bars in a flume were compared with (Ginzburg-)Landau-type models. The group was the first to explore data assimilation for morphodynamic predictions. Further work concentrated on using data assimilation to combine field data with sand wave amplitude models for maintenance dredging management of navigation channels and sand wave-related pipeline problems. Also, North Sea data were analysed and a new bed mode, called long bedwaves, was discovered. The origin of nearshore bars was addressed. A method was developed for modelling human interferences in a morphodynamic setting. This has opened perspectives for a new approach towards modelling large-scale sand mining in shallow seas. A project for developing tools for evaluation of human interference in the North Sea for optimal management of the seabed started recently and sediment transport concerning near-shore sand pits is being investigated. Since 2000 the group has studied the use of morphodynamical models in a societal context. Recently, a method for decision making based on quantitative information including uncertainties was developed in the multidisciplinary project Flyland, which opens the field of designing an assessment framework for appropriate modelling.

Project Aim

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 biogeo-morphological interactions are further analysed.

Dissertations

-

Scientific Publications

1. Borsje, B.W., van Wesenbeeck, B., Dekker, F., Paalvast, P., Bouma, T.J., de Vries, M.B., 2011. How ecological engineering can serve in coastal protection – a review Ecological Engineering 37, 113-122. doi: 10.1016/j.ecoleng.2010.11.027.
2. Borsje, B.W., P.C. Roos, W.M. Kranenburg, S.J.M.H. Hulscher, 2011. Modeling sandwave formation in a numerical shallow water model, In: Shao, X., Z. Wang & G. Wang. RCEM 2011, 7th IAHR symposium on River, Coastal and Estuarine Morphodynamics, Beijing, China.
3. Elizondo García, F.A., D.C.M. Augustijn, B.W. Borsje, R.S.E.W. Leuven, 2011. Do invasive benthic mollucs impact river morphology? In: E. Mostert, L.J.E. Bouaziz (eds.) NCR-Days 2011: Controlling the Dutch Rivers, Book of Abstracts, p. 18-19.
4. De Vries, M.B., Borsje, B.W., De Vriend, H.J., 2011. Understanding biogeomorphological interactions as basis for building with living nature. In: (Eds). Proceedings of the NCK-days 2011, Texel, The Netherlands, pp. 30.
5. Borsje, B.W., Cronin, K., Holzhauer, H., De Mesel, I., Ysebaert, T., Hibma, A., 2011. Biogeomorphological interactions on a nourished tidal flat: lessons learned on building with nature. Dredging Days.

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

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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
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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

The main progress of last year was we starting this PhD project. In the first stage of the project, a literature study was carried out, and the research questions were formulated. The candidate followed some courses which contributed to the project, and developed a simple 2DV model, as an excise to develop the final 3D model.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

Short-term biophysical interactions in coastal mangroves

Project Aim

Quantify the bio-physical interactions that control the dissipation of hydrodynamic energy and sediment transport and deposition in coastal mangroves. Develop a process-based hydrodynamic and morphodynamic model to describe the attenuation of hydrodynamic energy by bio-physical interactions within coastal mangroves and the effects on the local morphology. Determine the potential use of coastal mangroves to attenuate hydrodynamic energy and the effect on the local morphology, using this process-based model.

Progress

The past year has been mainly spent on an extensive fieldwork campaign in Trang Province, Thailand. Wave heights, current velocities, suspended sediment concentrations, sediment deposition, bottom elevation and vegetation density are being monitored along two transects through the mangroves (6/7 points, up to 300 m) and in a mangrove creek catchment (24 points, 100x100 m2). Initial analysis of the collected field data focussed on flow routing through a mangrove creek catchment and its dependency to bottom elevation and vegetation densities. Next is the linking of flow routing to sediment transport and distribution in mangrove creek catchments. Further analysis will also include wave attenuation through mangroves.

Dissertations

-

Scientific Publications

1. Balke, T., Bouma, T.J., Horstman, E.M., Webb, E.L., Erftemeijer, P.L.A. & Herman, P.M.J. (2011). Windows of opportunity: thresholds to mangrove seedling establishment on tidal flats. Marine Ecology Progress Series, 2011(440), 1-9.
2. Bouma, T.J., Erftemeijer, P.L.A., Balke, T., Horstman, E.M., Yaakub, S.M., Tanzil, J.T.I., Friess, D.A., Galli, D., Dohmen-Janssen, C.M., Jeuken, M.C.J.L., Todd, P.A. & Webb, E.L. (2011). Sediment and Ecology: how to minimize impacts of dredging and create opportunities for restoration on tropical coasts?, CEDA dredging days, 10-11 November 2011, Rotterdam.
3. Friess, D.A., Krauss, K.W., Horstman, E.M., Balke, T., Bouma, T.J., Galli, D. & Webb, E.L. (available online). Are all intertidal wetlands naturally created equal? Bottlenecks, thresholds and knowledge gaps to mangrove and saltmarsh ecosystems. Biological reviews.
4. Horstman, E.M., Siemerink, M., Balke, T., Dohmen-Janssen, C.M., Bouma, T.J. & Hulscher, S.J.M.H. (2011). Sediment dynamics in a mangrove creek catchment in Trang, Thailand. In X. Shao, Z. Wang & G. Wang (Eds.), Proceedings of the 7th IAHR Symposium on River, Coastal and Estuarine Morphodynamics (RCEM), 6-8 Sept 2011, Tsinghua University, Beijing (pp. 675-685). Beijing: Tsinghua Univ. Press.
5. Horstman, E.M., Siemerink, M., Dohmen-Janssen, C.M., Bouma, T.J. & Hulscher, S.J.M.H. (2011). Sediment dynamics in a mangrove creek catchment. In Book of abstracts 5th International Short Conference on Applied Coastal Research, 6 - 9 June 2011, Aachen, Germany (pp. 27-28). Aachen: Institute of Hydraulic Engineering and Water Resources Management.
6. Horstman, E.M., Balke, T., Bouma, T.J., Dohmen-Janssen, C.M. & Hulscher, S.J.M.H. (2011). Optimizing methods to measure hydrodynamics in coastal wetlands: evaluating the use and positioning of ADV, ADCP and HR-ADCP. In J. McKee Smith & P. Lynett (Eds.), Proceedings of 32nd International Conference on Coastal Engineering (ICCE), 30 June - 5 July 2010, Shanghai (pp. 1-11). Shanghai: Coastal Engineering Research Council.

