Conclusions
Ideas for new research collaborations and programmes in fluid mechanics

Evaluation report of the JMBC-FOM workshop
"Changing Flows: teaming up for new scientific challenges"
with participants from industries, TNO, GTI's and groups of the J.M. Burgerscentrum and FOM, in Utrecht on 19 June 2009.

By Pieter de Witte (FOM) and Gijs Ooms (JMBC)

Some facts about the workshop:

Presentations by industry/GTI/TNO: 12
Workshops by academic groups: 7
Participants: 121
from
Academic institutions: 61
Industry: 39
GTI/TNO: 16
Funding agencies: 5

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Ideas for new research collaborations and programmes in fluid mechanics

Summary
The aim of the JMBC-FOM workshop was to generate ideas for new collaborations and joint research programmes. During the meeting several proposals were discussed and actions were taken to further develop these proposals and submit them for sponsoring via the 2nd and 3rd money stream. The details are given in this report. Besides, a number of new 'players' started in this field recently, hence several new contacts were established among the participants. The new programme ideas together with the possibility to discuss these with the different stakeholders made the workshop very successful.

Introduction
There has always been a close co-operation between the groups of the J.M. Burgerscentrum and industries, TNO and GTI’s. FOM traditionally has strong ties to academic and industrial research on fundamental aspects of fluid mechanics.

The goal of this meeting was to learn about each other's research problems, state-of-the-art knowledge, to pinpoint options for collaboration, and to strengthen the network. In the morning focused 10-minute presentations were given by representatives from industries, TNO and research institutes about problems they encounter on the topic of fluid mechanics. In the afternoon, parallel workshops were organised by academic groups to present themselves and their expertise and discuss ideas for new research programs with the participants.

Below you can read about the main outcome of the day in a bird's-eye view. Conclusions of these afternoon workshops can be found in appendix 1. The programme of the workshop is depicted in appendix 2, while the abstracts of all the sessions can be read in appendix 3.

A bird's-eye view
Based on the combined presentations of both industries, TNO, GTI’s and academia, the following themes can be distilled from the meeting:

Industries, TNO and institutes welcome very much a close cooperation with university groups. In this way it is possible to combine research efforts, both on applied and more fundamental topics. It gives them also the possibility to come in contact with young people with the proper expertise in fluid mechanics and recruit them for their organisations.
Almost all presentations showed that multiphase flow is the rule rather than the exception. There is a need for continued research in this area, both aiming at short-term improvements that can directly be implemented and applied (e.g. in the form of new industrial correlations) and aiming at long-term new fundamental insights that can replace the exhausted current engineering approaches. The plan is to prepare a proposal for a new large FOM/STW/EZ programme on multiphase flow with interface phenomena, i.e. interface heat and mass transfer, including physical and chemical conversions. Co-sponsoring by industrial partners is needed. More information about this proposal is given in appendix 1.

Another topic that was often mentioned was rheology. It was for instance discussed by representatives from Unilever, Shell, Teijin Aramid, AkzoNobel and DOW. In industrial applications the rheology of liquids can be very complex with large differences in length and time-scale. There is a tendency towards an experimental/empirical approach with often cheap ingredients and fairly standard equipment. The research on rheology has received new interest in The Netherlands, in particular because a number of new groups with a more physical background study this topic (Bonn, Westerweel, Van Hecke). This new development is supported by the FOM programme "Rheophysics, connecting jamming and rheology". At the TUD the possibility is investigated to start a chair at the interface between fundamental research and technical, industrial applications in the area of rheology. See also appendix 1.

There was a considerable interest in mixing. There are two parts. The part "Flow and mixing in urban environments" is aimed at the growing need for accurate models for the dispersion of pollutant and toxic gases, as well as "acoustic pollution", in the urban environment. A new research program together with local and national government organisations and industries is currently being considered. The part "Physics of mixing" is restricted to non-turbulent mixing processes. It aims at answering two questions. 1) How can a deeper insight in the physical processes and mathematical modeling of mixing (as developed by several academic groups) contribute to improved mixing processes for different industrial applications? And in reverse order: 2) how can specific and fundamental questions from industries be translated into academic research programmes? As a follow-up step a workshop will be organised to bring national and international specialists in this field together with colleagues from R&D departments of Dutch industries, TNO and GTI’s. More information about this topic is given in appendix 1.

During the workshop developments of modern solvers for CFD problems and also particle-based simulation techniques were discussed. It is clear that these techniques are of crucial importance for many applications. During the workshop it appeared, that a growing number of university groups as well as
participating industries have started (or are about to start) with OpenFOAM software as an alternative to either in-house codes or commercial CFD software. Thus OpenFOAM could play an important role in models and knowledge transfer between academia and industry. It was suggested that JMBC could play a co-ordinating role in setting up a Dutch OpenFOAM community. It is also important to mention the fact that the mathematics groups at the three TU’s have started the Applied Mathematics Institute. The idea is to position applied mathematics research better and to stimulate the cooperation between groups working in this area. New challenging research themes will be studied. The 3TU-federation has been asked to financially support this initiative. See appendix 1 for more details.

