Annual Report

2022

J.M. Burgerscentrum

Research School for Fluid Mechanics

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TUD, TU/e, UT, RUG, WUR, UU, UvA

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Preface

The present annual report of the J.M. Burgerscentrum provides an overview of the activities of our research school during the year 2022. The core of the report consists of a pointwise summary of the 2022 research initiatives and achievements within each of the participating JMBC groups. In addition, also six research highlights are provided in the form of short articles, as prepared by junior JMBC members who received their PhD degree in 2022. The Annual Report also provides general information about the research school, such as its goals, its organization, and its relation with industries and technological institutes.

The number of PhD projects carried out by the JMBC groups has remained large (approximately 340). In addition, about 40 Postdocs are registered at the school. The work is supported by about 250 senior scientific staff members (i.e., full, associate, and assistant professors), registered at the Burgerscentrum. Finding funds for our PhD projects remains an important task for all JMBC groups. The financing of projects via NWO and via industries and technological institutes remains at a high level. Also, the sponsoring of projects via the European Research Council is substantial.

In the year 2022, the University of Amsterdam was accepted as 7th university in the Netherlands to participate in the Burgerscentrum, specifically with their Soft Matter Group. Also, two groups from the already participating universities were added to the Burgerscentrum, namely: Reservoir Engineering (Delft University of Technology) and Computational Mechanical and Materials Engineering (University of Groningen). We welcome the new groups, as they make the coverage of the broad area of fluid flow research within the Burgerscentrum more complete. In 2022, two board members of the Burgerscentrum, namely prof. Hans Hilgenkamp from the University of Twente and prof. Philip de Goey of Eindhoven University of Technology, ended their term. They are acknowledged for their important contribution in the past years. Two new board members will be announced in 2023.

A main achievement in 2022 within the Burgerscentrum is the delivery of 90 PhD Theses, among which a few with honours. A full list is given in this report.

In the year 2022, eight JMBC courses were organised. The course on “Technological Innovation with Fluid Mechanics” was given for the first time. Very positive feedback from the participants of the different courses was received. It is important to maintain our courses at a high level, and to continue looking for new topics. Organizing such courses remains a key task of the Burgerscentrum; they provide the JMBC PhD students the opportunity to deepen their knowledge in various aspects of fluid dynamics, but also to widen their perspective and give them an overview of the full field of fluid dynamics.

An important means to promote networking and collaboration on fluid mechanics within and outside the research school is the annual Burgers Symposium. This is a two-day gathering in Hotel De Werelt in Lunteren. Also in 2022 this was a great success with over 200 participants. The programme included the Burgers Lecture by prof. Dan Henningson, 50 talks by PhD students and postdocs, awards for the best presentations, and the Award Ceremony of the 2021 Hoogendoorn KIVI Award to dr. ir. Sina Tajfirooz.

In 2022, some of the scientific staff in the Burgerscentrum received prestigious grants. Among them are: an Advanced ERC grant for prof. Hans Kuipers, an ERC Proof of Concept grant for Alvaro Marin, an ERC Starting grant for Francesco Allone, Guillaume Lajoinie, and Tim Segers, and an NWO Vidi grant for Corentin Coulais and Willem Haverkort. Congratulations to all for this major achievement.

Collaboration between JMBC groups and teams in the industry and in the technological, as represented in the JMBC Advisory Board, is also of great importance to demonstrate the societal and economic impact of the fundamental and applied research efforts. In 2022, the representatives of the industry have helped with the preparation of the report "Flow for Future in the Netherlands", that quantifies the economic and societal impact of fluid flow. This supports the requirement to invest in fluid flow in the Netherlands to help solving the large challenges for a resilient and sustainable future in the Netherlands. The report will be published and promoted in 2023.

We are looking back at a very productive year 2022. We are grateful to all that actively contributed to the activities in the Burgerscentrum. We are confident that the Burgerscentrum will remain to play the leading role in the Research, Technology, and Engineering of Fluid Flow in the Netherlands.

Prof. dr. ir. Hans van Duijn	Prof. dr. ir. Ruud Henkes
Chairman of the JMBC Board	Scientific Director JMBC

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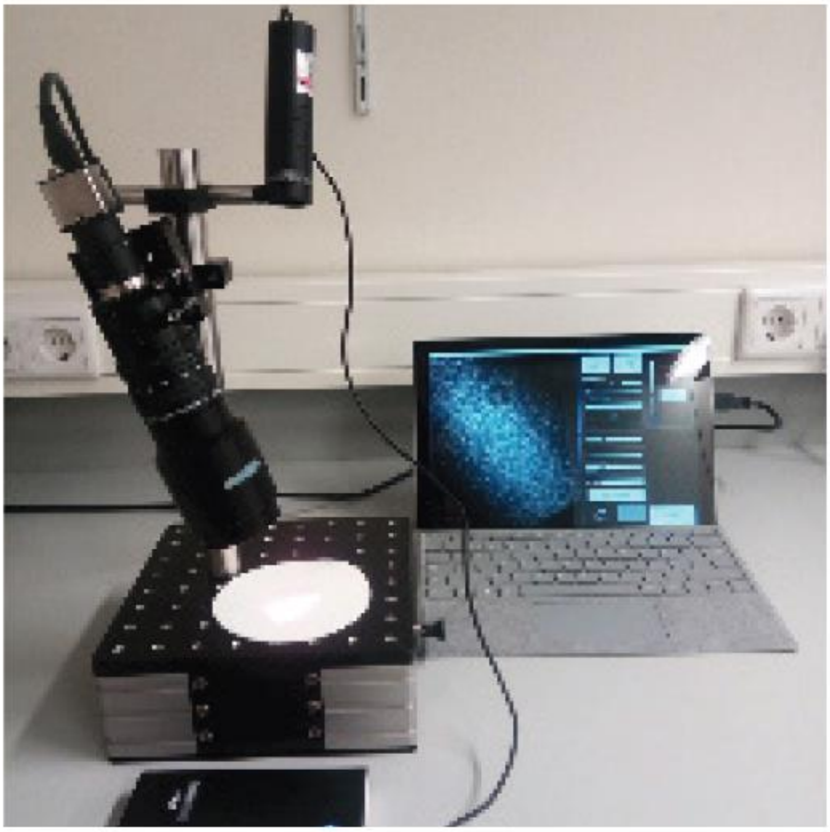

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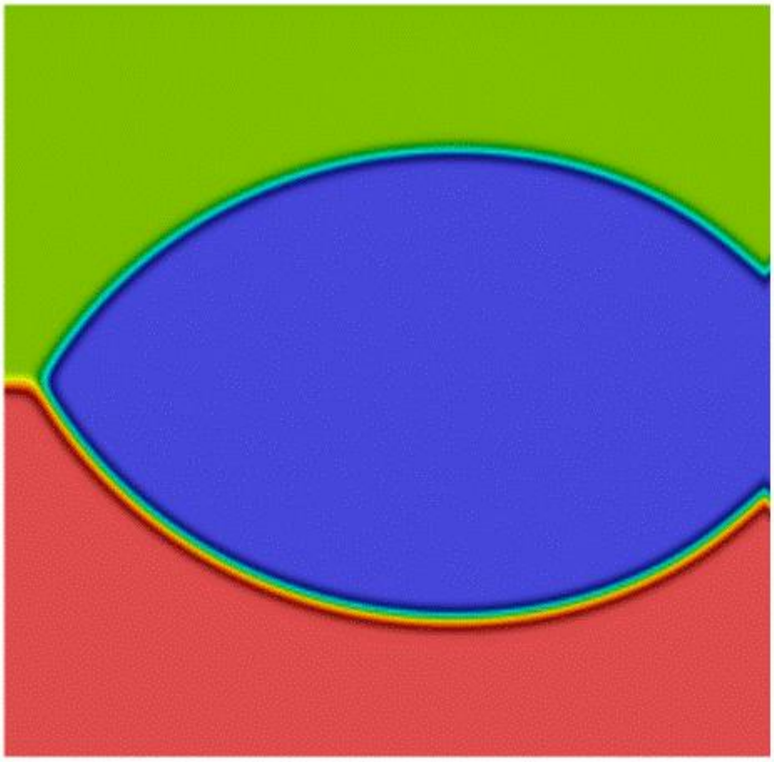


Introduction

The JM Burgerscentrum (JMBC) is the national research school for fluid mechanics in The Netherlands. Its main goals are:

- Stimulation of collaboration of the participating groups with respect to their research efforts. The JMBC aims at being one of the leading institutes for fluid mechanics in the world.
- Organization of advanced courses for PhD-students. These courses are also attended by postdocs and by researchers from industries and technological institutes.
- Co-operation with industries and technological institutes. The aim is to promote the use of up-to-date knowledge on fluid mechanics for solving practical problems.
- Strengthen the contacts between fluid mechanics research groups at Dutch universities and the international fluid mechanics community.

In total about 250 senior scientific staff members participate in the JMBC. The groups are located at the universities in Delft, Eindhoven, Twente, Groningen, Wageningen, Utrecht, and Amsterdam. The various fluid mechanics groups are based in different departments, and in different disciplines: in Civil Engineering; Mechanical Engineering, Maritime Technology, (Applied) Physics, Aerospace Engineering, Applied Mathematics, Chemical Technology, Biology, and in Physical Oceanography. The professors with their senior staff form the Council of Project leaders, which meets regularly. At the end of 2022, about 350 PhD-students and 40 postdocs were registered as participants of the JMBC.

The scientific director of the JMBC is assisted by the Management Team, consisting of the local directors in Delft, Eindhoven and Twente (who are also representing the groups in Groningen, Wageningen, Utrecht, and Amsterdam). The running of the JMBC takes place under final responsibility of the Board of the JMBC.

A number of contact groups in different topical areas are active, in the sense that they strengthen the network between researchers at different groups, promoting the exchange of expertise and experience between the participating groups. The various JMBC groups have intensive, active contacts and close links with industries and technological institutes in The Netherlands. This connection is formally facilitated by the Industrial Advisory Board, with members representing a large number of companies and technological institutes.

The JMBC research groups have various scientific contacts with research groups in other countries, often in the form of individual collaboration projects, but also in the form of organised networks. This international setting implies joint publications with other researchers from all over the world, and also exchange of staff: external visitors to the JMBC groups and JMBC staff visiting foreign fluid-mechanics groups.

As common practice in the scientific community, the research groups present their work at international conferences and in the form of journal publications. The number of publications from JMBC staff in well-known scientific journals is considerable.

An important activity of the JMBC is the organisation of the Burgers Symposium, which is the annual two-day meeting of the research school. This annual meeting is attended by more than 200 participants (both staff, PhD students, and postdocs). In addition to the plenary Burgers Lecture and the Evening Lecture the Symposium programme includes oral and poster presentations by the JMBC PhD students.

Each academic year the JMBC organises a number of special courses, meant primarily as advanced fluid-dynamical education of the PhD students and postdocs of the JMBC. The topics of these courses varies from one year to another, although some courses are given every other year. These courses are also open to participants from other research schools and from industry.

Research Program

The research program of the JMBC has been grouped into three main research themes. The reason for this structure is to present a combination of projects which have coherence, either in terms of physical models or in terms of mathematical methods.

The three themes are:
1. Complex dynamics of fluids
2. Complex structures of fluids
3. Mathematical and computational methods for fluid flow analysis

Fluid flows in the environment or in industrial applications are almost always characterised by some complexity. Frequently, it is this complexity that makes the flow an interesting topic of research. The first form of complex dynamics that comes to mind is turbulence, in contrast to laminar flow. In particular aspects like laminar-turbulence transition, effects of thermal buoyancy, compressibility and rotation, density stratification and the interaction with chemical reactions are topics that are actively being studied by a number of the JMBC groups.

Also, the presence of different phases, e.g. in the form of particles, bubbles or drops, may add to the complexity of flows. This class of flows, generally denoted as ‘dispersed multi-phase flow’ forms a strong focal point of research within the JMBC. Non-Newtonian and granular flows form a special class of complex flows that is being studied by a number of groups. Also, micro- and nanofluidics has become a topic that has attracted substantial attention, not in the least because of its important industrial and biomedical applications.

Advanced mathematical and computational techniques have become indispensable instruments for the description and understanding of complicated flow phenomena. The rapid increase of computational power has significantly stimulated the use of simulation techniques. In areas such as turbulent flow simulation, important progress has been made through refined modelling via Large-Eddy Simulation (LES), Direct Numerical Simulation (DNS) and stochastic methods. In other areas similar trends have become feasible, such as PDF modelling in combustion, and particle-based methods, like the Lattice-Boltzmann method.

Experimental techniques also play a crucial role in modern fluid-dynamics research. Many experimental methods are based on various forms of laser diagnostics, like e.g. PIV and PTV for flow measurements and CARS and LIF for measurements of temperatures and concentrations. Also, recording of ultrafast flow phenomena via high-speed camera techniques is playing an essential role in present-day fluid mechanics.

Within the JMBC, the various groups have built up extensive expertise on these aspects of experimental, theoretical and computational fluid dynamics. Within the framework of the network provided by the research school, stimulated by the contact groups, all groups benefit from this common pool of knowledge and expertise.

As usual in the scientific community, progress in the research projects is reported in the form of PhD theses, journal publications, contributions to conference proceedings, (chapters of) books, and in the form of presentations at conferences. In a number of industry-funded projects, some of the JMBC groups produce output in the form of special reports for industries and technological institutes.

Burgers Program for Fluid Dynamics at the University of Maryland

Inspired by the intellectual heritage of Johannes M. Burgers, who had a second career (1955 - 1981) at the University of Maryland after his retirement at Delft University of Technology, the mission of the Burgers Program for Fluid Dynamics is to enhance the quality and international visibility of the research and educational programs in fluid dynamics and related areas at the University of Maryland, in partnership with the J.M. Burgerscentrum (JMBC). Fluid dynamics in this context is viewed to include a broad range of dynamics, from nanoscales to geophysical scales, in simple and complex fluids.