Projectleaders

SJMH Hulscher,
CM Dohmen-Janssen

Researchtheme

Complex dynamics of fluids

Participants

EM Horstman,
CM 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

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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
Closely linked to: SANTOSS (Sand Transport in Oscillatory flow in the Sheet-flow regime) and Hydralab IV-WISE
Funded
Hydralab III-SANDS (EU-project)
Hydralab IV-WISE (EU-project)
University of Twente

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

Start of the project
2008
Information
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Project Aim

The main objective of this project is the development of a validated process-based numerical model for sand transport under progressive surface wave in the sheet-flow regime. A second objective is to gain insight in the effects and relative importance of various processes on sediment transport by application of the model on cases with various hydrodynamic and morphological conditions. To enable implementation of results from phase 1&2 into morpho-dynamic models on engineering scale, the third objective is to develop a parameterization of the model results.

Progress

After earlier focus on model development and hydrodynamic validation (see publications), 2011 research activities focussed on the influence of progressive wave streaming on sand transport beneath waves. This progressive wave streaming, an onshore directed wave-averaged boundary layer current that originates from vertical transport of horizontal momentum in the horizontally non-uniform flow under free surface waves, was shown to contribute significantly to onshore sediment transport. However, also other free surface effects turned out to be important to explain the differences in transport rates found earlier between experiments in wave flumes (with a free surface) and oscillating flow tunnels (without a free surface). Based on the model results, a parameterization has been developed to include these processes into practical sand transport models.

Dissertations

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Scientific Publications

1. Wouter Kranenburg, Jan Ribberink, Rob Uittenbogaard; ‘Net currents in the wave boundary layer: balance of wave shape and free surface effects’, Proceedings Coastal Sediments 2011, Miami, Florida, USA, May 2011(best student paper award).
2. Kranenburg, W. M., J. S. Ribberink, R. E. Uittenbogaard, and S. J. M. H. Hulscher, ‘Net currents in the wave bottom boundary layer: on wave shape streaming and progressive wave streaming, conditionally accepted for Journal of Geophysical Research.

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

This research project started with a literature study on dunes and sediment transport, and an exploration of the dune evolution model developed by Paarlberg et al. [2009]. The second part of the first year research has been filled with writing research proposal and defending it successfully in a formal meeting, in front of the Disciplinary council of Civil Engineering. Furthermore, several planned courses are completed in the first year of research e.g. course on Turbulence, Technical editing and writing, and Programming in Engineering. In 2011 the postdoc started on this project. In addition, a first step has been taken to extend the dune evolution model by incorporating suspended sediment transport. To realize transition of dunes to upper stage plane beds, the bed load transport equation used in the current model is being adjusted as well. Laboratory experiments have been carried out this year (summer) to give us insight in the behaviour of dunes and upper stage plane beds. Two conference papers were written about the preliminary results, these are still under review. A benchmark study is carried out to calibrate the existing model of Paarlberg et al. [2009] for field data. Furthermore, a comparison between exiting flume and field data was carried out to improve the understanding of bed form evolution under varying discharge waves. In the next step the acquired knowledge will be used to improve the exiting model for water level forecasting..

Dissertations

-

Scientific Publications

1. Van Duin, O.J.M., J.S. Ribberink, C.M. Dohmen-Janssen and S.J.M.H. Hulscher. (2011). Modelling non-equilibrium bed load in a parameterized dune evolution model. In Shao, X., Z. Wang and G. Wang (Ed.), Proceedings of the 7th IAHR Symposium on River, Coastal and Estuarine Morphodynamics. Beijing, China: Tsinghua University Press.
2. Naqshband, S., Sterlini, F., Dohmen-Janssen, C.M. & Hulscher, S.J.M.H. (2011). A model study on the influence of suspended sediment transport on river dune morphology and evolution. In Shao X. J., Wang, Z. Y., Wang G.Q. (Ed.). Abstracts of the 7th IAHR Symposium on River, Coastal and Estuarine Morphodynamics (RCEM), Tsinghua University Beijing, China, pp. 162.

Projectleaders

SJMH Hulscher,
CM Dohmen-Janssen

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

OJM van Duin, S.Naqshband, JJ Warmink, FM Sterlini-van der Meer, 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

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Turbidity dynamics in Lake Naivasha ecosystem

Projectleaders
SJMH Hulscher

Researchtheme
Complex dynamics of fluids

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	100 %
Industry	-
TNO	-
GTI	-
EU	-
Scholarships	-

Start of the project
2010

Information
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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

The whole of 2011 was spent on fieldwork in Lake Naivasha in Kenya. A draft report is almost complete which was done in January 2012. One paper has also been drafted from the data collected in the field.