The Dutch industries and institutes have a great need for intensified co-operation with universities on research in the area of **microfluidics, wetting and flow transport in thin layers**. Possible topics are lab-on-a-chip applications, superhydrophobic surfaces, optofluidics, oil-recovery, chip cooling, two-phase flow in microchannels, coating flows, dynamic contact lines. There are already several co-operations with industries (co-sponsored by FOM through its Industrial Partnership Programme) on this topic. New research plans in this field are under discussion. See also appendix 1.

In the field of **bioinspired design** several topics relating to fluid mechanics were discussed, e.g. swimming robots. This field is growing in the Netherlands, and industrial funding is still limited, hence an academic multidisciplinary research programme through STW, ALW and FOM should be considered.

**Conclusions**
Topics with follow-up activities (could lead to new research programmes):
- New programme on Multiphase Flow with interface phenomena (FOM/STW/EZ).
- Chair in rheology (TUD).
- Follow-up workshop on Physics of non-turbulent mixing (industries, institutes, academia).
- New programme on the Urban environment.
- Dutch Open FOAM community (JMBC co-ordinator).
- New programme on solver development (FOM (IPP)).
- Bio inspired design in fluid mechanics projects (STW).
- Multidisciplinary programme bio inspired design (FOM, ALW, STW).

Based on the combined presentations of both industry, and academia, the main conclusions from the workshop are:
- Industries, TNO and institutes are keen on establishing good contacts with university groups. They are prepared to sponsor new research proposals, when they are well prepared in close co-operation with them.
• Next to joint programmes industries, TNO and institutes often want to cooperate with a particular university group. In this way they can guide the programme better. Also confidentiality of the research plays a role.
• Many industries and institutes find the training of experts in the area of fluid mechanics the most important result of the PhD projects. They are mutually divided, how specific the knowledge of the experts must be.

Some more general conclusions of the meeting are:
• A very good knowledge of fluid mechanics is of crucial importance for many industries, TNO and institutes.
• Industries, TNO and institutes find it difficult to remain in control of the direction of the PhD-projects that they sponsor. It is essential that they have experts in their own organisations, who are allowed to participate regularly in the projects.
• The large industries in particular find the PhD-projects often too fundamental. They need also engineering correlations that can be used for applications. Technological advancement must be in a usable form for the industry.
• CFD-type modelling can be too time-consuming for industrial applications. A trade-off between computational effort and level of detail is often needed.
Appendix 1
Conclusions from the individual workshops

**Multiphase Flows**
Already in the morning sessions almost all industrial presentations showed that multiphase flow is the rule rather than the exception. There is a need for continued research in this area, both aiming at short-term improvements that can directly be implemented and applied (e.g. in the form of new industrial correlations) and aiming at long-term new fundamental insights that can replace the exhausted current engineering approaches.

In the afternoon the focus was on the plan to prepare a proposal for a new large FOM/STW/EZ program (aiming at 20+ PhD candidates over 6 years) on multiphase flow with interface phenomena, i.e. interface heat and mass transfer, including physical and chemical conversions. Co-sponsoring by industrial partners is needed. Three presentations from the industry were given (by DSM, Corus, and Shell), which all showed that there is lack of knowledge on the interface behaviour. There was a lively discussion with all the attendees on how to best set up the research program. The program should be: industry-driven, focused, and collaborative. Many of the applications seemed to be related to: production processes, production quality, and energy. The balanced focus in the new program should be on interface heat and mass transfer in dense dispersions (>10% volume fraction) in wall bounded configurations.

There are many challenging questions requiring new computational and experimental approaches. It was realized that developments in complex multiphase flow are hampered by the fact that the systems are opaque meaning that conventional optical measurement techniques as used for single-phase flow are not applicable. However there are high expectations from developing and using new measurement techniques like MRI and X-ray. This should be part of the new research program. A computational and experimental benchmarking configuration is planned to be set up, with contributions from various research groups. The configuration should be chosen such that it is of sufficient interest to a broad number of the industrial partners.

It was agreed that a program committee would be established to prepare the research proposal. Follow-up discussions with all interested industrial partners will be planned.

**Rheology and rheophysics**
The rheology workshop showed the great interest of industry in this topic and on collaboration with academic partners. To facilitate exchanges between industry and academics, the Soft Matter group of the University of Amsterdam has set up a rheology platform accessible to all. This is an example of the workshop discussion which showed that rheology is rapidly
changing at Dutch universities. It is evolving from more classical rheology to 'physical' rheology in which materials are not only characterized mechanically, but the physical, often microscopic reasons for the mechanical behaviour is also investigated. The Netherlands plays a pioneering role in this field; the FOM program on 'rheophysics' is merely one key example that was mentioned in the workshop.