The establishment of the Burgers Program was celebrated with an inaugural symposium at the University of Maryland in November 2004. Prof. Gijs Ooms, the Scientific Director of the JMBC at that time, gave a lecture on the life and legacy of Burgers on that occasion. The interdisciplinary Burgers Program encompasses almost 80 faculty members spread over 22 different units in the College of Computer, Mathematical and Natural Sciences and the A. James Clark School of Engineering. The program is currently led by Prof. James Duncan, Keystone Professor at the Department of Mechanical Engineering, University of Maryland.

In the fall of 2022, Prof. Hans Kuerten of Eindhoven University of Twente gave the Burgers Lecture at the 19th Annual Burgers Symposium. His (on-line) presentation was entitled: “Numerical simulation of particle-laden flow for improved plastic recycling”.

2022 Participation

The table shows the number of participants in the Burgerscentrum as per end 2022.

	TUD	TU/e	UT	RUG	WUR	UU	UvA	Total
Scientific staff	**92**	**70**	**69**	**6**	**6**	**2**	**7**	**252**
PhD students	**118**	**108**	**102**	**8**	**8**	**0**	**0**	**344**
Postdocs	**10**	**13**	**13**	**1**	**2**	**0**	**0**	**39**

2022 PhD Courses

31 January – 3 February 2022, Turbulence, Delft University of Technology, 38 participants.

31 January - 4 February 2022, Combustion, JMBC/ERCOFTAC, Eindhoven University of Technology, 44 participants.

4 – 8 April 2022, Complex Flows & Complex Fluids, CISM and Burgerscentrum, 22 participants.

9 – 13 May 2022, Capillarity-driven flows in microfluidics, Eindhoven University of Technology, 25 participants.

13 – 17 June 2022, Machine Learning in Fluid Mechanics, Eindhoven University of Technology, 46 participants.

20 – 24 June 2022, Computational Fluid Dynamics 1 (CFD 2), Delft University of Technology, 25 participants.

10 – 14 October 2022, Particle Image Velocimetry (PIV), Delft University of Technology, 35 participants).

7 – 11 November 2022, Technological Innovation with Fluid Mechanics, Delft University of Technology, 18 participants).

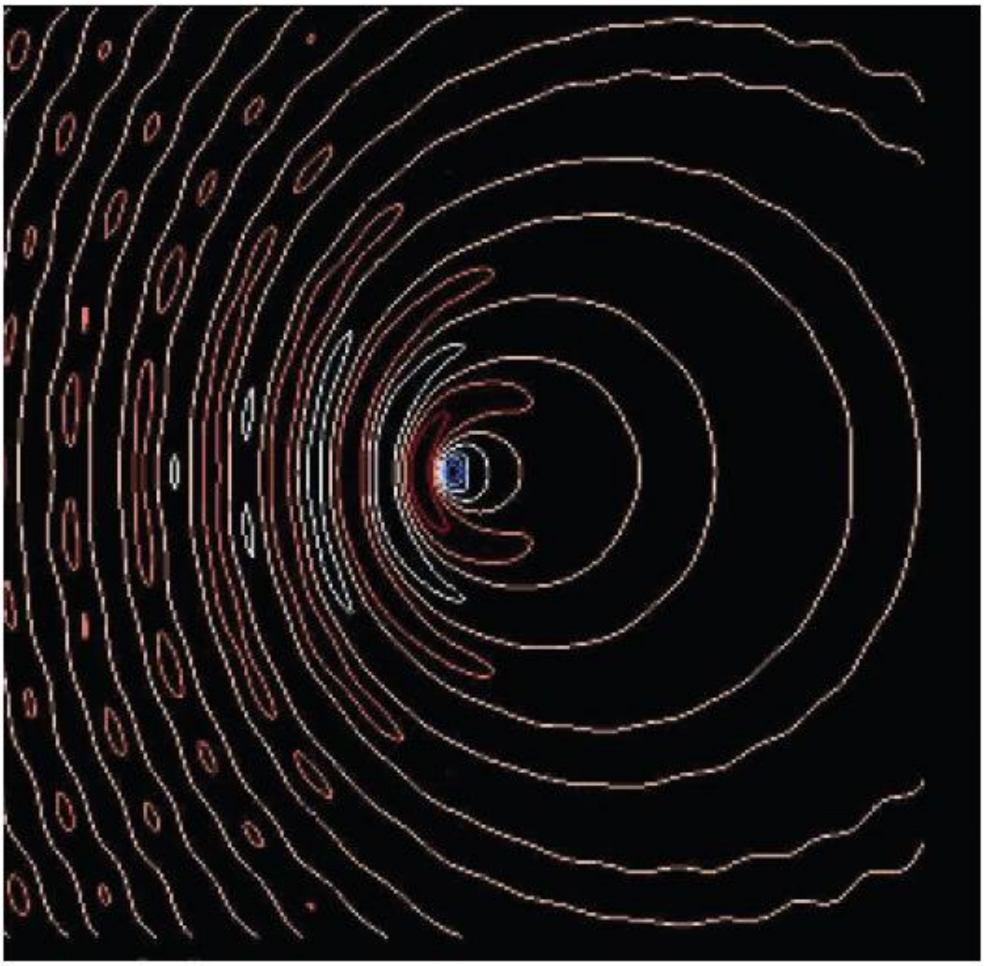
2022 Burgers Symposium

The yearly Burgers Symposium was held (in person) on 8 and 9 June 2022 in Hotel De Werelt in Lunteren. There was a large attendance (230 persons) from PhD students, postdocs, professors in the Burgerscentrum, as well as delegates from industries and technology organisations. The programme included the following:

- Burgers Lecture by Prof. Dan Heningson (KTH, Sweden), "Large scale numerical experiments of pitching wings and the role of laminar-turbulent transition".
- Evening Lecture by Prof. Brooke Flammang (New Jersey Institute of Technology /Rutgers University - Newark), “Fins in Flow: Fish-Fluid Interactions”.
- Farewell celebration for Prof. GertJan van Heijst, former Scientific Director of the Burgerscentrum.

- 50 oral presentations by PhD students and postdocs
- 6 oral presentations by new staff in the Burgerscentrum
- 3 oral presentations in the session “Fluid Flow in Industry”.
- 65 posters and 3 movies in the Burgers Gallery
- 2021 KIVI Hoogendoorn Fluid Mechanics Award (Laudatio and prestation) for dr. ir. Sina Tajfirooz (Eindhoven University of Technology)
- Burgers Symposium Awards for the 2 best oral best presentations (to Emma Hinderink and Jordi Casacuberta Puig), for the best poster with pitch (to Tsz Kin Timothy Chan), and for the best movie (to Uddalok Sen).

HIGHLIGHTS



This highlight refers to the PhD Thesis by Alexander Spoelstra (2022)

Ring of Fire as a novel approach to study cycling aerodynamics

Alexander Spoelstra, Wouter Terra and Andrea Sciacchitano

Delft University of Technology, Aerospace Engineering, Flow Physics and Technology

In many speed sports such as cycling or skating, aerodynamic drag constitutes up to 90% of the total resistance an athlete has to overcome. Understanding the physical mechanisms responsible for the production of the aerodynamic drag is key to maximize the athlete's performance, hence providing them with a competitive advantage. The research conducted in this PhD project introduces a new measurement concept for on-site aerodynamics investigation based on large-scale stereoscopic particle image velocimetry (stereo-PIV) measurements past an athlete, a vehicle or an object travelling through a quiescent environment (Spoelstra, 2022). The analysis of the momentum deficit past the transit poses the basis to estimate the aerodynamic drag. Such an approach, where the object crosses the illuminated measurement plane, is referred to as "Ring of Fire". The measurements are conducted with cyclists both in in-door and out-door environments (Spoestra et al. 2019, 2021a), skaters (Spoelstra et al., 2023) and road vehicles (Huetting et al., 2023). The effect of drafting in cycling is also investigated (Spoelstra et al., 2021b), assessing the aerodynamic benefit of the trailing rider depending on their lateral and longitudinal offset with respect to the leading rider. This document provides a concise overview of the working principle and main results of the Ring of Fire concept.

Working principle of the Ring of Fire concept

In this section, the Ring of Fire concept is explained for the analysis of the flow field and aerodynamic drag of a moving cyclist; however, the conclusions can be extended to other problems such as speed sports in general and ground vehicles. In contrast to typical wind tunnel conditions where the cyclist is at rest, in the Ring of Fire the cyclist is in motion, transiting through a fixed measurement plane (i.e. the laboratory frame of reference, $R = \{X',Y',Z'\}$ in Figure 1). A control volume centred at the cyclist location is considered to move with the cyclist ($R = \{X,Y,Z\}$ in Figure 1) at constant cycling velocity u_C with respect to the laboratory frame of reference.

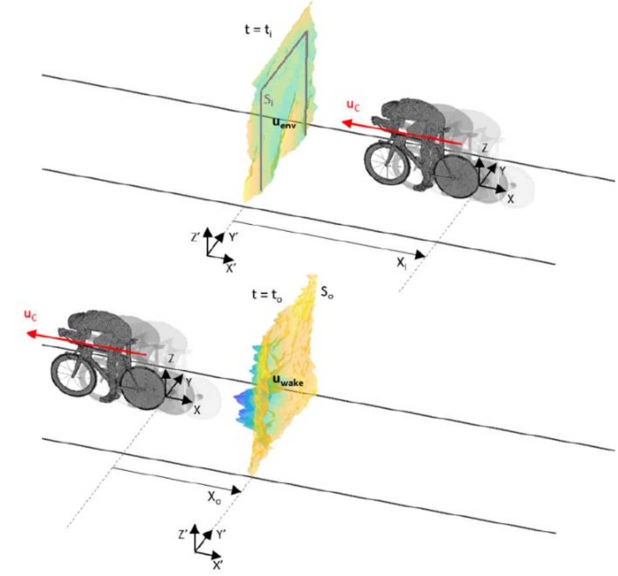


Figure 1. Control volume approach in the Ring of Fire concept: upstream flow (u_{env}) measured at ti, downstream flow (u_{wake}) at to.

The air motions prior to the passage of the cyclist feature a chaotic velocity u_{env} resulting from the environmental effects. After the passage of the cyclist, the flow velocity features a coherent wake with a velocity distribution, u_{wake}, which follows the moving cyclist. By writing the conservation of momentum in a control volume enclosing the cyclist, the cyclist's aerodynamic drag can be retrieved:

$$D(t) = \rho \iint_{S_i} \left(u_{env} - u_C\right)^2 dS + \rho \iint_{S_i} p_i dS - \rho \iint_{S_o} \left(u_{wake} - u_C\right)^2 dS - \rho \iint_{S_o} p_o dS \qquad (1)$$

where ρ is the fluid density, p_i and p_o are the static pressures before and after the passage of the cyclist, respectively. Equation (1) is valid at the condition that the mass flow is conserved across the inlet and outer surfaces S_i and S_o, respectively. Ensemble-averaging equation (1) in time and across multiple passages of the rider provides the ensemble-average aerodynamic drag of the cyclist.

A large-scale stereoscopic Particle Image Velocimetry (PIV) system is employed for the measurement of the flow velocity prior and after the passage of the rider. Neutrally-buoyant helium-filled soap bubbles (HFSB) of 300 µm median diameter are used as flow tracers due to their large scattering cross section. The HFSB are illuminated by a pulsed laser (Nd:YAG or Nd:YLF) and images are acquired via digital cameras (typically CMOS or sCMOS). An example of experimental arrangement for Ring of Fire measurements is reported in Figure 2 (Spoelstra et al., 2019).

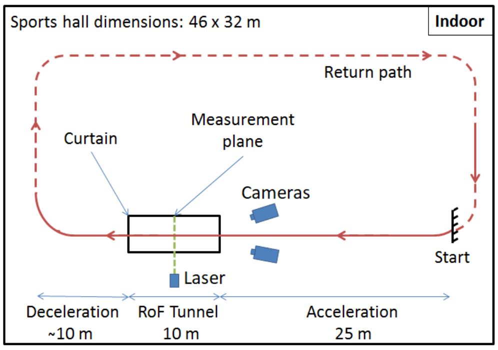


Figure 2. Example of experimental arrangement for indoor Ring of Fire measurements for cycling aerodynamics.

In the following, the streamwise velocity component and time are expressed in non-dimensional units as follows, considering the athlete's torso chord length *c* = 600 m as reference length:

$$u_x^* = \frac{u_{wake} - u_{env} - |u_C|}{|u_C|}; \qquad t^* = \frac{t \cdot |u_C|}{c}. \tag{2}$$

Application to cycling

Some of the results of the indoor and outdoor measurements for cycling aerodynamics are shown here, with the rider in the upright and time-trial configurations. The temporal development of the ensemble average streamwise velocity field $\overline{u_x^*}$ past the cyclist is shown in Figure 3. The ensemble average is obtained from 28 and 10 individual runs from the indoor and outdoor experiments, respectively. The maximum deficit in the wake (~45%) is observed at the shortest time delay after the passage. The deficit is not uniformly distributed and attains its maximum behind the legs. The turbulent diffusion causes a rapid redevelopment of the flow in the wake. The flow entrainment smoothens the fine details of the streamwise velocity distribution and, internally to the wake, the peak velocity deficit reduces. The diffusion process causes the wake to exceed the measurement region, with consequences on the uncertainty of the drag estimate. This occurs earlier for the outdoor experiment (t^* ~ 9) than for the indoor experiment (t^* ~ 13), which is ascribed to the higher intensity of the velocity fluctuations in the surrounding environment.