Dissertations

-

Scientific Publications

-

Modelling semi-fixed layers in rivers

Project Aim

The aim of the project is to develop model concepts to describe the vertical sorting of grain size fractions in the riverbed. In particular the sorting of actively transported grain size fractions and the coarser immobile size fracions is described. We aim to describe the formation of immobile layers in large scale morphodynamical river models. This way the effects of bed armoring and fixed layer break up on natural rivers can be assessed.

Progress

In 2011 the model concepts have been applied to simulate the morphological development of a part of the Dutch Rhine branches, namely the Boven Rijn, Pannerdensch Kanaal and the Waal. These model results have been compared to the simulation results of more traditional modelling approaches. Futhermore the effect of a sediment nourishment on the morphological development has been simulated.

Dissertations

-

Scientific Publications

1. A. Tuijnder and J.Ribberink (2011) A morphological model concept for semi-fixed layers. CE&M research report 2011R-003/WEM-003.
2. A. Tuijnder, J.Ribberink and A. Spruijt (2011) Modelling semi-fixed layers with Delft3D. CE&M research report 2011R-004/WEM-004.

Projectleaders

JS Ribberink

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

AP Tuijnder

Cooperations

Deltares, TU Braunschweig

Funded

Deltares

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

Start of the project

2009

Information

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Prof.dr.ir. HB Levinsky

The mission of the Combustion Science and Engineering program is to:

- provide insight into the fundamental physical and chemical processes responsible for the behavior of high-temperature reacting systems, such as flames and low-temperature plasmas,
- conceive ways to control this behavior based on the insight gained,
- "translate" the results obtained into terms useful for engineering practice,
- disseminate the knowledge generated to both the scientific and practical communities,
- analyze the technical consequences of energy policy choices.

Combustion can be defined as a self-sustaining transition of a system from a non-equilibrium state, e.g., unreacted fuel and oxidizer, to equilibrium, accompanied by energy release. The combustion of even the simplest fossil fuel, methane, is exceptionally complex. Hundreds of elementary reactions involving many tens of chemical species are intimately coupled to energy and mass transport, yielding a spatial structure: the flame. The coupling of chemical reaction to transport renders the details of flame structure sensitive to external factors, and changes in fluid flow, heat transfer and identity of the fuel have major impacts on combustion properties (ignition, flame extinction, pollutant formation). The emphasis of the program is to formulate a microscopically correct and theoretically coherent description of the energy conversion process.

Since the only reliable source of information on this process is experiment, we develop and use non-invasive laser-spectroscopic methods (such as laser-induced fluorescence, spontaneous and coherent anti-stokes Raman scattering) to analyze stationary and instationary high-temperature reacting systems. Deeper insight is gained into system behavior by performing theoretical analyses of the phenomena under study, including the use of advanced numerical codes that solve the full conservation equations (i.e., including detailed transport and chemistry).

CURRENT ACTIVITIES

The majority of the current projects concern the effects of hydrogen addition on fossil fuel combustion. The results of these studies are used to point out the technical consequences of the future integration of hydrogen into the energy supply. Particularly, the limitations posed by the combustion behavior of hydrogen in existing equipment will have a major impact on any transition to a hydrogen economy.

- Flame structure: In two projects, laser diagnostics are developed and applied in flames at low pressure (to enlarge the size of the primary reaction zone) to study key intermediates responsible for pollutant formation, particularly NOx and soot. Analysis of the experimental results and comparison with those from numerical models help identify the shortcomings in the models, such as potentially incorrect boundary conditions, uncertainties in transport phenomena and failures in chemical mechanisms. Also, the possible effects of hydrogen addition to natural gas and other alkanes (suggested in energy policy for the transition to sustainable energy) on oxidation mechanism and pollutant formation are examined. Further, in a third project, the flame structure of pure hydrogen flames and hydrogen/alkane flames at atmospheric pressure are being studied. Here, the peculiar transport properties of hydrogen are particularly manifested.

- Ignition phenomena: A RCM is being built for a dual purpose: to assess the effects of sustainable fuels (hydrogen and biogas) on alkane ignition (related to engine knock) and to serve as an instrument with which, in combination with laser diagnostics currently being developed, elementary chemical processes in ignition are to be studied.
- Laser diagnostics: Raman, IR-absorption and laser-fluorescence methods are being developed for quantitative analysis of high-temperature reacting systems.

Projectleaders
HB Levinsky, AV Mokhov
Researchtheme
Complex structures of fluids
Participants
R Klein-Douwel
Cooperations
KEMA, Kiwa
Funded
EDGaR, Gasunie

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

Start of the project
2011
Information
HB Levinsky
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Project Aim

Siloxanes are organosilicon compounds found in many food and health care products. In landfill sites and waste water treatment processes, they are also found in the biogas that is derived from the processes. Upon combustion, siloxanes form silica that can clog combustion equipment, resulting in equipment failure. Little is known about the details of silica growth/cluster formation. In this project, we shall analyze the growth of silica clusters using laser diagnostic methods and physical models.

Progress

The potential methods for in-situ measurement of cluster growth have been scrutenized, and choices for asymmetric and/or dynamic light scattering, combined with TEM measurements, have been chosen. The experimental setup (lasers, burners, seeding systems) has been constructed and shaken down. The first measurements are currently being analyzed.