There is a demand for new rheological instruments that can access shear rates over the areas of interest, and that can also provide data at high pressures and high temperatures. A possible synergy is foreseen between the fluids community and materials community, in terms of the 'design of fluids/materials with specific rheological properties.'

**Flow and mixing in microfluidics, process industry and urban environment**

As mentioned there was a considerable interest in **mixing**. There are two parts. The part "**Flow and mixing in urban environments**" is aimed at the growing need for accurate models for the dispersion of pollutant and toxic gases, as well as "acoustic pollution", in the urban environment. Scientific challenges lie in the very large Reynolds and Rayleigh numbers, in the extreme disparity of the relevant scales, and in the importance of small-amplitude phenomena. An important issue is inverse modeling, i.e. tracing back pollution sources from measurement networks data. Urban flow phenomena are strongly influenced by meteorological conditions, such as wind and stratification. Therefore, fluid dynamics researchers should closely collaborate with boundary layer meteorologists. The CLEAR-Delft (Combined Delft Laboratories for Environmental and Atmospheric Research) initiative combines the knowledge and facilities of academic groups and has expertise in modeling of urban and atmospheric flows, next to large-scale laboratories and wind tunnels.

A new research program together with local and national government organizations and industries is currently being considered.

Industrial mixing and (emerging) micro-fluidics technologies are important motivations for scientific research on the physics of mixing. As mixing in industrial and environmental flows covers huge length, time and velocity scales the deliberate choice has been made to restrict the "**Physics of Mixing**" proposal to non-turbulent mixing processes. It aims at answering two questions. 1) How can a deeper insight in the physical processes and mathematical modeling of mixing (as developed by several academic groups) contribute to improved mixing processes for different industrial applications? And in reverse order: 2) how can specific and fundamental questions from industries be translated into academic research programs. The feasibility of a research program that can be set up in a co-operation between industries, institutes and academic is investigated. Several highlights from academic and industrial research have been illustrated with emphasis on mixing in laminar flows, including industrial mixing devices and micro-fluidic applications,
mixing across interfaces and in granular systems. As a follow-up step a workshop will be organized to bring national and international specialists in this field together with colleagues from R&D departments of Dutch industries, TNO and GTI's. This workshop will be considered a success when increased collaboration emerges between groups with a fundamentally oriented research programme in the field of mixing and those in the applied sciences and industries.

**Microfluidics, wetting, and thin film flows**
Prof. Frieder Mugele (Physics of Complex Fluids, UTwente), Prof. Michiel Kreutzer (Product- and Process Engineering, TU Delft) and Prof. Anton Darhuber (Mesoscopic Transport Phenomena, TU Eindhoven) presented the main research thrusts of their groups and highlighted a representative selection of past and ongoing projects. Their presentations were followed by a lively discussion of several industry-specific problems, which helped establish new contacts between Dutch high-tech companies and academic research groups. One remark put forward from industry was that the solution of some particular difficult problems occasionally may require very specific know-how about material properties and processing conditions that are not typically available at universities. While concrete ideas for new large-scale research programs did not immediately emerge due to the diversity of topics discussed, there was consensus among all participants about the usefulness of the workshop.

**Particle simulation methods and modern solvers for CFD**
WHY do we need new, alternative, faster (for example particle) numerical methods/solvers?
1) Atoms, particles, and other discrete objects are NOT a continuum →
particle methods
2) Unresolved main challenges (for modeling) are:
   - coupling of continuum & particle systems
   - large gradients (free, moving surfaces)
   - (very) large deformations in general
   - multi-phase flows (solid-fluid-gas)
   - turbulent and reacting flows (e.g. flames: in this case the particles represent the continuum. The stochastic trajectories they follow mimic some features of turbulent motion of eddies. This is particularly useful for reacting flow, because in this method the chemical source terms appears in closed form ).
3) Modern solvers have seen tremendous progress in the last decade and The Netherlands must keep a pool of know-how and expertise.

Direct relations of this workshop to Industrial presentations:
particle methods for particle problems
+ Unilever (e.g. segregation, particle-fluid-temperature)
+ CORUS (e.g. particle flow, solid-fluid melting)
Challenges for modern solvers (CFD):
- free surfaces, large gradients, multiple phases
- particles and their interactions <=> validation
- particle methods can also solve CFD problems
- interfaces: anisotropic grids vs. no-grid

Needed is a fresh combined view on modeling, including physics&numerics and computers&mathematics

Chances for financial support:
- possibly FOM (Industrial Partnership Programme?) opportunities for solver development including particle- and modern continuum methods.
- SPH (Smooth particle hydrodynamics) → expertise is poor/missing in The Netherlands.