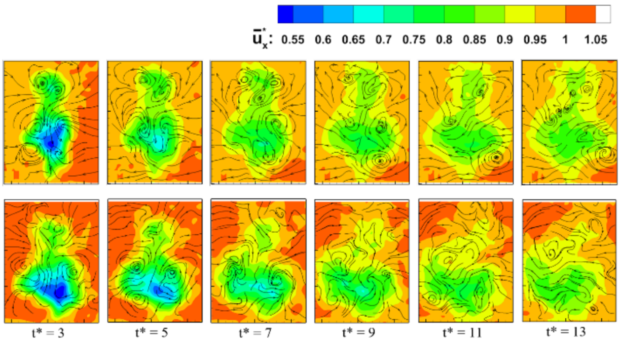


Figure 3. Development over time of the dimensionless ensemble average streamwise velocity behind the cyclist in time-trial position. Indoor experiment (top) and outdoor experiment (bottom).

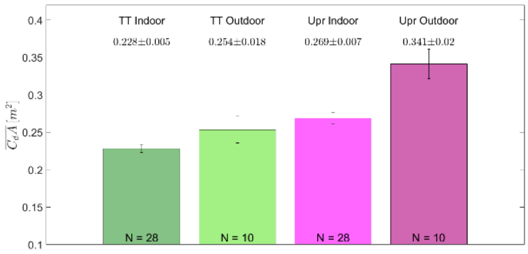


Figure 4. Ensemble-average drag area for the different cyclist postures (time-trial and upright) and measurement conditions (indoor and outdoor); uncertainty bars for 95% confidence interval. N indicates the number of cyclist's passages per case.

The evaluation of the cyclist's drag area, illustrated in Figure 4, shows that the time-trial position leads to a reduction of the aerodynamic drag by up to 35% compared to upright position, which is in agreement with literature. Additionally, the drag areas in the outdoor experiment were found higher than in the indoor experiments, which is ascribed to differences in the rider's postures and frontal areas and in the environmental conditions.

Application to speed skating

Experiments were performed in February 2021 in the ice-rink of Thialf in Heerenveen, the Netherlands, to investigate the effect of skater's posture on the aerodynamic drag. Two athletes transited through the Ring of Fire 20 times each, 10 times in each skating configurations. The configurations investigated were: two arms on the back versus one arm on the back and one loose; low trunk versus high trunk postures. All tests were performed at a nominal skating speed of 11 m/s. The experimental setup, illustrated in Figure 5, consisted of two high-speed CMOS cameras recording images of the HFSB tracers, illuminated by a Nd:YLF pulsed laser and confined within a tunnel of 10×13×3 m^3.

The average streamwise velocity fields measured 0.5 m behind the lower back of the skater for the low trunk and high trunk postures are shown in Figure 6. The streamwise velocity contours clearly show two different shapes, thus indicating a strong dependence on the skating posture. The near wakes of the two configurations clearly exhibit similar streamwise velocity contours; nevertheless, the wake of the low trunk posture is shorter. Both contours show the strongest velocity deficit behind the trunk and upper legs and some smaller velocity deficits behind the extended (right) arm and (left) leg. The wake of the high trunk posture features slightly higher velocity deficits ($u_x^* < 0.4$) compared to the wake of the low trunk posture ($u_x^* = 0.5$). From the analysis of the momentum deficit in the control volume enclosing the athlete, it was found that skating with low trunk angle resulted in a statistically significant drag reduction by 7.5% compared to skating with high trunk angle. Instead, the difference in drag area between skating with both your arms on the back or with just one arm on the back was not statistically significant.

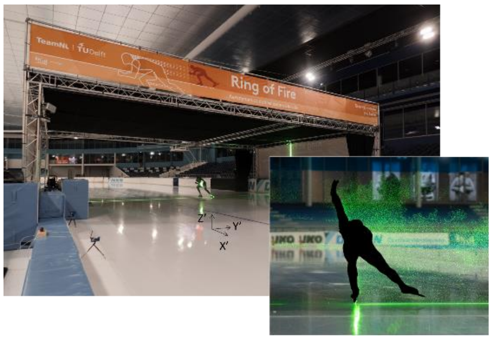


Figure 5. Ring of Fire setup in the skating rink of Thialf, the Netherlands. An athlete skating through a cloud of helium filled soap bubbles illuminated by laser light.

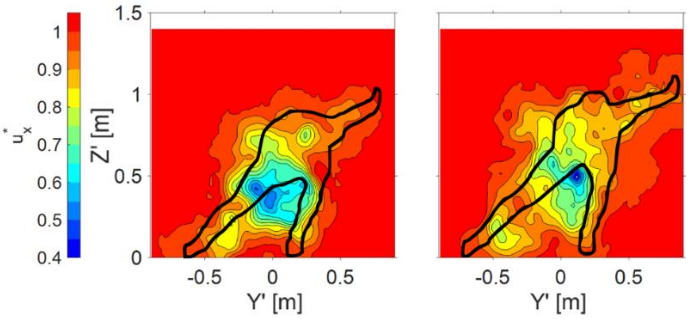


Figure 6. Average streamwise velocity u_x at X = 0.5 m for the skater in low trunk posture (left) and high trunk posture (right).*

Conclusion and outlook

A new measurement concept has been introduced for the investigation of the wake flow and aerodynamic drag of transiting objects such as sports athletes and ground vehicles. The measurement system relies upon the use of stereoscopic PIV, whereby neutrally-buoyant sub-millimeter helium-filled soap bubbles (HFSB) are used as flow tracers to capture the wake dynamics over planes of the size of several square meters. The application of the conservation of momentum in a control volume enclosing the transiting object allows the determination of the object's aerodynamic drag. The measurement system has been assessed experimentally for cycling aerodynamics in both indoor and outdoor conditions, as well as for skating aerodynamics, shedding light on the aerodynamics of these sports and the physical mechanisms responsible for drag variations in different configurations of the athletes. A dedicated study of the drag resolution of the Ring of Fire system showed that the uncertainty of the average drag measurements is currently within 5%. Although such value is considered rather coarse when compared with state-of-the-art force balance measurements conducted in a wind tunnel, it shows great potential for a range of applications, such as drones, cars, trains and birds, due to the possibility to determine the aerodynamic drag in-field rather than in the lab environment. Future applications are envisaged in the automotive and UAV sectors, both to increase the understanding of the flow physics and for the generation of experimental databases for the validation of numerical simulations.

References

Huetting,. S., Gericke, T., Sciacchitano, A., and Akkermans, R. A. D. (2023), On the use of large-scale PIV for on-site car aerodynamics, in preparation

Spoelstra, A., de Martino Norante, L., Terra, W., Sciacchitano, A., & Scarano, F. (2019). On-site cycling drag analysis with the Ring of Fire. Experiments in Fluids, 60, 1-16, https://doi.org/10.1007/s00348-019-2737-y

Spoelstra, A. M. C. M. G., Hirsch, M., Sciacchitano, A., & Scarano, F. (2021). Uncertainty assessment of the Ring of Fire concept for on-site aerodynamic drag evaluation. Measurement Science and Technology, 32(4), 044004, https://doi.org/10.1088/1361-6501/abb50d

Spoelstra, A., Sciacchitano, A., Scarano, F., & Mahalingesh, N. (2021). On-site drag analysis of drafting cyclists. Journal of Wind Engineering and Industrial Aerodynamics, 219, 104797, https://doi.org/10.1016/j.jweia.2021.104797

Spoelstra A. M. C. M. G. (2022), Ring of fire as a novel approach to study cycling aerodynamics, PhD Thesis, Delft University of Technology, https://doi.org/10.4233/uuid:5b51be97-aca7-4935-836a-be9b75f819df

Spoelstra A., Terra W. and Sciacchitano A. (2023), On-site aerodynamics investigation of speed skating, under review in Journal of Wind Engineering and Industrial Aerodynamics

Terra, W., Spoelstra, A., & Sciacchitano, A. (2023). Aerodynamic benefits of drafting in speed skating: Estimates from in-field skater's wakes and wind tunnel measurements. Journal of Wind Engineering and Industrial Aerodynamics, 233, 105329, https://doi.org/10.1016/j.jweia.2023.105329

VIDEOS

NWO video on the Ring of Fire project	Video on the Ring of Fire in the ice-rink of Thialf (in Dutch)	TU Delta TV video on the Ring of Fire for cycling aerodynamics

This highlight refers to the PhD Thesis by Yous van Halder (2022)

An adaptive minimum spanning tree multi-element method for uncertainty quantification of smooth and discontinuous responses

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Background

Uncertainty Quantification (UQ) has become increasingly important for complex engineering applications. Determining and quantifying the influence of parametric and model-form uncertainties is essential for a wide range of applications, among which fluid dynamics.

A well-known sampling method for propagating uncertainties through a model is the Monte Carlo method. Despite its easy implementation and wide applicability, the Monte Carlo method suffers from slow convergence with increasing number of model evaluations when approximating the quantity of interest (QoI); it requires many samples for obtaining high-quality stochastic solutions. As an alternative to Monte Carlo methods, stochastic collocation (SC) methods were introduced, replacing the slow convergence of Monte Carlo methods by an exponential convergence rate. For a smooth QoI as a function of the uncertainties, fast convergence is achieved indeed with SC. However, if the QoI is highly non-linear or even discontinuous, Gibbs phenomena may occur, which deteriorate the accuracy globally. To avoid the occurrence of Gibbs phenomena, several alternatives to the SC methods were introduced, but they focus solely on discontinuous QoIs, leading to a significant increase in the number of samples needed for approximating smooth QoIs. As a remedy against this, the multi-element stochastic collocation (ME-SC) method was introduced. The idea of ME-SC is to decompose the domain, spanned by the uncertainties, into smaller non-overlapping sub-domains (called elements), in each of which the QoI is amenable for using an SC method. Gibbs phenomena still appear in the elements where there is a discontinuity in the QoI, but they are confined to these specific elements. Improving the multi-element approach is an active field of research and focuses on more efficient and robust domain decomposition. It is often unknown in advance if a QoI is smooth or non-smooth. Hence, choosing a method which is suited for either smooth or discontinuous responses is often not recommended.

Method

We created a surrogate model, which works for both smooth and discontinuous QoIs and which requires no a-priori knowledge about the QoI. For this purpose, we proposed a novel domain decomposition method in combination with adaptive sampling for constructing the surrogate. The adaptive sampling procedure in our method is based on minimum spanning trees (MST), which add new sample points at places which are associated with a high probability density and/or where the QoI changes rapidly. The adaptively placed samples are classified and a support vector machine (SVM) is used to obtain a classification boundary, which serves as an approximation for the discontinuity location. This decomposition of the random space leads to elements on which each local QoI is amenable for interpolation without Gibbs phenomena. For constructing a surrogate model in each element a least orthogonal interpolant is employed, which is suited for interpolation on the scattered data points that we obtain with our adaptive sampling. Our method is abbreviated as MST-ME (minimum spanning tree multi-element) method. When assuming uniformly distributed probability density functions for the input parameters, the MST-ME method is also well suited to obtain a parametric solution of the partial differential equation (PDE) under consideration.

Results

We study the performance of the MST-ME method applied to a system of 1D conservation laws. This system consists of the 1D shallow water equations (SWEs), which describe the inviscid flow of a layer of fluid with free surface, under the action of gravity, with the thickness of the fluid layer small compared to the other length scales.

The initial condition for the system of PDEs is shown in the left graph of Figure 1. The solution of this Riemann problem can be computed exactly when working on an infinite spatial domain. The solution consists of two waves, a smooth one and a discontinuous one, travelling through the spatial domain, see right graph in Figure 1.

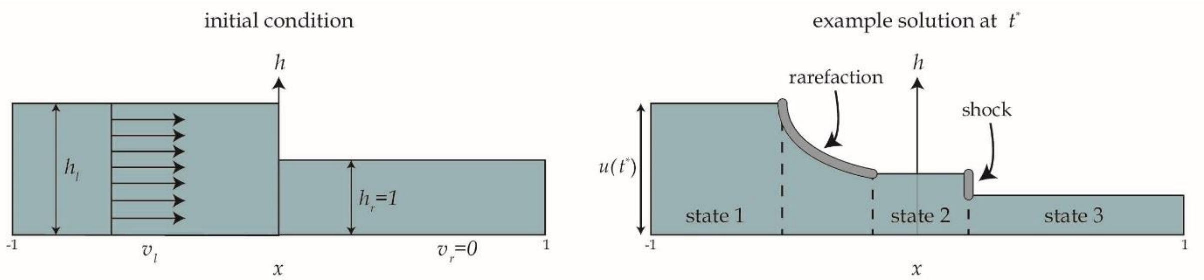

Figure 1: Shallow-water test case.

Solid-wall boundary conditions are imposed at $x = \pm 1$, and we employ a finite-volume method with an exact Riemann solver to compute the cell-face fluxes, and solve the SWEs using 256 finite volumes. An appropriate numerical method is used to integrate the SWEs in time and a ghost-cell method with respective properties is used for the boundaries. The initial left state (h_l,v_l) (Figure 1) is assumed to be uncertain and uniformly distributed. The uncertainty in the initial conditions is large to ensure that we get different characteristic behaviours of the QoI, which is defined as the fluid height at $x = -1$ at a certain time t^*.

Notice that the characteristics of this QoI will change significantly as time progresses. Either a transition between a shock and rarefaction wave, or a difference in wave speeds can result in a discontinuity in the QoI. This allows us to study the robustness of the MST-ME method, as this test case comprises both smooth and discontinuous QoI responses. We emphasize that the constructed surrogate for the QoI at time t^* cannot be reused for other time instances, because the MST-ME method uses the QoI at the current time t^* as a measure to place new samples.

The MST-ME method is used for the QoI at three different times, corresponding with a mildly non-linear (rather smooth), highly non-linear (rather non-smooth) and close to discontinuous QoI, respectively. The surrogate model and sample grids after 10 iterations are shown in Figure 2. The discontinuity in the QoI in the close to discontinuous case is caused by a shock wave (water jump), which hits the left boundary for certain values in the random space, but does not yet hit the left boundary for other values in the random space.