Dissertations

-

Scientific Publications

-

NOx formation in ultra-dilute, preheated combustion

Project Aim

Combustion using highly preheated air, together with diluted air and/or fuel, is a clean combustion concept that combines high efficiency and low pollutant emissions in industrial heating processes. To permit the optimization of NOx control, and to provide insight into the ultimate low-NOx potential of these methods, in this research we investigate the paths to NO formation in dilute, high temperature combustion. Towards this end, we perform quantitative laser-diagnostic measurements of flame structure, using LIF, Raman and TDLAS methods in the laminar coflow geometry, combined with detailed numerical simulations of the structure of the reaction zone.

Progress

Measurements of flame structure on highly preheated and highly diluted methane flames demonstrate that MILD combustion can be simulated in a jet in hot coflow geometry. Raman scattering of major species (CH4, N2, CO, CO2, H2O and O2) and temperature show a diffusion-flame-like structure with a wider spatial extent than in normal diffusion flames. Furthermore, the maximum temperature increasse due to combustion was restricted to <300 K. Measurements of NO (LIF) in these flames shows negligible NO formation in the combustion zone, with most NO originating in the hot coflow. The mixture fraction analysis also indicates the strong influence of mixing on the NO profile.

Dissertations

-

Scientific Publications

1. Sepman, A.V., Mokhov, A.V. and Levinsky, H.B., The effects of hydrogen addition on HCN formation in atmospheric-pressure, fuel-rich-premixed, burner-stabilized methane, ethane and propane flames, Int. J. Hydrogen Energy, Vol. 36(21), 13831-13837 (2011).
2. Sepman, A.V., Mokhov, A.V. and Levinsky, H.B., Extending the predictions of chemical mechanisms for hydrogen combustion: comparison of predicted and measured flame temperatures in burner-stabilized, 1-D flames, Int. J. Hydrogen Energy Vol. 36(15), 9298-9303 (2011).
3. Sepman, A.V., Mokhov, A.V. and Levinsky, H.B., The effects of hydrogen addition on NO formation in atmospheric-pressure, fuel-rich-premixed, burner-stabilized methane, ethane and propane flames, Int. J. Hydrogen Energy Vol. 36, 4474-4481 (2011).

Projectleaders
HB Levinsky, AV Mokhov

Researchtheme
Complex structures of fluids

Participants
AV Sepman

Cooperations
TU/e, Tata, Numeca

Funded
STW, Tata, Numeca

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

Start of the project
2009

Information
HB Levinsky
KEMA
050 7009739
www.flame.fmns.rug.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

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 UPC on symmetry-preserving regularization models for turbulence is continued. In particularly, spatial filters and dissipation models for unstructed meshes have been considered. 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. The parallel scaling of our DNS/LES simulation code has been evaluated. The QR eddy viscosity model for turbulent flow has been improved.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

1. Julian E. Jaramillo, Carlos D. Perez-Segarra, Oriol Lehmkuhl, Jesus Casto, Detailed analysis of turbulent flows in air curtains, Progress in Computational Fluid Dynamics, 11(6), pp. 350--362, 2011.
2. O. Lehmkuhl, R. Borell, C.D. Perez-Segarra, A. Oliva and R. Verstappen, LES modeling of the turbulent flow over an Ahmed car. In: Direct and Large-Eddy Simulation VIII, pp. 89--94, Springer, 2011.
3. F.X. Trias, A. Gorobets, R.W.C.P. Verstappen and A. Oliva, Symmetry-preserving regularization of wall-bounded turbulent flows,Journal of Physics: Conference Series, 318, paperno:042060, 2011.
4. F.X. Trias, A. Gorobets, A. Oliva and R. Verstappen, Regularization modeling of buoyancy-driven flows,. In: Direct and Large-Eddy Simulation VIII, pp. 21-26, Springer, 2011.
5. F.X. Trias and R.W.C.P. Verstappen, On the construction of discrete filters for symmetry-preserving regularization models, Computer & Fluids, 40(1), pp. 139-148, 2011.
6. Roel Verstappen, When does eddy viscosity damp subfilter scales sufficiently?, Journal of Scientific Computing, 49, pp. 94-110, 2011.
7. Roel Verstappen, Scale-separation models for the larger eddies in turbulent flow. Bulletin of the American Physical Society, 56(18), p. 207, 2011.
8. Roel Verstappen, On eddy viscosity models that restrict the dynamics to the larger eddies, Journal of Physics: Conference Series, 318, paperno:042034, 2011.
9. R. Verstappen, An eddy-viscosity model based on the invariants of the rate-of-strain tensor. In: Direct and Large-Eddy Simulation VIII, pp. 83-88, Springer, 2011.