Bioinspired design: smart solutions from nature

Nature has produced an overwhelming number of solutions for technical problems through a long evolutionary process by natural selection. These solutions can be studied and used to derive engineering solutions for many practical problems. A famous example is Velcro which was invented by George de Mistral who was inspired by the sticking properties of the tiny hooks of the burs (seeds) of Burdock plants.

Bioinspired design is an expanding field of activity as apparent from a number of new journals in this area and a rising number of papers/year. Examples in the realm of fluid mechanics that were discussed during the meeting by representatives from the Universities of Wageningen, Delft and Eindhoven are autonomous micro air vehicles (inspired by birds and insects), underwater swimming robots (inspired by fish and squid), and propulsion in microfluidics (inspired by the motion of cilia).

In spite of the potential of this field, funding from industry is still limited. Within the JMBC several initiatives are currently available for the formulation STW projects, based on PhD studies and additional pilot work. Given the multidisciplinary nature of this field, it was proposed that ALW and FOM should be approached for a joint funding programme in this area. It was also proposed to extend the biofluiddynamicis section of the JMBC with work on bioinspired designs.
## Appendix 2 – Programme

### Morning

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<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Location</th>
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<tbody>
<tr>
<td>8.30 – 09.00</td>
<td>Registration/Coffee</td>
<td>Unico van Wassenaer zaal</td>
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<tr>
<td>09.00</td>
<td>Opening and Introduction – <em>Gijs Ooms</em></td>
<td>Graaf van Leicester Auditorium</td>
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<tr>
<td>09.15</td>
<td>Fluid mechanics in the Foods and Home- and Personal Care Industry</td>
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<td></td>
<td><em>Jo Janssen, Unilever</em></td>
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<tr>
<td>09.30</td>
<td>Multi scale flows in ship design</td>
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<td><em>Henk Prins, MARIN</em></td>
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<td>09.45</td>
<td>Fluid mechanics in the steelmaking industry</td>
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<td></td>
<td><em>René Duursma, Corus</em></td>
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<td>10.00</td>
<td>Fluid mechanics at TNO: accuracy in flow control</td>
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<td><em>Arij van Berkel, TNO</em></td>
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<td>10.15</td>
<td>Fluid mechanics at Shell</td>
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<td><em>Peter Veenstra, Shell</em></td>
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<td>10.30</td>
<td>Fluid mechanics at ECN/NRG</td>
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<td><em>Herman Snel, ECN/NRG</em></td>
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<td>10.45</td>
<td>BREAK</td>
<td>Unico van Wassenaer zaal</td>
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<tr>
<td>11.15</td>
<td>Fluid mechanics at Teijin Aramid</td>
<td>Graaf van Leicester Auditorium</td>
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<td><em>Hans Meerman, Teijin Aramid</em></td>
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<tr>
<td>11.30</td>
<td>The ESA Landscape of Fluid Mechanic Applications in Space</td>
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<td><em>Gorgio Saccoccia and Johan Steelant, ESA-ESTEC</em></td>
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<td>11.45</td>
<td>Fluid dynamics within Akzo Nobel</td>
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<td><em>Joop Baltussen, Akzo Nobel</em></td>
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<td>12.00</td>
<td>How to disseminate reference values in the nano-flow region?</td>
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<td><em>Mijndert van der Beek, VSL- Dutch Metrology Institute</em></td>
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<td>12.15</td>
<td>Fluid mechanics at Dow</td>
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<td><em>Gerrit Hommersom, Dow Benelux</em></td>
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<td>12.30</td>
<td>Fluid mechanics at Deltares</td>
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<td><em>Arthur Mynett, Deltares</em></td>
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<td>12.45</td>
<td>Closing remarks - <em>Gijs Ooms</em></td>
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<tr>
<td>13.00</td>
<td>LUNCH</td>
<td>Unico van Wassenaer zaal</td>
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**Programme**