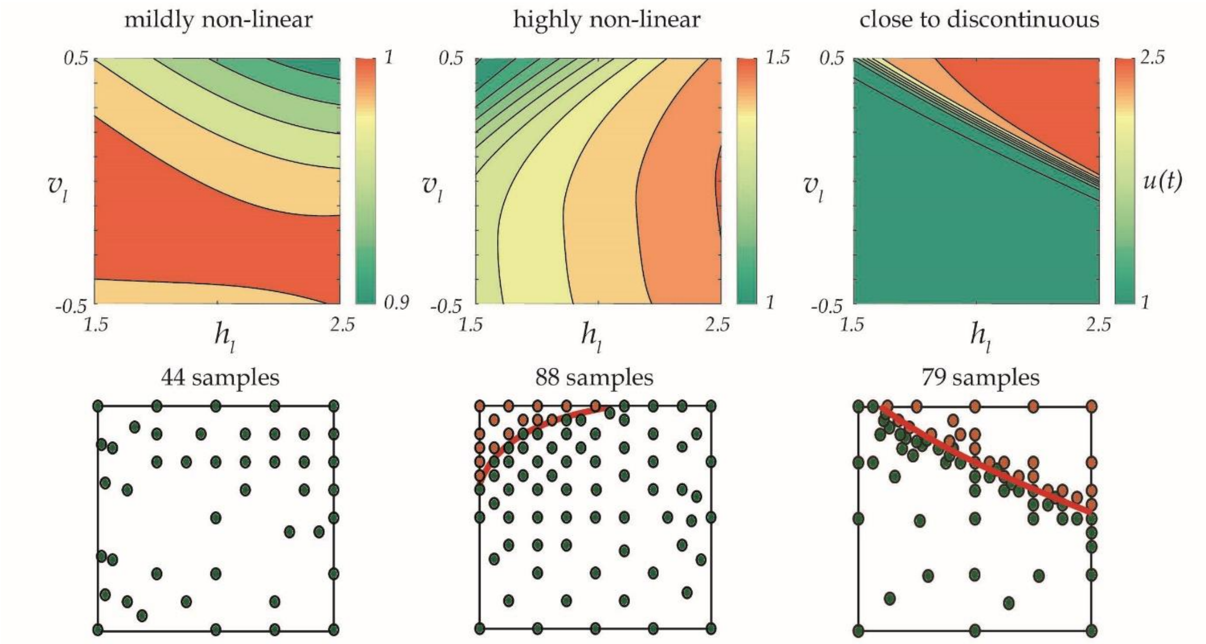

Figure 2: The three QoI surrogate models and corresponding sample grids after 10 iterations.

To investigate the accuracy of the MST-ME method, we determine the convergence. The error is based on 10^6 Monte Carlo samples. The convergence of the $L_{2,\rho}$ error (see Van Halder et al., 2019) is shown in Figure 3. The results show that the error as a function of the samples decays fast for the mildly and highly non-linear case, as expected. The highly non-linear case shows a sudden drop in the error, which is caused by transition in the domain decomposition. First, the classification procedure detects a large enough jump in the sampled QoI to conclude that there is a discontinuity present in the QoI. As the MST-ME progresses, samples are added in the area of the possible discontinuity, until the jumps in the QoI values become small enough to classify the samples properly. This transition to a correct classification explains the sudden drop in the error for the highly non-linear case. MST-ME automatically detects the smoothness of the QoI, as the number of samples increases.

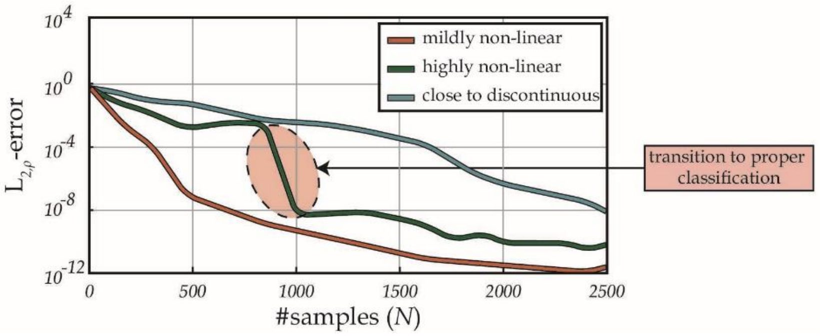

Figure 3: Convergence of the MST-ME solution in the $L_{2,\rho}$-error.

Acknowledgement

This work was part of the NWO-AES Perspective Program SLING (Sloshing of Liquefied Natural Gas).

References

Van Halder, Yous 2022. Efficient sampling and solver enhancement for uncertainty quantification, PhD Thesis, Eindhoven University of Technology.

Van Halder, Y., Sanderse, B., Koren, B. An adaptive minimum spanning tree multielement method for uncertainty quantification of smooth and discontinuous responses, SIAM Journal on Scientific Computing 41, A3624-A3648, 2019.

This highlight refers to the PhD Thesis by Maaike Rump (2022)

Meniscus dynamics and evaporation in inkjet printing

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There are many challenges encountered in the inkjet printing process when droplets are desired to be jetted with a higher velocity or smaller volume, or have a multicomponent composition. The phenomena studied in this thesis are the bubble entrainment from an oscillating meniscus, the meniscus shape as function of the driving frequency, the measurement method of the liquid composition in the nozzle during drying via the acoustics in the channel, and the role of surfactants on the droplet formation.

Bubble pinch-off

We studied the bubble pinch-off from an oscillating meniscus in an optically transparent DOD printhead as a function of the driving waveform. We show that bubble pinch-off follows from low-amplitude high-frequency meniscus oscillations on top of the global high-amplitude low- frequency meniscus motion that drives droplet formation. In a certain window of control parameters, phase inversion between the low and high frequency components leads to the enclosure of an air cavity and bubble pinch-off. Although phenomenologically similar, bubble pinch-off is not a result of capillary wave interaction such as observed in drop impact on a liquid pool. Instead, we reveal geometrical flow focusing as the mechanism through which at first, an outward jet is formed on the retracted concave meniscus. The subsequent high-frequency velocity oscillation acts on the now toroidal-shaped meniscus, and it accelerates the toroidal ring outward resulting in the formation of an air cavity that can pinch-off. Through incompressible boundary integral simulations we reveal that bubble pinch-off requires an unbalance between the capillary and inertial time scales and that it does not require acoustics. The critical control parameters for pinch-off are the pulse timing and amplitude. To cure the bubble entrainment problem, the threshold for bubble pinch-off can be increased by suppressing the high frequency driving through appropriate waveform design.

We continued our study using ultrafast X-ray phase-contrast imaging and direct numerical simulations to study the factors underlying bubble entrainment in a piezo-acoustic printhead. We first demonstrate good agreement between experiments and numerics. The numerical results are then used to show that the baroclinic torque that is generated at the gas-liquid interface due to the misalignment of density and pressure gradients, results in a flow-focusing effect that drives the formation of the air jet from which a bubble can pinch-off.

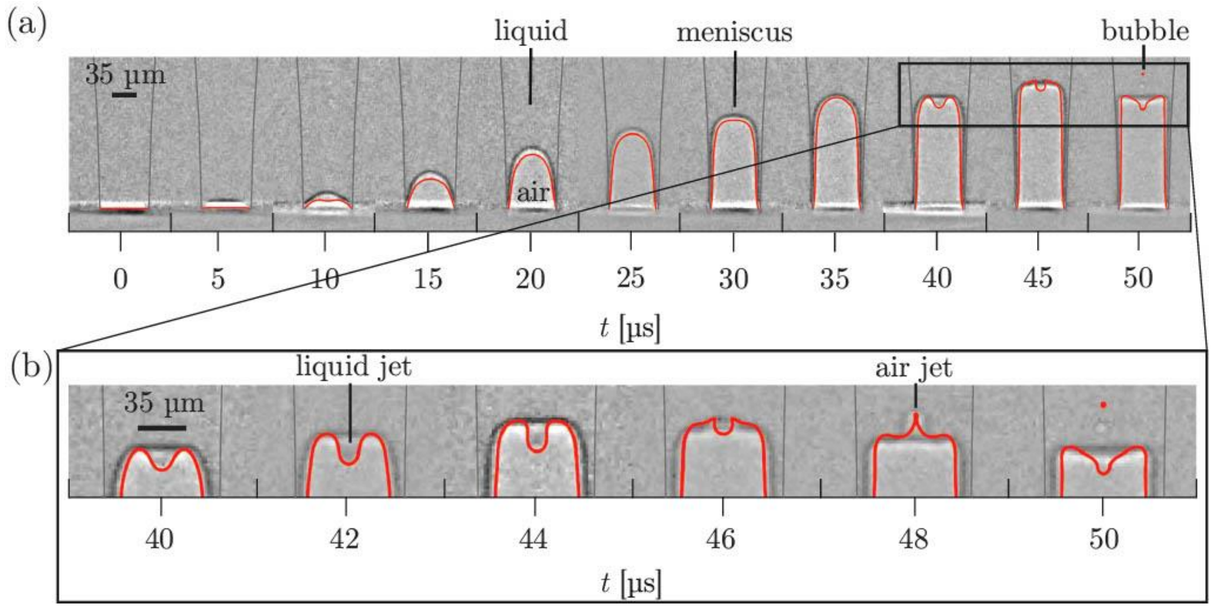

Figure 1: (a) Meniscus position during different time instants of the bubble entrainment phenomenon as observed in the experiment (grayscale images) and the numerical simulations (red curves) for V_{max} = 70V and τ = 34 µs. (b) A zoomed-in image of the same bubble entrainment phenomenon. The outline of the nozzle is highlighted with gray lines.

Shape of the oscillating meniscus

We obtained experimental time-resolved 3D topography profiles of an oscillating meniscus driven at frequencies from 1 kHz to 400 kHz with an accuracy of length scales down to tens of nanometers and microsecond timescales. Furthermore, we obtain the resonance curve for multiple axisymmetric and non-axisymmetric modes of the system. The resonance frequency does not correspond to the eigenfrequency obtained from the capillary dispersion equation for an undriven system. The resonance frequencies for a driven system determined using boundary integral simulations show an improved understanding of the system.

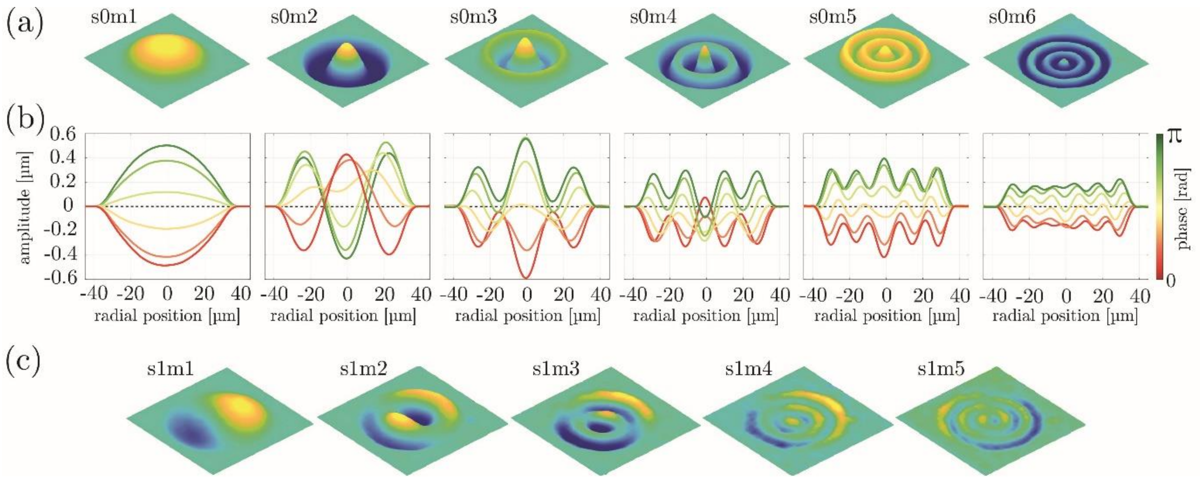

Figure 2: Measured axisymmetric surface oscillation shapes obtained at different frequencies and a nozzle radius of 35 µm and (b) the corresponding cross sections. (c) Measured non-axisymmetric surface oscillation shapes using the same nozzle.

Selective evaporation

We studied selective evaporation from an inkjet nozzle for water- glycerol mixtures. Through experiments, analytical modeling, and numerical simulations, we investigate changes in mixture composition with drying time. By monitoring the acoustics within the printhead, and subsequently modeling the system as a mass-spring-damper system, the composition of the mixture can be obtained as a function of drying time. The results from the analytical model are validated using numerical simulations of the full fluid mechanical equations governing the printhead flows and pressure fields. Furthermore, the numerical simulations to reveal that the time independent concentration gradient we observe in the experiments, is due to the steady state of water flux through the printhead. Finally, we measure the number of drop formation events required in this system before the mixture concentration within the nozzle attains the initial (pre-drying) value, and find a stronger than exponential trend in the number of drop formations required.

Furthermore, we studied the influence of surfactants on droplet formation in piezo-acoustic inkjet printing while we vary the time between the formation of two successive droplets over 5 orders of magnitude, i.e., from microseconds to minutes. During jetting, a large amount of new surface area is created when the liquid is ejected from the nozzle. Jetting occurs on a microsecond timescale, which is shorter than the typical timescale of surfactant adsorption. Here, we vary the time between the ejection of two droplets to allow surfactants to accumulate on the meniscus. At a waiting time of milliseconds to one second, we observe a change in break-up dynamics, but no effect on the droplet velocity and volume. When the waiting time is longer than one second, when evaporation starts to play a role, the droplet velocity and volume increases. We measured the surface tension of the ejected droplets from their dynamics in flight, which showed that the increased local concentration of surfactant due to evaporation allows for faster surfactant adsorption on the freshly formed surface. Interestingly, increasing the bulk concentration of surfactant does not lead to an increase in droplet velocity, as viscosity starts to play a role as well. Thus, the increased local concentration of surfactant due to evaporation is required to increase the droplet velocity. Numerical simulations demonstrate that the increased concentration at the nozzle exit covers the droplet during the droplet formation process, thereby allowing for surfactant adsorption along the freshly formed surface.