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), P Moin (Stanford)

COOPERATIONS

NLR, MARIN, TUD, UT, Politechnical University of Catalunya (Barcelona, E), Stanford University (USA)

FUNDED

Agentschap.nl (EZ), Ubbo Emmius Fonds (RUG), AGAUR (Spain)

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

START OF THE PROJECT

1996

INFORMATION

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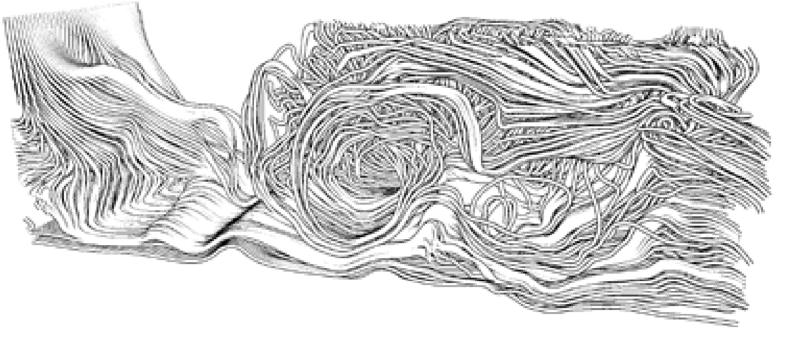
10. Roel Verstappen, When does eddy viscosity damp subfilter scales sufficiently? In:M.V. Salvetti et al. (eds), Quality and Reliability of Large-Eddy Simulations II, ERCOFTAC Series 16, Springer, pp. 421-430, 2011.
11. Roel Verstappen, Eddy viscosity models that restrict the dynamics to large eddies. In: Proceedings 13th European Turbulence Conference (ETC13), Warsaw, Poland, 2011.



Visualization of a simulated thermally-driven turbulent flow using a depth-dependent halo technique (selected by the American Physical Society for the Gallery of Fluid Motion, November 2011)

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 STW-funded ComFLOW-3 project on hydrodynamic wave loading by extreme waves was continued. Main collaborators are TU Delft, MARIN, Deltares and FORCE Technology Norway. A new release of the simulation software (v3.0) has been distributed among the industrial sponsors. In the new developments, physical emphasis is on modeling viscous effects during wave impact (e.g. for sloshing and side-by-side mooring). Hereto, a regularization model from our turbulent-flow research is being implemented. Numerical efficiency is improved with local grid refinement and parallelization. The TUD-part of the project focusses on improved wave generation and absorption. Finally, a PhD student form the University of Galati (Romania) spent 8 months at RUG.

Dissertations

-

Scientific Publications

1. B. Duz, R.H.M. Huijsmans, P.R. Wellens, M.J.A. Borsboom and A.E.P. Veldman, Towards a general-purpose open boundary condition for wave simulations. In: 30th Conf. on Ocean, Offshore and Arctic Eng. OMAE2011, Rotterdam, Netherlands, June 19-24, 2011 (paper OMAE2011-49979; 9 pags.)
2. B. Duz, R.H.M. Huijsmans, P.R. Wellens, M.J.A. Borsboom and A.E.P. Veldman, An absorbing boundary condition for regular and irregular wave simulations. In: L. Eca, E. Onate, J. Garcia, P. Bergan and T. Kvamsdal (eds.) Proc. V Int. Conf. Comp. Meth. Marine Eng. MARINE2011, Lisbon, Portugal, September 28-30, 2011 (paper 41, 12 pags.)
3. R. Luppes, B. Duz, H.J.L. van der Heiden, P. van der Plas and A.E.P. Veldman, Numerical simulation of extreme wave impact on offshore platforms and coastal constructions. In: L. Eca, E. Onate, J. Garcia, P. Bergan and T. Kvamsdal (eds.) Proc. V Int. Conf. Comp. Meth. Marine Eng. MARINE2011, Lisbon, Portugal, September 28-30, 2011 (paper 54, 12 pags.)
4. A.E.P. Veldman, R. Luppes, T. Bunnik, R.H.M. Huijsmans, B. Duz, B. Iwanowski, R. Wemmenhove, M.J.A. Borsboom, P.R. Wellens, H.J.L. van der Heiden and P. van der Plas, Extreme wave impact on offshore platforms and coastal constructions. In: 30th Conf. on Ocean, Offshore and Arctic Eng. OMAE2011, Rotterdam, Netherlands, June 19-24, 2011 (paper OMAE2011-49488; 12 pags.).

Projectleaders

AEP Veldman

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

HJL van der Heiden, R Luppes, P van der Plas, AEP Veldman; B Duz (TUD), RHM Huijsmans (TUD), T Bunnik (MARIN), PR Wellens (Deltares), MJA Borsboom (Deltares), S Dianescu (Galati)

Cooperations

TU Delft, MARIN, Deltares, FORCE Technology (Norway), University of Galati (Romania)

Funded

STW

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

Start of the project

1999

Information

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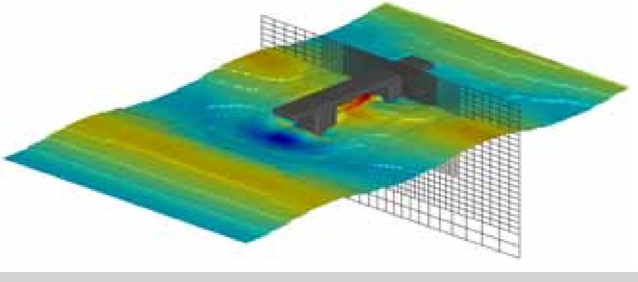

Simulation of flow past a semi-submersible with local grid refinement

Numerical methods for the incompressible Navier-Stokes equations

Projectleaders
FW Wubs
Researchtheme
Mathematical and computational methods for fluid flow analysis
Participants
J Thies, FW Wubs, HA Dijkstra (UU). U Erdogan (Ege Univ.)
Cooperations
IMAU (UU), UL Bruxelles (B), TU Braunschweig (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
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050 363 3994
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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 two level 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.