**Afternoon**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Venue</th>
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| 14:00  | **1 Multiphase Flows - I**  
*Hans Kuipers (UT), Rob Mudde (TUD), Ruud Henkes (Shell, TUD)*  
Graaf van Leicester Auditorium |                                    |
|        | **2 Rheology and rheophysics**  
*Jerry Westerweel (TUD), Daniel Bonn (UvA)*  
Hertog van Brunswijk zaal |                                    |
|        | **3 Flow and mixing in microfluidics, process industry and urban environment**  
*Herman Clercx (TUE), Chris Kleijn (TUD)*  
Hertog van Alva zaal |                                    |
|        | **4 Flows: interactions with structures and electromagnetism**  
*Hester Bijl (TUD), Sasa Kenjeres (TUD)*  
Anna van Oostenrijk zaal |                                    |
| 15:00  | **BREAK**  
Unico van Wassenaer zaal |                                    |
| 15:15  | **1 Multiphase Flows - II**  
*Hans Kuipers (UT), Rob Mudde (TUD), Ruud Henkes (Shell, TUD)*  
Graaf van Leicester Auditorium |                                    |
|        | **5 Microfluidics, wetting, and thin film flows**  
*Frieder Mugele (UT), Anton Darhuber (TUE)*  
Hertog van Brunswijk zaal |                                    |
|        | **6 Particle simulation methods and Modern solvers for CFD**  
*Stefan Luding (UT), Kees Vuik (TUD)*  
Anna van Oostenrijk zaal |                                    |
|        | **7 Bioinspired design**  
*Johan van Leeuwen (WU)*  
Hertog van Alva zaal |                                    |
| 16:15  | **BORREL**  
Unico van Wassenaer zaal |                                    |
| 16:30  | **2 min. presentations of the results of every workshop by one of the workshop leaders, during the Borrel (=7x2 min)**  
Unico van Wassenaer zaal |                                    |
| 18:00  | **END** |                                    |
Appendix 3 – Abstracts

Morning

Fluid mechanics in the Foods and Home- and Personal Care Industry
Jo Janssen, Unilever
Unilever is a global manufacturer of foods and home- and personal care products. Part of the product portfolio can be classified as particulate systems, varying from fairly uniform granules (e.g. laundry detergent powders, granulated seasonings) to powder mixtures with a wide shape- and size range (e.g. dry soups). The flow of such mixtures and their segregation during processing and in-pack are topics of interest. Interaction between liquid and particles in granulation or coating processes is relevant as well. Many other Unilever products (e.g. spreads, dressings, ice cream, skin creams and liquid detergents) can be described as structured dispersions (emulsions, suspensions, foams). The complex rheology of these systems often limits detailed quantitative process modeling, and educated trade-offs between computational effort and level (and accuracy) of detail have to be made. The main approach is still experimental, facilitated by the fact that ingredients are relatively cheap and equipment is often rather standard. The development of appropriate measuring methods and sensors for dense, opaque systems (in-line and off-line) is clearly of interest in this context.

Multi scale flows in ship design
Henk Prins, MARIN
Traditionally, when designing a ship an engineer designs the hull shape for minimal resistance. With the resulting hull shape, the designer of the propulsion system tries to achieve an optimal efficiency by varying the geometry of the propeller. In this search for efficiency, he is constraint by problems cause by cavitation: pressure fluctuations, noise, vibrations, and erosion. It is easily understood that a better overall performance of a ship may be obtained by designing the ship hull and propeller in one design cycle: a slightly higher resistance may yield a better inflow into the propeller, thus a higher efficiency of the propeller, and thus fuel savings. However, this combined analysis of hull and propeller poses some serious problems: the steady flow around the hull has to be combined with the unsteady flow around the propeller. And the length of a ship (about 300m) is very large compared to the length-scale of the cavitation that needs to be predicted (order of millimetres). And above all, the total design of a ship can take no longer than a few weeks, thus limiting the time for a coupled calculation to less than a day. And then we are still dreaming about the influence of ocean waves, manoeuvres of the ship, and fluid-structure interactions.

Fluid mechanics in the steelmaking industry
René Duursma, Corus
Corus is a steelmaking company belonging to Tata. Tata operates worldwide and has production facilities stretching from the UK to Vietnam. All these facilities start with raw materials in solid form. Therefore Corus has strong interests in the behavior of granular matter. The needs will be illustrated with amounts handled in Corus. Processing of the materials includes inevitably a change from ores to liquid steel.
Handling of liquid metal simultaneous with the flow of gas and the change of chemical state attracts Corus interests. However, the interest in multi-phase flow is larger than in single flow. Our current interests will be illustrated with typical examples, including the scale of the application. The application of protective covers to Corus products is sometimes a more exotic subject, which will be illustrated with Corus' interests in the behavior of polymers.

**Fluid mechanics at TNO: accuracy in flow control**  
Arij van Berkel, TNO

Flow plays a central in many technologies. Some of the applications of flow in which TNO is involved are: oil and gas production, lithography, chemical reaction and separation and dispersion of emissions in the atmosphere. In all of these areas the trend is toward more accurate prediction and control of the flows.
The development of smart wells in the oil and gas industry calls for models that can visualize the flow patterns in the well based on only a small amount of data. On the basis of these models, the flow patterns in the well must be optimized. In lithography, both liquid gas flows are increasingly critical for the accuracy of the patterning and for contamination control. Prediction of flow phenomena in near vacuum or in very small channels or droplets is increasingly important. In some cases the flow must be manipulated at the droplet level.

Process intensification is an important new development in process technology. The underlying idea is to be able to control the reactions and separations at the level where they take place: the molecular level. This can only be achieved with sufficient knowledge and understanding of mass and energy transfer, or fluid dynamics in the equipment.