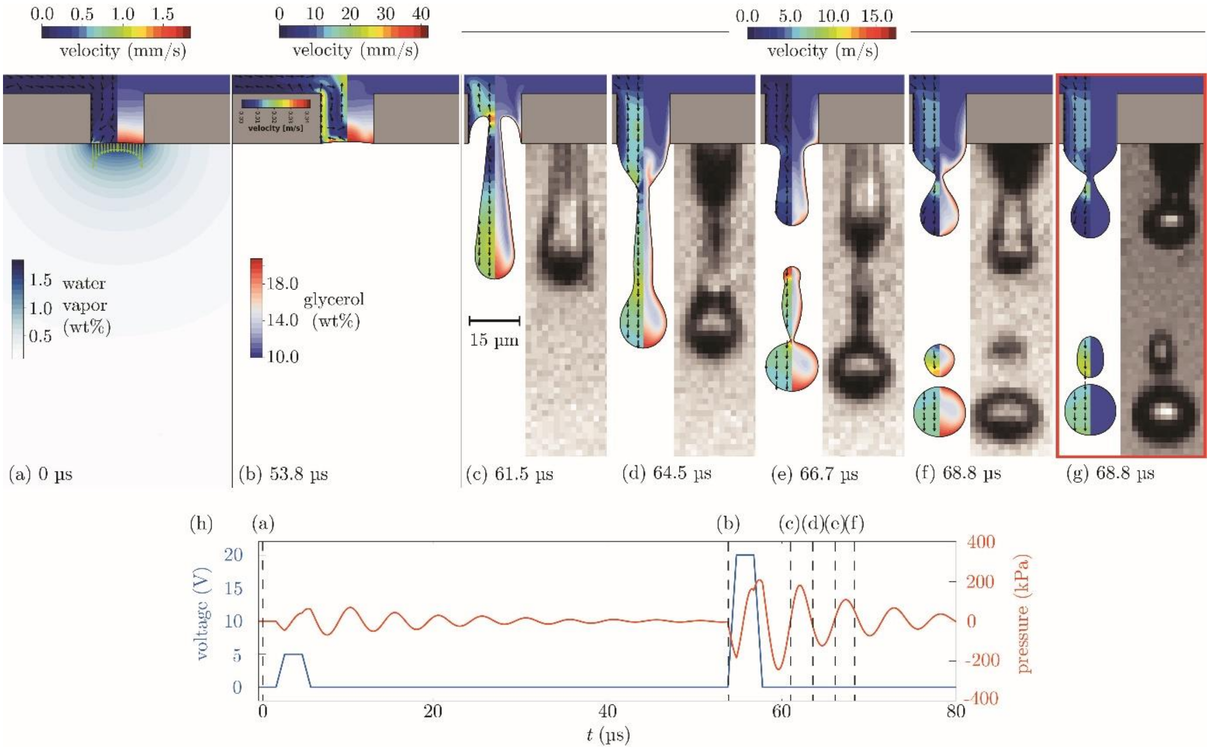

Figure 3: Snapshots from numerics and the corresponding experiment for the droplet formation process with a drying time of 100 ms (Movie available online). The numerical simulations provide two colour schemes inside the liquid: the left-hand side of the nozzle shows the velocity profile while the right-hand side shows the glycerol concentration. The water evaporation rate is around 100 g/(m2s). Snapshots (a) and (b) show the nozzle before droplet formation, and (c)-(f) show the droplet formation process. (g) Snapshot at same time as (f) but for the case of 1.5 ms drying time. (h) Demonstrates the actuation pulses (blue) and numerical pressure signal in the link chamber (red), where the time instants of the snapshots are also indicated.

Reference

Maaike Rump, 2022. Meniscus dynamics and evaporation in inkjet printing. PhD Thesis, Twente University of Technology.

This highlight refers to the PhD Thesis by Thejas Hulikal Chakrapani (2022)

Mesoscale modelling of multiphase flow and wetting

Thejas Hulikal Chakrapani and Wouter K. den Otter

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Introduction

In the PhD thesis by Thejas Hulikal Chakrapani (2022) wetting and multi-phase flow problems pertinent to ink-penetration in paper are studied using computer simulations. Jetting ink is composed of water, glycerol and constituents such as colourants, surfactants and polymers; the physico-chemical interactions of these components renders ink complex. Paper is a complex porous solid manufactured by compressing cellulosic fibres, characterised by irregular pore shapes, a broad pore-size distribution and (de)swelling of fibres upon (de)hydration. The complex interaction between ink and paper gives rise to interesting problems, several of which we investigate by systematically increasing the complexity of the fluid, the complexity of the solid, or both, in highly idealised models.

Simulation methodology

Many-body Dissipative Particle Dynamics (MDPD) is a coarse-grained particle-based simulation technique used to resolve flow at mesoscopic length scales from nanometer to micrometer. The particles, each representing a collection of fluid molecules, interact through short-ranged conservative forces, friction forces and fluctuating Brownian forces obeying the fluctuation-dissipation theorem. Thermodynamic properties such as viscosity, surface tension and (de)mixing of fluids emerge as natural consequences of these forces. Rigid bodies such as colloids and walls are implemented by introducing harmonic springs between particles or by restraining particles to fixed positions.

A complex fluid in a simple geometry: the imbibition of fluid mixture into a pore

The capillary imbibition of cylindrical pores by fluids is investigated (see Hulikal Chakrapani and den Otter, 2020). A seminal result describing this process is the Bell-Cameron-Lucas-Washburn (BCLW) theory: the imbibition depth increases with the square root of time. Quantitative agreement with BCLW theory is observed for pure fluids and fluid mixtures, provided the imbibing fluid has a small equilibrium contact angle and its viscosity is sufficiently high. The imbibition of partially wetting fluids and fluid mixtures is modestly enhanced by slip at the wall. Binary mixtures of fluids differing in their affinities to the wall show partial segregation during imbibition: the wall-philic component forms a monolayer covering the wall, while the wall-phobic component is over-represented in the centre of the pore. Since the flow velocity is higher in the centre, the wall-phobic component is carried – on average – further into the pore than the wall-philic component and consequently dominates at the imbibition front, as illustrated in Figure 1. This enrichment of the wall-phobic component at the front is of non-equilibrium origin, and gradually disappears after cessation of the flow; the enrichment of the wall-philic component at the walls is of thermodynamic origin and persists in the absence of flow.

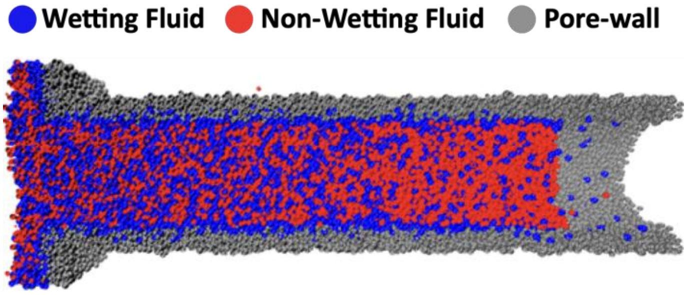

Figure 1. Simulation snapshot of the spontaneous imbibition into a cylindrical nanopore of a binary liquid mixture, composed of equal concentrations of perfectly wetting and non-wetting fluids.

A simple fluid in a complex geometry: the permeability of micro-pillared channels

Darcy's law describes the volumetric flux of a Newtonian fluid flowing through a bulk porous media as the product of the applied pressure difference, the fluid's viscosity and the medium's permeability. Brinkman extended Darcy's law with a viscous stress term, thereby enabling boundary conditions to the flow field at the boundaries of the medium. Our porous media are ordered and disordered arrays of parallel cylindrical pillars, bounded by flat walls, see Figure 2. The validity of Brinkman's term, and the value of its effective viscosity, have been heavily debated since their introduction nearly 75 years ago. We find that the simulated velocity profiles are well described by an expedient interpretation of Brinkman's theory that combines the permeability of ideal pillar arrays (devoid of boundaries, i.e. infinitely long pillars) with drag by the walls. Depending on the solid volume fraction and pillar arrangement, Brinkman's effective viscosity varies between two and three times the fluid's viscosity. The calculated effective permeabilities of the flow devices, by combining established expressions for the permeability of ideal pillar arrays with Brinkmans' theory, agree well with our experimental data; see Hulikal Chakrapani et al., 2023). This approach enables fast and accurate estimates of the effective permeability of micropillared chips. Contrary to this simple picture, the force distributions extracted from the simulations indicate that the drag forces at the walls are still governed by the bulk viscosity, while the permeability of the pillar array varies with the distance to the wall.

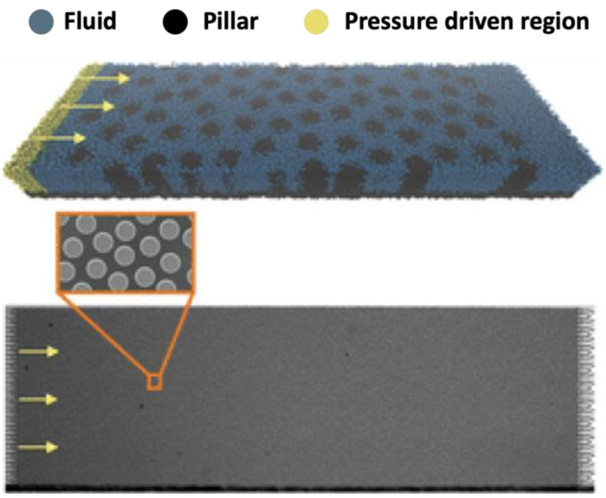

Figure 2. Pressure-driven fluid flow through a microchannel containing a disordered array of cylindrical pillars. Identical pillar arrays are used in simulations (top) and silicon-etched micro-fluidic chips (bottom).

A complex fluid in a complex geometry: the imbibition of ink into a model paper

The complexities of fluid and solid are combined to study the capillary-assisted penetration of ink droplets into disordered fibrous structures (Hulikal Chakrapani. and W.K. den Otter, 2023); see Figure 3. The toy-model substrate mimics the fibrous composition, fibre orientation and wide pore-size distribution of paper. The droplets are binary mixtures composed of carrier fluid particles and 0% to 20% dye fluid particles, with the latter having a higher affinity for the fibre particles than the former. The heterogeneity of the substrate is taken into account by averaging droplet penetration times and deposition patterns over multiple deposition points. Droplets containing dye penetrate quicker into the fibre assembly than pure carrier droplets. Irregular anisotropic patterns develop around the deposition points, caused by the irregular anisotropic stacking of the fibres. Interestingly, these patterns are unaffected by the dye concentration in the droplet. Though the heterogeneity of the substrate affects the details of the penetration process, the overall trends are robust.

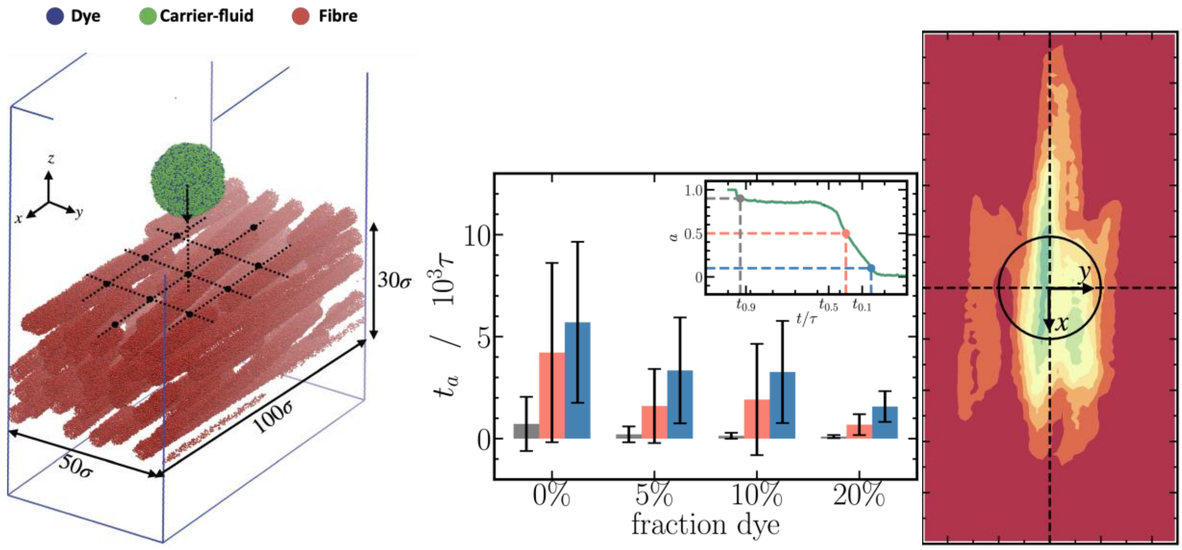

Figure 3. (Left) Simulation snapshot of an ink droplet (green and blue) descending on a porous assembly of disordered fibres (red) of 52% porosity. The fibres are tilted by random small angles to the x axis. The black dots mark deposition points, i.e. intersections of the top 'surface' of the fibre assembly and the lines of approach of the vertically descending droplets. (Center) Average residence times t_a of fractions a of the initial droplet mass remaining above the top surface, where a = 90% (grey), 50% (orange) and 10% (blue), for droplets with dye-concentrations from 0% to 20%. The inset shows the typical evolution of the mass fraction remaining on the surface after impact, highlighting the three aforementioned fractions and the corresponding residence times. (Right) An example deposition pattern after imbibition into the substrate, demonstrating preferential spreading along the average direction of the fibres. The black lines indicate the droplet's initial size and impact point.