Progress

In the research on sparse-matrix solvers it could be shown theoretically that for HYMLS the convergence is independent of the grid size. A multilevel variant is currently under development. Also the work on solving eigenvalue problems was picked up again (Sleijpen &Wubs 2003) since solving bordered/ augmented systems with the HYMLS preconditioner is easy and robust. This is not only relevant for eigenvalue computation, but also for continuation and for the solution of Stochastic PDEs. It appears that with HYMLS we can also get convergence independent of the grid for this kind of problems. Also an interface is made to OpenFoam in order to be able to profit from the easy way of defining problems in this package.

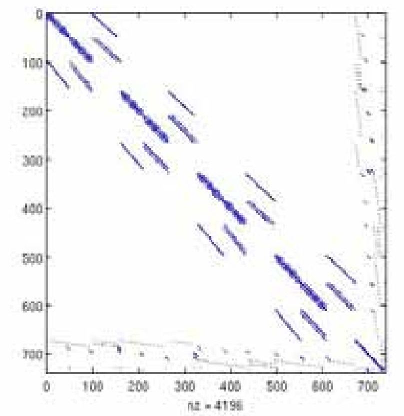
Dissertations

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. Jonas Thies and Fred Wubs, Design of a Parallel Hybrid Direct/Iterative Solver for CFD Problems. Proceedings of the 2011 IEEE 7th International Conference on E-Science, pp. 387--394, 2011.
2. Matthijs den Toom, Henk A. Dijkstra, and Fred W. Wubs. Spurious multiple equilibria introduced by convective adjustment. Ocean Modelling, 38(1-2):126-137, 2011.
3. Fred W. Wubs and Jonas Thies. A Robust Two-Level Incomplete Factorization for (Navier-)Stokes Saddle Point Matrices. SIAM. J. Matrix Anal. and Appl., 32:1475--1499, 2011.

Sparsity pattern of a re-ordered matrix from an oceanographic calculation.



PROJECT AIM

Research focuses on numerical methods to investigate stability and bifurcation behaviour of large-scale problems from our other research applications. Of particular interest are the stability of the global ocean circulation and of coherent structures in turbulent flow.

PROGRESS

The numerical bifurcation analysis project focuses on the computation of self-sustaining coherent structures (unstable periodic solutions) in flow models in the turbulent regime. In this way a link with our turbulent flow research is established. Continuation methods have been developed in MATLAB to find traveling wave solutions. In the cooperation with IMAU we started to work on bifurcation analysis for stochastic PDEs.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

PROJECTLEADERS

FW Wubs

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

H Kırbaş, FW Wubs, RWCP Verstappen, AEP Veldman, S Matle

COOPERATIONS

University of Leuven

FUNDED

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

START OF THE PROJECT

2004

INFORMATION

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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
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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.

Dissertations

-

Scientific Publications

1. H.A. Bijleveld and A.E.P. Veldman, Prediction of unsteady flow over airfoils using a quasi-simultaneous interaction method. In: Proceedings of 7th EAWE PhD Seminar on Wind Energy in Europe, Delft, the Netherlands, October 27-28, 2011 (10 pags.)

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

Multilevel preconditioners have been applied to the solution of 3D unstructured RANS models for compressible and incompressible turbulent CFD simulations. The results have been presented at the Conf. on Parallel Processing and Appl. Math. (Torun, Poland). Continuing the work started in 2010 on Krylov subspace solvers, in 2011 stable variants of the BiCOR family of iterative methods have been developed in collaborations with the University of Chengdu. Results with the new family of solvers have been presented at the conferences in Moscow and Chengdu. A PhD vacancy has been filled on matrix solvers for sparse matrices. The research on numerical methods for electromagnetics has driven to new fertile contacts with the Group by Prof. Xin-Qing Sheng at the Beijing Institute of Technology, leading to a paper submission and a joint conference presentation.

Dissertations

-

Scientific Publications

1. B. Carpentieri, Y.-F. Jing and T.-Z. Huang, The BiCOR and CORS Iterative Algorithms for Solving Nonsymmetric Linear Systems, SIAM J. Scientific Computing, 33 (2011) 3020-3036.
2. B. Carpentieri, Y.-F. Jing, T.-Z. Huang, W.-C. Pi and X.-Q. Sheng, A novel family of iterative solvers for method of moments discretizations of Maxwell equations. In: Levent Gurel (ed.) In CEM'11 Computational Electromagnetics, Bilkent University, Computational Electromagnetics Research Center, 2011, 85-90.
3. 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, In: Levent Gurel (ed.) In CEM'11 Computational Electromagnetics, Bilkent University, Computational Electromagnetics Research Center, 2011, 80-84.

Projectleaders

B Carpentieri

Researchtheme

Mathematical and computational methods for fluid flow analysis

Participants

J Liao, B Carpentieri, YF Jing (Chengdu)

Cooperations

University of Chengdu (China), Beijing Institue of Technology (China)

Funded

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

Start of the project

2010

Information

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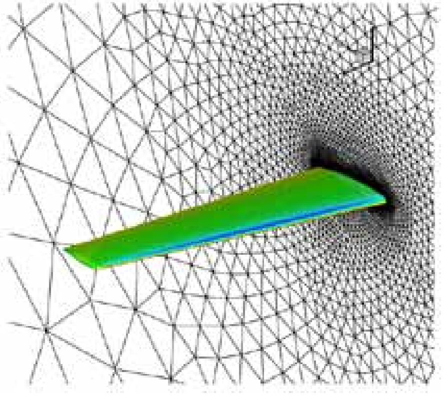

Unstructured grid, around wing, on which implicit RaNS is solved with a Krylov method.