Dispersion of emissions in the near field atmosphere is increasingly important in safety analyses and environmental studies. Little is known about how to treat plumes and atmospheric, boundary layer, turbulence accurately enough in the first few hundred meters.

The coming years call for unprecedented accuracy in flow control and understanding.

**Fluid mechanics at Shell**  
Peter Veenstra, Shell

Contributions from the fluid flow area have proven to play an important role across most of our business applications. Basic knowledge of single phase flow and rheology is of importance. However, experience shows that people who studied and observed fluid flow phenomena in combination with another fluid phase and / or other discipline are contributing faster towards solutions. Areas where we are looking for improved knowledge and new tools are for example erosion, suspension and transport of a solids phase, mass transfer between phases with and without reaction, creation and separation of dispersions, and heat transfer between fluids and walls. A natural drive is to intensify the processes and push the operating envelopes towards extremes in terms of temperature, pressure and concentration. Fouling, nucleation and flow restriction due to choking can become an issue at those extremes conditions.

**Fluid mechanics at ECN/NRG**  
Herman Snel, ECN/NRG
At ECN/NRG, there are various areas of interest with respect to fluid mechanic phenomena. NRG has a computational fluid mechanics group which to a large degree offers consultancy services, mainly for industrial type flows. At ECN, one of the core interest areas is the aerodynamics of wind turbine rotors. The presentation will be restricted to this area.

With the growing size of wind turbine rotors (the largest commercial rotor has a diameter of 126 m, while a 150 m diameter rotor is in the design phase), ever more reliable design calculations are needed. Factors that complicate the phenomena include the frequent operation near or in stall, the aero-elastic interaction (stability issues), the high external turbulence levels, the strong interaction with the vorticity dominated wake and rotational effects on the boundary layer flow, transition and turbulent structures. Theoretical, computational and experimental (validation) developments are needed.

Fluid mechanics at Teijin Aramid
Hans Meerman, Teijin Aramid

Teijin Aramid is an international company selling worldwide aramid based yarn, staple and pulp under the trade names Twaron, Technora, Sulfron and Teijin Conex. Teijin Aramid is a part of the Teijin Group located in Japan. The common applied spinning technology in aforementioned products is in principle based on extrusion of a nematic/isotropic polymer solution into many small fibers (diameter app. 50 microns) followed by fixation of shape and structure of the fibers by solidification (cooling and/or phase separation) in the spinning bath. Fluid mechanics is present in several steps of the production processes. However, two main items on fluid mechanics occur in the hart of the spinning processes of above mentioned products: 1) The extrusion process and polymer flow of the nematic/isotropic polymer solution and 2) the heat, mass and momentum transfer between yarn and fluid in the spinning bath.

The ESA Landscape of Fluid Mechanic Applications in Space
Gorgio Saccoccia and Johan Steelant, ESA-ESTEC

Experimental campaigns, physical modelling and numerical simulation of fluid mechanics for aerospace applications require a wide coverage of operational conditions. This demands a vast variety of test rigs, simulation tools and physical models in multiple domains:
- subsonic to highly reactive and radiant hypersonic flows,
- continuum to rarefied environments
- multi-phase flow crossing sub-, trans- and supercritical conditions with both equilibrium and non-equilibrium thermodynamic behaviour
- flows in micro-units, micro-gravity, turbomachinery,...
- nose-to-tail computations of entire, propulsive vehicles
- ...

Applications vary from internal flows in (non)-cryogenic tanks and propulsion systems towards external flows around launch vehicles during ascent, (re)-entry vehicles during descent and spacecraft in orbit.

Special evolutions are therefore needed in accurate models, advanced numerical tools and dedicated experiments which can cover:
- radiant and non-equilibrium flows in plumes, combustion chambers and (re)-entry,
- (non)-catalytic interaction and ablative processes for thermal protection systems
- Flow interaction and control by means of MHD, EHD and plasma
- Multi-phase aspects during priming of propulsion lines, propellant injection, spray combustion...
- Fast transients in combination with non-equilibrium thermodynamics phenomena
- Coupling of Multi-disciplinary and multi-physical processes evolving towards overall optimization and performance assessment.

**Fluid dynamics within Akzo Nobel**
Joop Baltussen, Akzo Nobel

Most applications within Akzo Nobel concern processes of the Chemicals Business Units. Experimental and numerical flow modelling comprise many different single and multi phase systems. The largest challenges are in the simulation of highly loaded multi-phase systems. For the Coatings Business flow of fluids with a complex rheology is of interest.

Most important for Akzo Nobel is that the academia deliver young well-educated experts in Fluid Flow and Chemical Engineering who easily can integrate in our industrial or research groups and have the right education to continue their career within Akzo Nobel. An important asset of that is that the students have the right background and practical experience to communicate with the Chemical Engineers running the plants in our company. This implies that apart from a good knowledge of Fluid Dynamics a general education and experience in the application of CFD in Chemical Processes is relevant.