References

Hulikal Chakrapani, T., 2022. Mesoscale Modelling of Multiphase Flow and Wetting, PhD thesis, University of Twente, Enschede, The Netherlands.

Hulikal Chakrapani, T. and den Otter, W.K., 2020. Capillary imbibition of binary fluid mixtures in nanochannels, Langmuir 36, 12712.

Hulikal Chakrapani, T., Bazyar, H., Lammertink, R.G.H., Luding, S., and den Otter, W.K., 2023. The permeability of pillar arrays in microfluidic devices: an application of Brinkman's theory towards wall friction, Soft Matter 19, 436.

Hulikal Chakrapani, T. and W.K. den Otter, W.K., 2023. Dye-assisted imbibition of liquid droplets into fibrous porous media, manuscript in preparation.

This highlight refers to the PhD Thesis by Pulkit Goyal (2022)

How flying bees land

Pulkit Goyal, Johan L. van Leeuwen and Florian T. Muijres
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Landing is arguably one of the most critical and difficult behaviours that flying animals regularly perform. It involves a precise control of approach speed as an animal draws closer to the landing surface. Poor control can result in high-impact collisions with the surface which can be harmful for animals. Despite its importance in flight, how animals approach a surface for landing is not yet fully understood. Here, we contribute to answering this question by examining the landing approaches of bumblebees and honeybees (Goyal, 2022). Bees, including bumblebees and honeybees, perform 100 to 1000 landings in a single hour of foraging. They perform these landings relentlessly to gather the nectar and pollen from flowers, which are essential for their survival and reproduction. We use novel real-time videography-based tracking of flying bees and dedicated control-theory-based analyses methods to investigate how these bees land.

Bumblebees land rapidly and robustly using a sophisticated modular flight control strategy

Many flying animals use visual cues during landing. In the first thesis research chapter, we present how bumblebees use visual expansion cues to advance towards the landing surface (Goyal et al., 2021). For this purpose, we first designed an indoor experimental apparatus to automatically record the landing maneuvers of foraging bumblebees using real-time videography-based tracking. Using this approach, we tracked 4,672 landing maneuvers, which we then analyzed using a novel analysis method. This method analyses the individual maneuvers and is more comprehensive than the analysis method of averaging multiple maneuvers used in literature.

Using this novel method, we discovered the visual guidance strategy of landing bumblebees. Our results show that the landing bumblebees exhibit a series of deceleration bouts during which they keep the relative rate of optical expansion approximately constant (Figure 1). This constant is referred to as a set-point and from one bout to the next, bumblebees tend to shift to a higher set-point. This newly-found guidance strategy results in the approach dynamics that is strikingly similar to that of pigeons, mallards and hummingbirds (Lee et al., 1991; Lee et al., 1993; Whitehead, 2020). In addition, we also found how bumblebees adjust this visual guidance strategy to travel faster when landing directly after a take-off than from a free-flight condition. Moreover, we also elucidated how bumblebees adjust this guidance strategy in the presence of different strength of optic expansion cues available from the landing surface (checkerboard versus spoke patterns) and different light intensities ranging from twilight to sunrise. This guidance strategy helps to explain how these important pollinators rapidly visit flowers and forage in challenging environmental conditions.

In addition to the deceleration phases, we found that landing bumblebees also occasionally exhibit low approach velocity phases ($V < 0.05$ m/s) while transitioning from one set-point to another. These low approach velocity phases are similar to the hovering phases identified in literature, and result in bumblebees hovering or sometimes even flying away from the surface for a short period. We propose that these low approach velocity phases are likely the instabilities arising out of a control system that uses optical expansion rate as a control variable.

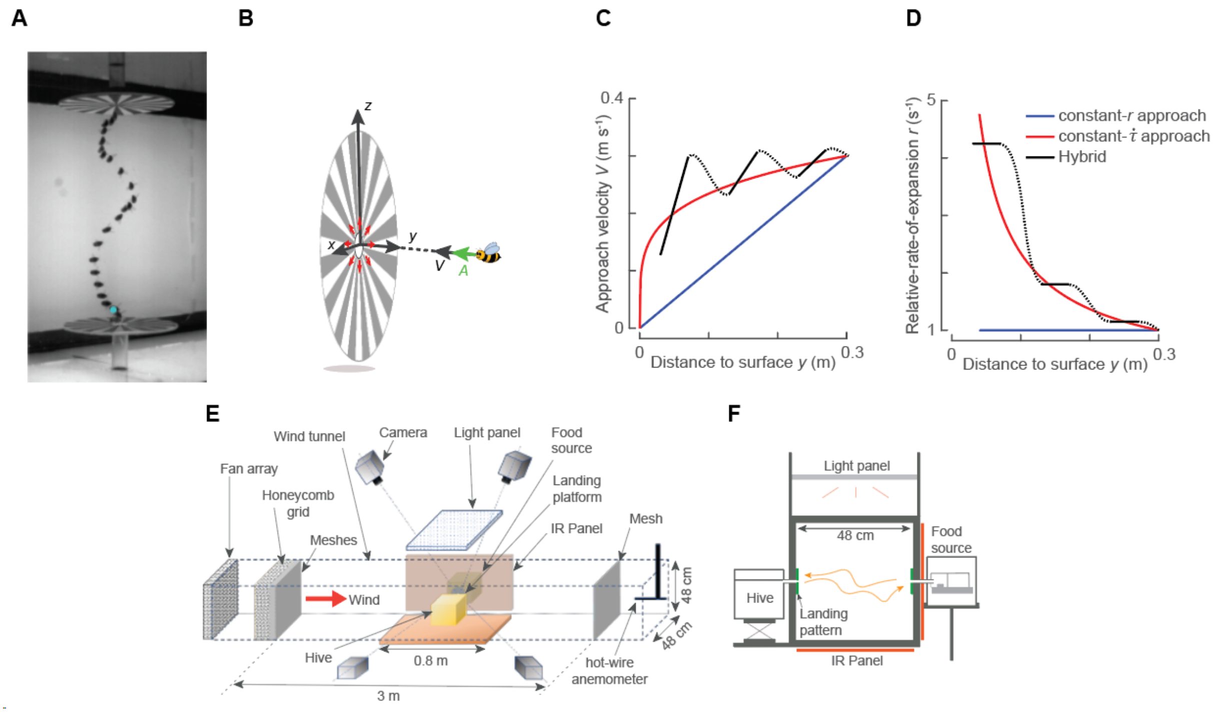

Figure 1 – The experimental set-up developed in this thesis, and the landing strategies described in honeybees (blue), birds (red) and bumblebees (black). (A) Photomontage from a downward-facing camera of a landing bumblebee, at a time interval of ~0.1 s. (B) An animal that approaches a vertical landing platform along its axial direction experiences a relative optical expansion rate as symbolized by the red arrows. At time t, the animal is at distance y from the object, has an approach flight velocity V, experiences a relative-rate-of-expansion of r=V/y, and has an instantaneous time-to-contact τ=y/V. (B,C) The variation with distance from the landing surface of (B) approach velocity V, and (C) relative-rate-of-expansion r, for the constant-r landing approach observed in honeybees (blue) (Baird et al., 2013), the constant-$\dot{\tau}$ landing approach of birds (red) (Lee et al., 1991; Lee et al., 1993; Whitehead, 2020), and the here-described hybrid landing approach of bumblebees (black) (Goyal et al., 2021). The hybrid landing approach consists of constant-r segments (solid lines), separated by transition phases (dotted curves). All results, and particularly the transition phases, are of idealized cases. (E,F) Our experimental setup consisted of a wind tunnel with two vertically placed circular landing surfaces connected to a hive and a food-source, respectively. Foraging bumblebees that flew between these landing surfaces were tracked in real-time using a four-camera videography system. Visible and IR LED light panel were used for background illumination and for videography, respectively.

Bumblebees land rapidly by intermittently accelerating and decelerating toward the surface during visually guided landings

For achieving a goal such as evading a threat or reaching a set-point, animals use their sensorimotor control system to continuously parse the sensory information and change the wingbeat and body kinematics to produce the required forces and torques. In the second thesis research chapter, we focused on the sensorimotor control system that landing bumblebees use to execute their visual guidance strategy (Goyal et al., 2022). We used the natural stepwise excitation that landing bumblebees offer to analyze how their different subsystems (sensory system, controller and motor system) function together to reach the set-points of optical expansion rate. Our results showed that their closed-loop sensorimotor control system regulates the relative rate of expansion during landing. The track segments before and during a set-point are the transient and steady-state responses of such a control system. Bumblebees use the transient response to mostly accelerate and steady-state response to always decelerate during their landing approach. We also identified how the transient response varies among the tested environmental conditions (light intensity and the strength of optic expansion cues) and starting conditions (landings from a free-flight or after a take-off). Based on these results, we propose a sensorimotor control system of landing bumblebees that facilitates a rapid and robust execution of their visual guidance strategy (Figure 2a).

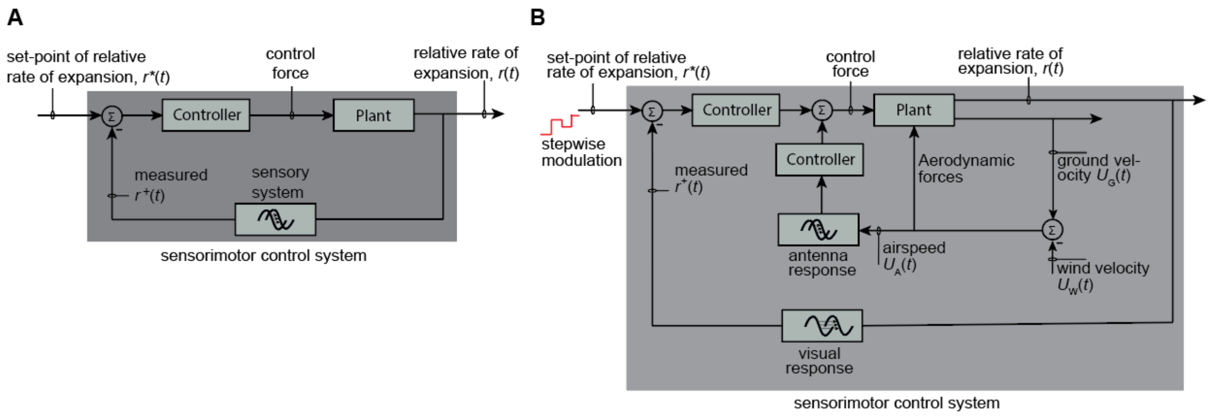

Figure 2 –The sensorimotor control system of landing bumblebees. (A) The closed-loop sensorimotor control system that landing bumblebees use to converge the optical expansion rate r to a set-point r. Using their visual system, bumblebees measure optical expansion rate as r+. Based on the difference between r+ and r*, the animal produces a proportional aerodynamic control force, which accelerates the animal ("plant" in control terminology). (B) The multimodal sensory integration model of landing bumblebees that explains the transient dynamics observed in the presence of steady sidewinds. Bumblebees use their antennae to measure the wind-induced mechanosensory input (airspeed) and integrate it with positive feedback in their vision-based sensorimotor control loop. This fast positive feedback can provide active damping that counteracts the unstable oscillations of a visual feedback loop.*

Bumblebees actively compensate for the adverse effects of sidewind during visually-guided landings

Bumblebees regularly experience winds during foraging. The winds in nature can be characterized as mean winds and fluctuations around them. In the third thesis research chapter, we investigated how the mean winds affect the visual guidance strategy, the sensorimotor control system and the landing performance of foraging bumblebees (Goyal, 2022). For this, we developed a wind tunnel in which bumblebees could forage by flying from one side of the tunnel to the other, and thereby experience a constant side wind (Figure 1E,F). Hereby, we used six steady sidewinds ranging from 0 to 3.4 m/s, which are sidewinds that foraging bumblebees naturally encounter.

We found that the visual guidance strategy and the sensorimotor control response of bumblebees in these wind conditions is similar to the still-air response, but bumblebees exhibit some important adaptations in winds. Compared to the still-air situation, bumblebees more often exhibit low approach velocity phases in higher wind speeds. This can lead to an increase in the travel time and hence, can adversely affect their foraging efficiency. But, bumblebees also exhibit faster transient responses and higher set-points with increasing wind speed which enable them to travel faster. This in turn allows bumblebees to compensate for the increase in travel time that would otherwise occur due to more low approach-velocity phases in higher winds.

In addition to revealing the adverse effects of winds and the compensation mechanism of bumblebees during landing, we also use the natural excitation of the sensorimotor control system that bumblebees offer during landing to propose how they integrate information from the airspeed measuring mechanosensors with their visual feedback loop (Figure 2b).

Visual guidance of landing approaches in honeybees

In the fourth thesis research chapter, we revise the visual guidance strategy of landing honeybees previously proposed in literature (Goyal, 2022). In literature, honeybees are shown to linearly decrease their approach velocity with the reducing distance by analyzing the average of multiple landing maneuvers (Baird et al., 2013). Based on this result, it has been suggested that they land by holding the relative rate of optical expansion constant throughout their approach. We use the novel analysis technique developed in this thesis to show that the individual honeybees do not follow such a strategy. They instead stepwise modulate their set-point of optical expansion rate during landing. Moreover, we extend the analysis to find the mechanism that allows honeybees to converge to a stereotypic landing maneuver closer to the landing surface, for a large range of initial flight speeds and visual landing platform patterns. Finally, we compare the landing strategies of bumblebees and honeybees found in this thesis (Figure 3) and elucidate the likely causes of the differences between their strategies.