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

The jamming transition of disordered systems has been widely studied theoretically in terms of an ideal linear regime. However, we know that the extent of this regime should vanish in the vicinity of the jamming point, therefore we need to study the non linearities, for example in terms of rearrangements of particles, or in terms of amplitude dependency in oscillatory rheology, to build a more accurate physical understanding of the jamming transition.

PROGRESS

We found out that our base system of numerical packings, widely used in the jamming community, presented in the static regime a natural instability to shear, endangering the pertinence of mechanical studies of these systems (static and dynamic). We understood and resolved this major difficulty with a relaxation of the boundaries of our system, and we are now including this concept to oscillatory rheology.

DISSERTATIONS

-

SCIENTIFIC PUBLICATIONS

-

.

PROJECTLEADERS

ML van Hecke

RESEARCHTHEME

Mathematical and computational methods for fluid flow analysis

PARTICIPANTS

ML van Hecke, Simon Dagois-Bohy

COOPERATIONS

Brian Tighe

FUNDED

FOM

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

START OF THE PROJECT

2010

INFORMATION

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Projectleaders
ML van Hecke
Researchtheme
Complex dynamics of fluids
Participants
Sole participant
Cooperations
-
Funded

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

Start of the project
2009
Information
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Project Aim

Probe the scaling of the bulk and shear modulus close to the jamming transition in two dimensional foams under a glass plate.

Progress

We have observed that the bulk modulus remains finite at the jamming transition, in agreement with theoretical and numerical analysis. In addition, it still remains quite clear that foams are tricky to work with, to no great surprise to the foam community.

Dissertations

-

Scientific Publications

-

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. Dijksman, Wortel, v. Dellen, Dauchot, Van Hecke, PRL, 2011.

Projectleaders
ML van Hecke

Researchtheme
Complex dynamics 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

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Rheology of jammed foams

Projectleaders
M van Hecke

Researchtheme
Complex dynamics of fluids

Participants
E Woldhuis, B Tighe, Vijayakumar Chikkadi

Cooperations
-

Funded

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

Start of the project
2008

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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

-

Prof.dr.ir. B Koren

In Koren's Scientific Computing group (Leiden University and Centrum Wiskunde & Informatica, Amsterdam), advanced numerical techniques are developed. Applications are computational problems in fluid dynamics, magnetohydrodynamics and risk management. At present, emphasis lies on the development of:

- immersed boundary methods for flow computations around complex moving and/or deforming bodies,
- a computational method for wind-farm aerodynamics, and
- a numerical method for the Hamilton-Jacobi-Bellman equation, for the control of the heights of primary dikes in the Netherlands. Research has also been started on the investigation of:
- Edge Localized Modes in tokamak plasmas, by further development and application of computational tools.

Development of a computational tool for the simulation of wind-farm aerodynamics

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

Research focused on time-integration methods for the unsteady incompressible Navier-Stokes equations, particularly on:

- energy-conserving, high-order time-accurate Gauss-Legendre Runge-Kutta methods; an article on energy-conserving Runge-Kutta methods is under review at the Journal of Computational Physics.
- accuracy analysis of velocity and pressure with explicit Runge-Kutta methods, including moving meshes and time-dependent boundary conditions; an article on this topic is published in the Journal of Computational Physics.

Furthermore, a new discretization for using actuator methods in fluid dynamics has been proposed and an article is being prepared. Such actuator methods will be used to model the effect of wind turbines blades on the flow.

Dissertations

-

Scientific Publications

1. B. Sanderse, B. Koren: Accuracy analysis of explicit Runge-Kutta methods applied to the incompressible Navier-Stokes equations, Journal of Computational Physics (231):3041-3063, 2011. doi:10.1016/j.jcp.2011.11.028.
2. B. Sanderse, S.P. van der Pijl, B. Koren. Review of computational fluid dynamics for wind turbine wake aerodynamics. Wind Energy (14):799-819, 2011. doi:10.1002/we.458.

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

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Investigation of edge localized modes by further development and application of computational tools

Projectleaders
B Koren, HJ de Blank

Researchtheme
Complex dynamics of fluids

Participants
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Cooperations
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Funded
FOM (FOM Program 120, "Burn Control")

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

Start of the project
2009

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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

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Dissertations

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Scientific Publications

1. The magnetohydrodynamic spectrum of toroidally rotating tokamak plasmas was investigated. Several types of modes were found numerically and studied analytically: J. W. Haverkort and H. J. de Blank, Plasma Phys. Control. Fusion 53, 045008 (2011).
2. A simple local magnetohydrodynamic stability criterion for tokamak plasmas including the effects of toroidal rotation was derived: J. W. Haverkort and H. J. de Blank, Plasma Phys. Control. Fusion 53, 045008 (2011).

Control and mitigation 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 find ways to control and mitigate ELMs in an early stage of their development.

Progress

A new finite difference and finite volume method for anisotropic diffusion was developed. This should result in a book chapter on advanced numerical methods, an article in the Journal of Computational Physics and a conference paper. Some preliminary work has been done to develop an approximate Riemann solver for MHD.