Most relevant for Akzo Nobel are multi phase processes at a high loading of dispersed phase. We are interested in experimentally validated correlations even if such correlations have a limited application window. We have a special interest in gas liquid flows with a high concentration of gas. Presently the coalescence of small, sub millimeter, bubbles has our attention. Use of results is greatly facilitated if newly developed code is implemented in commercial software codes or a general accessible open source code such as Open Foam.

**How to disseminate reference values in the nano-flow region?**
Mijndert van der Beek, VSL- Dutch Metrology Institute

The ultimate dream of some flow metrologists is to have primary standard for amount of substance for fluids and gases based upon a “Single Molecule Counter”, inspired by Single Electron Tunneling principle used by our Electrical colleagues. Although the realization of this SMC-dream is beyond the horizon yet, in the nano-flow region some progress has been made.

Recently a Proof-of-Principle of a nano-flow generator was demonstrated at VSL. The small system was build with the goal to realize a primary standard enabling the generation of a very small (gas)flow rate down to a few nano liters per hour on the bases of sound traceability and with acceptable accuracy.

The flow can be generated in suction as well as discharge mode. The uncertainty of the generated flow amounts to the order of 0.1% (2s) relative. Traceability is based upon volume and mass transfer (Dynamic Displacement principle).

During the presentation remaining challenges will be discussed like: “How to disseminate reference values for flow on nano scale?” , “Which existing transfer standards are available?” and “How to couple a small device (MEMS?) to the standard?”.
Fluid mechanics at Dow
Gerrit Hommersom, Dow Benelux
The chemical process industry faces major challenges in the area of process intensification, transformation to renewable feedstock processes and footprint reduction.
Yet, the current process technology and calculation methods will remain the backbone of the chemical process industries for some time in the future. The projects undertaken under the Burgers centre umbrella generate key scientific contributions to the industry. In addition, JMBC provides training opportunities for future staff. In that context, I want to impress on the individual curriculum leaders not to concentrate on a large scale into new research areas if such compromises the capability to train their students in present methods.
Fluid dynamics is a key enabler for the chemical process industry. It is typically not considered a core technology for the corporations. Students in fluid dynamics must be exposed to other key technologies to ascertain proper effectiveness in typical industrial research and design projects and provide an attractive career perspective.

Fluid mechanics at Deltares
Arthur Mynett, Deltares
Fluid Mechanics is an important discipline in the R&D program of Deltares, focusing on aspects related to hydrodynamics and geomechanics in Delta areas around the world.
The interest is not only in incompressible fluid (water) flow and waves in open water systems (rivers, lakes, canals, estuaries, coasts, oceans, ...), but also in multi-phase flow (sediment transport, mud & slurry flows, water quality aspects, ecosystem behavior, ...) as well as aspects related to multi-physics modeling.
There is a clear interest at Deltares in JMBC verifying some fundamental principles that are frequently being used in engineering design (e.g. initiation of sediment motion, drag and lift forces on hydraulic structures, fundamental aspects of fluid mixing (relevant for nutrient supply and harmful algal bloom event prediction). Some specific examples will be presented during the meeting, and concrete suggestions for joint research between Deltares and JMBC will be proposed.

Abstracts Afternoon

Workshop 1: Multiphase flows (part 1 and part 2)
Hans Kuipers (UT), Rob Mudde (TUD), Ruud Henkes (Shell, TUD)
The workshop will focus on applications of multiphase flows in which heat- and mass transfer, as well as conversion processes play a crucial role. In many cases these can be found at interfaces, either from the reactor or between the phases. First a summary will be given on the main achievements from the FOM/STW/EZ program on Dispersed Multiphase Flow. This is followed by three contributors from industry who will address the gaps in our knowledge seen from the application side. Furthermore, two contributions from academia will highlight future directions, sketch goals and address what is needed to reach them.
In the workshop, participants are invited to discuss the above. The workshop organizers would like to propose a new FOM/STW/EZ research program that concentrates on multiphase flows with heat- and mass transfer, as well as conversion processes. Input from the participants is highly appreciated. The outcome of the discussions will serve as the basis of ‘the new program in preparation’. For an applied program input from all partners is required. Moreover, the boundaries of such an applied research program can best be found from discussions.

Workshop 2: Rheology and rheophysics
Jerry Westerweel (TUD), Daniel Bonn (UvA)
The research on rheology is developing quickly in The Netherlands, in particular because a number of new groups with a more physical background study this topic (examples are groups at the UvA, Amolf, UL and TUD). This new development is supported by the FOM program ‘Jamming and rheology’, in which rheophysics is carried out with combined mechanical and optical techniques. The basic question in this research is: which microscopic phenomena cause a certain macroscopic flow behavior? This has led to activities at locations where in the past rheology was not a topic of study. A direct result is the formation of a platform on rheology at the UvA, where both academic and industrial researchers can use a number of rheological and rheo-optical instruments.