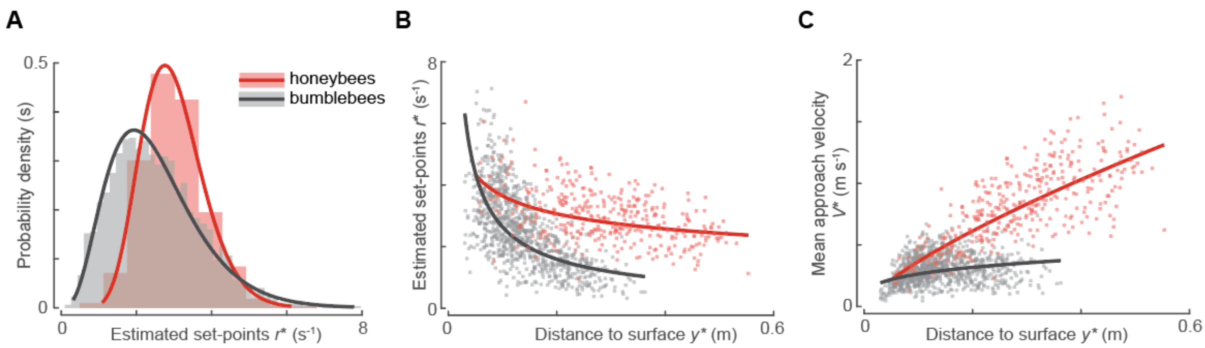

Figure 3 – Comparison of the landing strategies observed in honeybees (red) and bumblebees (grey). (A) The probability density of the set-points of relative rate of expansion r for the landings of honeybees (red) and bumblebees (grey). (B,C) The set-points of relative rate of expansion r* (B) and the mean approach velocity V* (C) with mean distance to the landing platform y*, for honeybees (red) and bumblebees (grey) as they approached a landing surface. Note that the solid lines in panels (B) and (C) also correspond to the theoretical curves that would result from following the constant time-to-contact-rate $\dot{\tau}$ landing strategies suggested in birds (Lee et al., 1991; Lee et al., 1993; Whitehead, 2020).*

Visual guidance and sensorimotor control of landing maneuvers in bees

Considering all results together, in this thesis we developed and used a novel analysis to demonstrate that bumblebees and honeybees have evolved a sophisticated flight control strategy to execute rapid landings. Moreover, we have shown that they have evolved ways to adjust this modular guidance strategy to deal with the challenges offered by the environment, such as high sidewinds.

References

Baird, E., Boeddeker, N., Ibbotson, M. R. and Srinivasan, M. V., 2013. A universal strategy for visually guided landing. Proc. Natl. Acad. Sci. 110, 18686–18691.

Goyal, P., 2022. How bees land. PhD Thesis, Wageningen University & Research.

Goyal, P., Cribellier, A., de Croon, G. C. H. E., Lankheet, M. J., van Leeuwen, J. L., Pieters, R. P. M. and Muijres, F. T., 2021. Bumblebees land rapidly and robustly using a sophisticated modular flight control strategy. iScience 24, 102407.

Goyal, P., van Leeuwen, J. L. and Muijres, F., 2022. Bumblebees Land Rapidly by Intermittently Accelerating and Decelerating Towards the Surface During Visually Guided Landings. iScience 25, 104265.

Lee, D. N., Reddish, P. E. and Rand, D. T., 1991. Aerial docking by hummingbirds. Naturwissenschaften 78, 526–527.

Lee, D. N., Davies, M. N. O., Green, P. R. and (Ruud). Van Der Weel, F. R., 1993. Visual control of velocity of approach by pigeons when landing. J. Exp. Biol. 180, 85–104.

Whitehead, J. G., 2020. An examination of the kinematics and behavior of mallards (Anas platyrhynchos) during water landings.

This highlight refers to the PhD Thesis by Jorge Aguayo Araneda (2022)

An inverse problem in fluid mechanics applied in biomedicine

Jorge Aguayo Araneda[1,2], Cristóbal Bertoglio[1] and Axel Osses[2]

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One of the main causes of problems in the human cardiovascular system is malformations in the aortic valve. There exist exploratory techniques to verify the status of an aortic valve, but these procedures are invasive. Also, magnetic resonance imaging (MRI) is not able to detect the valve geometry because the dimension of a voxel is greater than the thickness of the valve (between 0.5 and 0.8 mm). Using the perturbed version of the Navier-Stokes equations, a penalization parameter method for obstacle identification in an incompressible fluid flow is presented. The proposed method consists of adding a permeability term to the system such that some subset of its boundary support represents the obstacle, considering the maximum velocity on the inflow as unknown with a known velocity profile, and the use of backflow stabilization given by directional do-nothing condition (DDN) on the outflow. This allows to work in a fixed domain and to highly simplify the solution of the inverse problem via some suitable cost functional.

Substituting obstacles and domain deformations for a permeability term

From the steady Stokes and Navier-Stokes models, a penalization method has been considered by several authors for approximating those fluid equations around obstacles. In order to model our problem, we use fictitious domains to study obstacles immersed in incompressible viscous fluids through a simplified version of Brinkman's law for porous media. If the scalar function γ is considered as the reciprocal of the permeability, it is possible to study the singularities of γ as approximations of obstacles (when γ tends to $+\infty$) or of the domain corresponding to the fluid (when $\gamma = 0$ or is very close to 0). The strong convergence of the solution of the perturbed problem to the solution of the strong problem is studied, also considering error estimates that depend on the penalty parameter, both for fluids modeled with the Stokes and Navier-Stokes equations with inhomogeneous boundary conditions.

In order to validate this theory numerically, a straightforward benchmark is proposed considering a 2D domain containing an immersed obstacle and a domain deformation. This real domain is later transformed into a virtual domain where the obstacle and deformation are modeled in a permeability coefficient. The coefficient γ is set to 0 in the real domain and is equal to a positive constant R in the remainder of the domain. As R increases, the velocity obtained in the virtual domain becomes a better approximation of the velocity in the real domain in accordance with the theory. However, when using FEM with Taylor-Hood elements, the numerical result significantly exceeds the theoretical estimate obtained (see Aguayo and Carrillo, 2022).

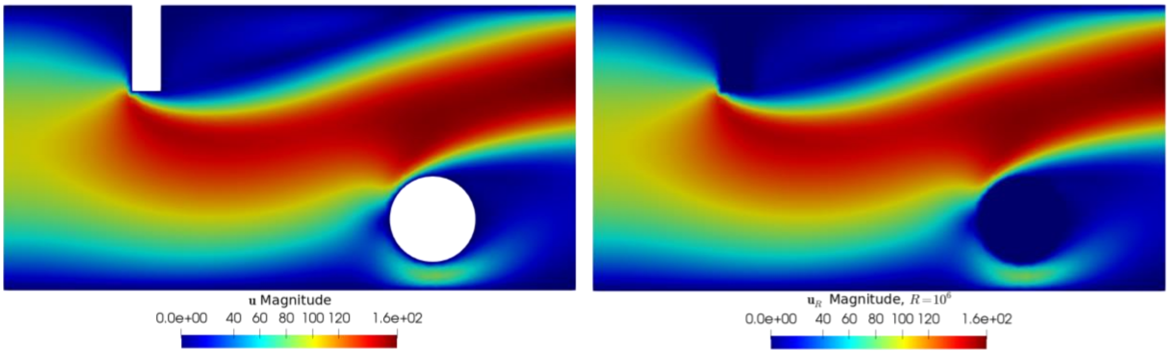


Figure 1: Velocity magnitude in real and virtual domains (from left to right) using FEM with Taylor-Hood elements, $R = 10^6$.

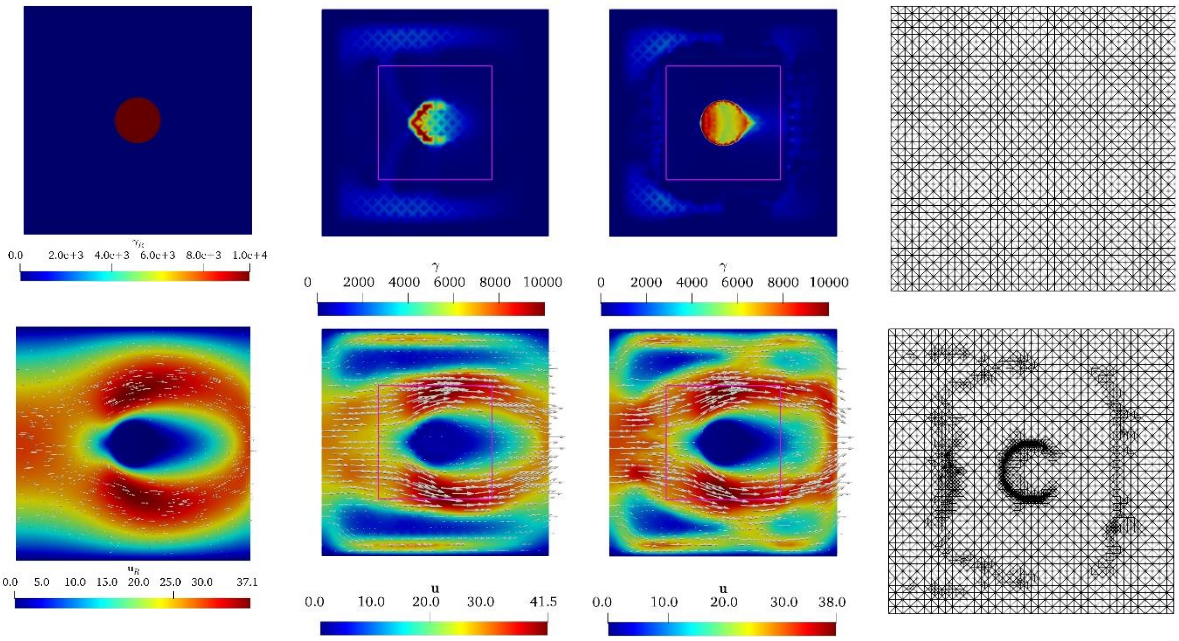


Figure 2: Permeabilities and velocity fields (column 1: references, column 2: optimum before refinement, column 3: optimum after 12 refinement stages). The measurement region is delimited by a rectangle with magenta lines. Column 4 shows the evolution of the mesh refinement (top: original mesh, bottom: refined mesh after 12 stages).

A result of stability for the inverse problem

From a mathematical perspective, the direct problem for the Navier-Stokes equations involves calculating the velocity and pressure of a fluid based on various parameters, including the domain, boundary conditions, viscosity, permeability, and other relevant factors. Our inverse problem involves reconstructing the shape of obstacles or domain deformations based on internal partial velocity measurements of a fluid. Given the knowledge of the domain structure, we aim to determine a permeability coefficient γ that represents the obstacles. While there are results indicating that small disturbances in the permeability coefficient result in proportional disturbances in velocity, the inverse problem requires certain theoretical assumptions to ensure a logarithmic inequality that supports stability in the reconstruction process (see Aguayo and Osses, 2022). Our result is applicable when γ is weakly differentiable from partial measurements of velocity and vorticity field, but it is insufficient when the desired coefficient is discontinuous from a theoretical perspective. However, a numerical test using FEM and adaptive refinement has shown promise in reconstructing a discontinuous coefficient that represents a circular obstacle immersed in the fluid from velocity field measurements within a small subdomain.

A parameter identification problem applied in valve geometry reconstruction

Consider a virtual domain Ω whose boundary $\partial\Omega$ is divided into three disjoint sets Γ_W, Γ_I y Γ_O. These parts represent the no-slip, inflow and outflow boundary conditions, respectively. If $\boldsymbol{u}_R$ denotes the velocity of the fluid being measured and the set ω denotes the velocity measurement region, where $\omega \subseteq \Omega$, we define a new minimization problem with a suitable smooth functional J

$$
\begin{aligned}
&\text{minimize } J(\gamma,\beta) = \frac{1}{2}\|\boldsymbol{u}-\boldsymbol{u}_R\|_{0,\omega}^2 + \frac{\alpha}{2}\|\gamma\|_{1,\Omega}^2 \\
&\text{subject to} \quad \begin{aligned}
-\nu\Delta\boldsymbol{u} + (\nabla\boldsymbol{u})\boldsymbol{u} + \nabla p + \gamma\boldsymbol{u} &= \boldsymbol{0} && \text{in } \Omega \\
\operatorname{div}\boldsymbol{u} &= 0 && \text{in } \Omega \\
\boldsymbol{u} &= \boldsymbol{0} && \text{on } \Gamma_W \\
\boldsymbol{u} &= \beta\boldsymbol{u}_I && \text{on } \Gamma_I \\
-\nu\frac{\partial\boldsymbol{u}}{\partial\boldsymbol{n}} + p\boldsymbol{n} + \frac{1}{2}(\boldsymbol{u}\cdot\boldsymbol{n})_-\boldsymbol{u} &= \boldsymbol{0} && \text{on } \Gamma_O \\
0 \le \gamma \le M_1 & \\
0 \le \beta \le M_2 &
\end{aligned}
\end{aligned}
$$

where $\|\boldsymbol{u}-\boldsymbol{u}_R\|_{0,\omega}^2 = \int_\omega |\boldsymbol{u}-\boldsymbol{u}_R|^2\,d\boldsymbol{x}$, $\|\gamma\|_{1,\Omega}^2 = \int_\Omega (|\gamma|^2 + |\nabla\gamma|^2)\,d\boldsymbol{x}$, $\boldsymbol{n}$ is the outer normal vector, $\boldsymbol{g}$ is a preset inflow profile, α, M_1 and M_2 are positive constants.

The cost functional J depends on the parameters γ and β, since the velocity of the fluid depends on both. In this case, the term $\frac{\alpha}{2}\|\gamma\|_{1,\Omega}^2$ corresponds to a Tikhonov regularization that helps the problem to be solved more easily from a numerical perspective. As the constant α is smaller, the parameters will be better adjusted to the velocity $\boldsymbol{u}_R$. However, if this measurement has a considerable amount of noise or if its resolution is low, it is necessary to use a larger α parameter to avoid overfitting. In addition, the fact of not measuring the vorticity makes it imperative that a regularizing term be added. Existence of local minimizers and first and second order optimality conditions are derived through the differentiability of the solutions of the Navier-Stokes equations, including the directional do-nothing condition, with respect to γ and β (see Aguayo et al,, 2020).