Dissertations

-

Scientific Publications

-

Projectleaders

B Koren, HJ de Blank

Researchtheme

Complex dynamics of fluids

Participants

B van Es

Cooperations

FOM Institute for Plasma Physics "Rijnhuizen", CWI

Funded

FOM (FOM Program 120, "Burn Control")

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

Start of the project

2011

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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. Biomechanics of horses
4. Evolutionary mechanics of live bearing fish
5. Biomechanics of tongues and tentacles
6. Biophysics of sensory systems
7. Biofluid dynamics of filter feeding in invertebrates

Mechanisms of manoeuvrability through undulatory fin propulsion

Project Aim

Undulating fin propulsion as used by seahorses and catfish (Sepia, ‘nearly’ rigid-bodied animals) offers many advantages: from stable, low speed swimming, hovering at certain depths to an unsurpassed maneuvrability. Catfish (Sepia) use a body-surrounding muscular fin, while seahorses use a combination of one caudal and two pectoral fins to perform complex maneuvers. 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

A lot of effort was put into the holding, handling and training of the animals since this is the key to be able to conduct experiments with the least stress and discomfort for the animals. A first seahorse locomotion experiment was conducted, looking at the caudal fin and body kinematics by respectively two and three high-speed video cameras. To extract the relevant kinematic data, a calibration method which takes into account the refraction and distortion of the acquired images is being developed, together with a new automated hull tracking algorithm, focused on Sepia and seahorse locomotion. A new test setup is being developed to link the fin and body kinematics of arbitrary Sepia movements, including recordings from 8 synchronized high-speed camera’s. Initial steps were taken for future fluid mechanic experiments with Sepia and seahorses. Henrion presented the underwater robot project ‘’Galatea’’ on June 7th at the NWO event ‘’Bessensap’’ for a general audience. A BSc design synthesis exercise by a team students at the TU Delft on the development of an underwater robot with lateral undulating fin propulsion was guided by S. Henrion, T. Vercruyssen and others.

Dissertations

-

Scientific Publications

-

Projectleaders

JL van Leeuwen

Researchtheme

Complex dynamics of fluids

Participants

S Henrion, D Lentink

Cooperations

T Vercruyssen, MSc and Prof. FCT van der Helm, Biomechanical Engineering, TU Delft

Funded

Delphi Consortium and WU

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

Start of the project

2010

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JL van Leeuwen, D Lentink

Researchtheme
Complex dynamics of fluids

Participants
D Lentink

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

Start of the project
start PhD project: 2004 (diss. 2008)
start NWO ALW: 2007

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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

During the past year, we completed several experiments that will be published in the following years. The NWO project runs until March 31st 2012. Our main focus was to share our findings with the general public through the “Flight Artists” outreach project of team Lentink, that won the 2010 Dutch Academic Year Prize. The project was featured in NRC, Labyrint (VPRO) and the news section of Science in 2010, and in a broad range of media ever since. In 2011, the team educated 460 members of the general public to film flying animals using high-speed camera’s in their backyard. With our camera’s they made 1000 Casio (small format) and 1400 Phantom (HD up to 7500fps) movies of flying insects, birds and some bats. The results were featured in a special feature of Labyrint (VPRO-NTR) on national Dutch television in which the participants, their movies, and discoveries, were in the spotlight. NRC wrote an article about the project and we contributed to an extensive essay on how high-speed video cameras have revolutionized science ever since they were invented. We also used our camera to set the record for the smallest flying insect ever filmed at high speed, with a wing span of just 1 mm: http://www.youtube.com/watch?v=kZyIN23Cy4Y. We finished the first year (2011) of the project with a film festival in Wageningen in January 2012 with about 100 participants who contributed to the project. During the festival the participants shared their results with us. Artists also participated and one particularly successful project ‘a brief crack of light’ can be found here: http://vimeo.com/34828983 and in this movie clip they show the spirit of our outreach project: http://vimeo.com/33188741. The best movies were awarded by an international jury and featured in a press release that received world-wide attention, in particular by a story run by WIRED, which resulted in over 400.000 views on our YouTube winners channel: http://www.youtube.com/user/Vliegwinnaars/feed. Other movies and more information can be found here www.vliegkunstenaars.wur.nl.

Dissertations

1. D. Lentink (2008) Exploring the Biofluiddynamics of Swimming and Flight.

Scientific Publications

-

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.

Observational study of the equatorial boundary layer

Project Aim

Observations show that dynamically the ocean differs distinctly in a narrow zone of ±2 degree near the equator compared to off-equatorial regions. Geometric focusing of small–scale internal waves, traditionally neglected, might have an important effect on the dynamics of the equatorial zone, which we aim to illuminate by (1) three dimensional ray tracing study of internal wave beams in geophysical domains; (2) long term in situ measurements of physical fields along a cross-equatorial transect; (3) comparison to theoretical and numerical model predictions; and (4) development of these models.

Progress

A three dimensional ray tracing approach has been chosen and finalized in order to investigate internal wave behavior in enclosed domains of geophysical relevance, such as the sphere and the spherical shell. Focus is mainly on the physical correspondence between ray trajectories and energy paths for the spherical case, and on the 3D singular behavior in the spherical shell. The occurrence of singular features, the internal wave attractors, seems to dominate in the Equatorial band, where they are hypothesized to play a role in the real Ocean via wave-wave and wave-main flow interactions. Observational in situ data are currently under analysis in order to verify this hypothesis.

Dissertations

-

Scientific Publications

-

Projectleaders

LRM Maas

Researchtheme

Complex dynamics of fluids

Participants

LRM Maas, T Gerkema, H van Haren, A Rabitti

Cooperations

NIOZ, UU

Funded

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

Start of the project

2009

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