At the TUD the possibility is investigated to start a chair at the interface between fundamental research and technical, industrial applications in the area of rheology. The emphasis of this chair could be on flows of liquids with polymers (drag reduction in turbulent flows, elastic turbulence), flows with small particles or fibres (for instance blood flow), and micro- and nanofluidics (e.g. flows with a high shear rate for DNA-separation).

Workshop 3: Flow and mixing in microfluidics, process industry and urban environment
Herman Clercx (TUE), Chris Kleijn (TUD)
This workshop consists of two parts. The part "Flow and mixing in urban environments" is aimed at the growing need for accurate models for the dispersion of toxic gases and sound in the urban environment. This requires an approach in which different simulation techniques are combined with large-scale laboratory measurements. The Clear-Delft (Combined Laboratories for Environmental and Atmospheric Research) initiative combines the knowledge and facilities of academic groups and possesses next to expertise in modeling of atmospheric flows also large-scale laboratories and wind tunnels. The idea is to start a research program together with local and national government organizations and industries.

The part "Physics of mixing" aims at answering two questions. 1) How can a deeper insight in the physical processes and mathematical modeling of mixing (as developed by several academic groups) contribute to improved mixing processes for different industrial applications. And in reverse order: 2) How can specific and fundamental questions from industries be translated into academic research programs. We hope and expect to get a view during the workshop on the feasibility of a research program that can be set up in a cooperation between industries, institutes and academic groups.

Workshop 4: Flows: interactions with structures and electromagnetism

J.M. Burgerscentrum FOM
Hester Bijl (TUD), Sasa Kenjeres (TUD)
The first part of the workshop concerns numerical modelling of interactions between flows and structures. Examples of these interactions are found in many fields, from industrial processes - e.g. fiber spinning - to wind energy - e.g. vibrating wind turbine blades. Accurate solution of these complex, often non-linear, interaction phenomena is not trivial. Stability and efficiency of the simulations is of utmost importance. In the workshop a short presentation will be given on the current state-of-the-art in fluid-structure interaction simulations. Thereafter, in an open discussion, the main research questions will be collected, as well as possible ways to come to answers to these questions.

The second part of the workshop will address recent achievements in modelling and simulations of flows of electrically conductive fluids subjected to external electromagnetic fields (magnetofluidodynamic phenomena). Due to many limitations of the standard experimental techniques in providing simultaneous distributions of flow, turbulence, heat and electromagnetic field, numerical simulations can serve as powerful tools in providing such informations. Such fundamental insights are of great importance for better understanding, control and optimisation of many industrial and technological applications.

First we will demonstrate some recent results in simulations of magnetofluidodynamic phenomena in generic configurations used for detailed validation and benchmarking of the developed models and simulation techniques. Then, some real industrial and biomedical applications will be addressed (electromagnetic breaking in continuous casting of steel joining materials by arc-welding, electromagnetic heat transfer enhancement, and magnetic drug targeting).

Workshop 5: Microfluidics, wetting, and thin film flows
Frieder Mugele (UT), Anton Darhuber (TUE)
The aim of the workshop is to identify the needs of Dutch industries for intensified academic research in the area of microfluidics, wetting and flow transport in thin layers. Possible topics are lab-on-a-chip applications, superhydrophobic surfaces, optofluidics, oil-recovery, chip cooling, two-phase flow in microchannels, coating flows, dynamic contact lines. After introductions by Anton Darhuber and Frieder Mugele about earlier and current projects of cooperation with industries, there will be a discussion about new research plans in this field.

Workshop 6: Particle simulation methods and Modern solvers for CFD
Stefan Luding (UT), Kees Vuik (TUD)
In this workshop we would like to present some recent developments of particle simulation methods and modern solvers for CFD problems. It is well known that if the continuum hypothesis holds, then flows can be simulated by for instance the Navier Stokes equations, whereas for very diluted flows particle simulation methods are more appropriate. There is also the possibility of combining both approaches. The aims of this workshop are:
- present modern solution methods for both application areas
- investigate what type of problems are urgent in industries and GTIs
- what are the possibilities to formulate research proposals.

Workshop 7: Bioinspired design
Johan van Leeuwen (WU)
In biology, a great many solutions for complex fluid- and structural dynamics problems have been generated through evolution by natural selection. The unraveling of the underlying mechanisms requires the application of physical approaches. On the other hand, the solutions generated in Nature are a rich source of inspiration for technical designs, which generally deviate from biological examples owing to differences in functional demands, materials, and constructional constraints. The workshop will be started with an introduction of the participants and a presentation of a few typical examples of bioinspired design studies, including some current initiatives. Thereafter, a discussion will be started that aims to explore the mutual interests and possibilities for collaborative projects.