Several numerical experiments implemented in FEniCS (with dolfin-adjoint library) illustrate the applicability of the method, for the localization of a 2D and 3D cardiac valve from MRI flow type imaging data (see Aguayo, 2022). The numerical results for the 2D case are presented in Figure 3. We draw a magenta polyline that follows the points where the optimal state γ^* reaches its maximum values on each side of the axis of symmetry, which closely approximate the inner border of the valves. The optimum γ^* assumes values close to 0 between the valves, above and below them, as expected.

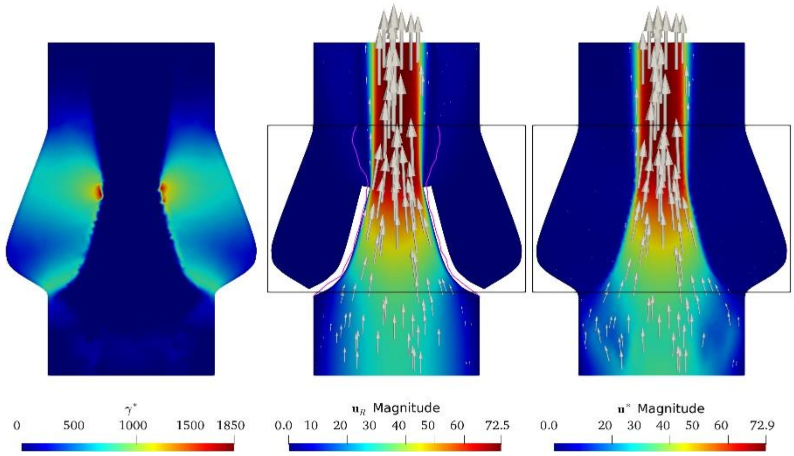


Figure 3. Optimal γ^*, reference solution $\boldsymbol{u}_R$ with reconstructed valve and optimal velocity $\boldsymbol{u}^*$ (from left to right). 2D Test, 366 iterations with L-BFGS-B. The measurement region is delimited by a rectangle with black lines (see Aguayo, 2022).

The 3D experiment is based on a parameterized valve, where the reference is transformed by projecting the velocity $\boldsymbol{u}_\mathrm{R}$ into the piecewise constant function space on a hexahedral mesh in order to simulate a 4D Flow MRI. It can be seen that the optimum γ^* assumes values close to 0 in areas before and after the valve, as well as in the area between the valves. Choosing the region where γ^* has values greater or equal than $0.4\max\{\gamma^*(\boldsymbol{x}) \mid \boldsymbol{x} \in \Omega\}$, following a threshold criterion to identify the valve, it can be seen that region delimits the space between the valves. The magnitude and direction of $\boldsymbol{u}^*$ and $\boldsymbol{u}_\mathrm{R}$ are similar.

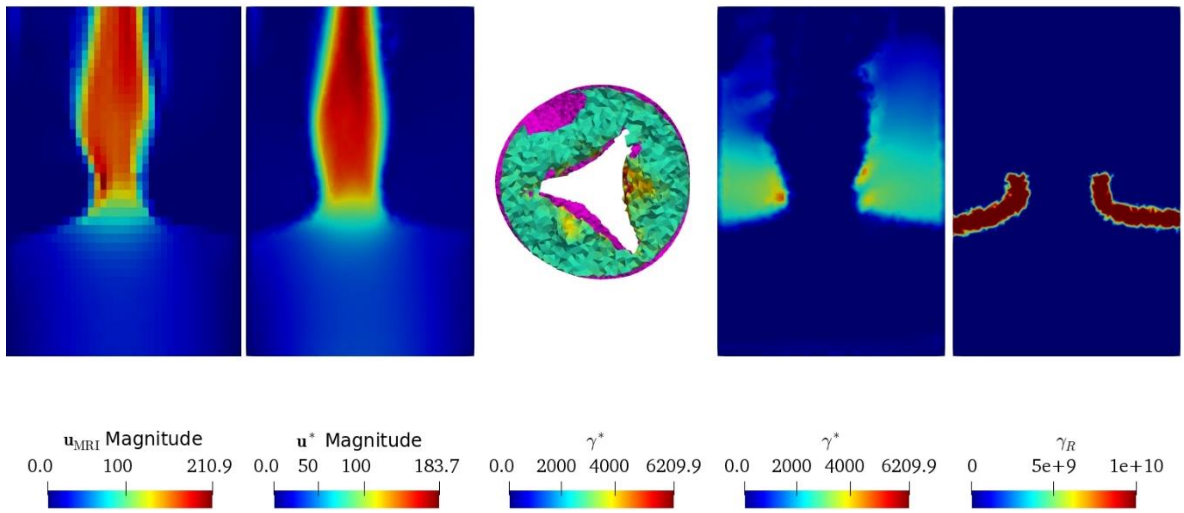


Figure 4. Isovalues cuts. Simulated MRI $\boldsymbol{u}_R$, $\boldsymbol{u}^*$, comparison between γ_R (magenta) and γ^*, γ^* and γ_R (from left to right). 3D MRI Test, 566 iterations (see Aguayo, 2022).

Conclusion and outlook

We have presented an inverse problem focused on recovering the coefficient of permeability in the Stokes and Navier-Stokes equations, with the goal of detecting obstacles and domain deformations.

Our research provides theoretical and numerical validation for using virtual domains and permeability functions to solve this inverse problem, with successful recovery of patency functions and valve shapes, although with some limitations due to numerical noise and running time. As the 3D model is particularly relevant to the medical community as a diagnostic tool for valvular conditions, our future work includes designing an improved and simplified version of our numerical algorithm.

References

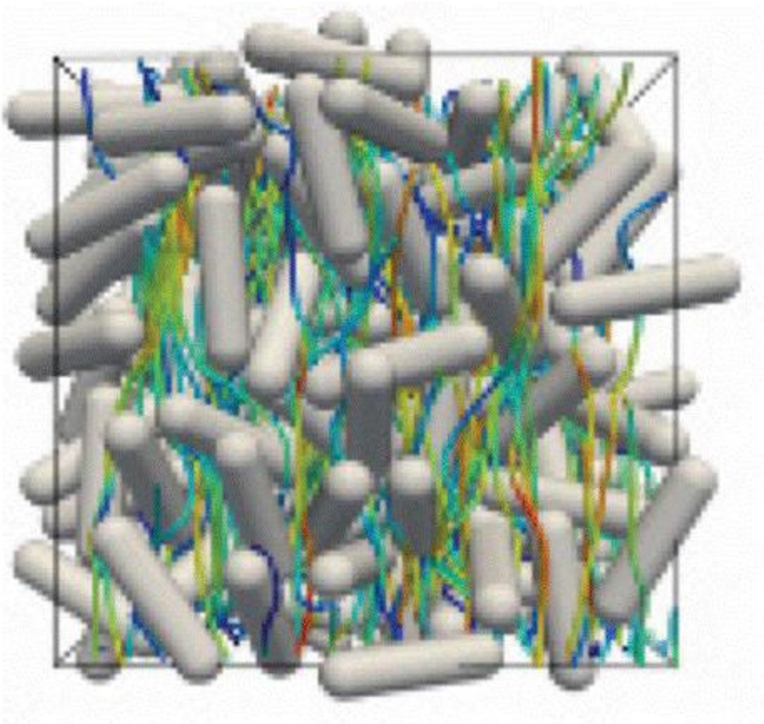
Aguayo J. and Carrillo H., 2022. Analysis of obstacles immersed in viscous fluids using Brinkman's Law for steady Stokes and Navier-Stokes equations. SIAM Journal on Applied Mathematics, 82, 4. https://doi.org/10.1137/20M138569X

Aguayo J. and Osses A., 2022. A stability result for the identification of a permeability parameter on Navier-Stokes equations. Inverse Problems. 38, 7. https://doi.org/10.1088/1361-6420/ac6971

Aguayo J., 2022. An inverse problem in Fluid Mechanics applied in Biomedicine. PhD Thesis, University of Groningen and Universidad de Chile. https://doi.org/10.33612/diss.234433778

Aguayo J., Bertoglio C. and Osses J., 2020. A distributed resistance inverse method for flow obstacle identification from internal velocity measurements. Inverse Problems, 37, 2. https://doi.org/1361-6420/abced8

PHD THESES



2022 PhD Theses

In 2022 a total of 90 PhD theses were delivered within the Burgerscentrum; Delft University of Technology (34), Eindhoven University of Technology (14), University of Twente (26), University of Groningen (2), WUR (7), Utrecht University (2), University of Amsterdam (5).

The thesis defenses in chronological order in 2022 are listed below.

18 January 2022 – Yous Van Halder – *Efficient sampling and solver enhancement for uncertainty quantification*, PhD Thesis, Eindhoven University of Technology, (Koren & Sanderse).

20 January 2022 – Yi Zhang – *Mimetic spectral element method and extensions toward higher computational efficiency*, PhD Thesis, Delft University of Technology, (Gerritsma, Hickel, Hulshoff).

25 January 2022 – Xiaohui Wang – Improving global tide and storm surge forecasts with parameter estimation, PhD Thesis, Delft University of Technology, (Lin and Verlaan).

26 January 2022 – Goyal Pulkit – *How bees land: Visual guidance and sensorimotor control of landing maneuvres in bees*, Wageningen University & Research, (Muijres, Van Leeuwen, de Croon).

27 January 2022 – Ruben Van Gaalen – *Evaporation and absorption of inkjet printed droplets with surfactants*, PhD Thesis, Eindhoven University of Technology, (Kuerten & Wijshoff).

7 February 2022 – Gianluca Romani – *Computational aeroacoustics of rotor noise in novel aircraft configurations: A lattice-boltzmann method-based study*, PhD Thesis, Delft University of Technology, (Casalino).

8 February 2022 – Tim Staps – *Towards experimental characterization of nanoparticle charging in plasmas*, PhD Thesis, Eindhoven University of Technology, (Beckers & Kroesen).

18 February 2022 – Alexander Spoelstra – *Ring of fire as a novel approach to study cycling aerodynamics*, PhD Thesis, Delft University of Technology, (Scarano & Sciacchitano).

18 February 2022 – Carola Seyfert – Shaping droplets, PhD Thesis, Twente University, (Marin & Lohse).

21 February 2022 – Peter Nooteboom – *There and back again: The journey of sinking marine microplankton and its implication for past, present and future climate*, PhD Thesis, University Utrecht, (Dijkstra & Von der Heydt).

2 March 2022 – Diana Garcia Gonzalez – *Capillary interaction on soft and textured surfaces*, PhD Thesis, Twente University, (Snoeijer).

2 March 2022 – Pengxu Zou – *Dynamic response of a submerged floating tunnel subject to hydraulic loading: numerical modelling for engineering design*, PhD Thesis, Delft University of Technology, (Uijttewaal & Bricker).

3 March 2022 – Koen Reef – *Exploratory modelling of barrier coast dynamics*, PhD Thesis, University of Twente (Hulscher, Roos, Schuttelaars).

7 March 2022 – André Jüling – *Climate variability and response in high-resolution earth system models*, PhD Thesis, University Utrecht, (Dijkstra & Von der Heydt).

9 March 2022 – Riande Dekker – *Emulsion stability and rheology*, PhD Thesis, University of Amsterdam, (Bonn).

10 March 2022 – Christopher Teruna – *Aerodynamic noise reduction with porous materials: aeroacoustics investigations and applications*, PhD Thesis, Delft University of Technology, (Casalino, Ragni, Avallone).

16 March 2022 – Constantin Jux – *Development of robotic volumetric PIV*, PhD Thesis, Delft University of Technology, (Scarano & Sciacchitano).

18 March 2022 – Sali Chandana Divi – *Scan-based immersed isogeometric analysis*, PhD Thesis, Eindhoven University of Technology, (Verhoosel, Reali, Van Brummelen).

18 March 2022 – Yesim Koca – *Optimal decision making under uncertainty in biomanufacturing*, PhD Thesis, Eindhoven University of Technology, (Adan & Martagan).

23 March 2022 – Stefan Engelhard – *Blood flow quantification in the aortoiliac arteries: from bench to bedside*, PhD Thesis, Twente University, (Reijnen, Versluis, Groot Jebbink).

30 March 2022 – Amin Ebrahimi – *Molten metal oscillatory behaviour in advanced fusion-based manufacturing processes,* PhD Thesis, Delft University of Technology, (Richardson & Kleijn).

1 April 2022 – Vera van Bergeijk – *Over the dike top: Modelling the hydraulic load of overtopping waves including transitions for dike cover erosion*, PhD Thesis, Twente University, (Hulscher).

1 April 2022 – Jilu Feng – *Maillard-reaction based routes for stable food emulsions,* Wageningen University & Research, (Vicenzo, Schroën, Benron-Carabin).

8 April 2022 – Daan Poppema – *Morphological effects of buildings in a sandy beach environment,* PhD Thesis, Twente University, (Wijnberg, Hulscher, Mulder).

8 April 2022 – Sven Boots – *The strong and the weak: Nucleating insight into the role of mechanical heterogeneity on material failure*, PhD Thesis, Wageningen University & Research, (van der Gucht & Kodger).

12 April 2022 – Andreas Pollet – *In vitro models for investigating vascular flow: A toolbox for recreating the vasculature on chip,* PhD Thesis, Eindhoven University of Technology, (den Toonder & Mischi).

13 April 2022 – Riccardo Madonia – *Laboratory study of rotation-dominated convective turbulence*, PhD Thesis, Eindhoven University of Technology, (Clercx & Kunnen).

22 April 2022 – Ankur Kislaya – *Particle manipulation-on-chip: Using programmable hydrodynamic forcing in a closed loop*, PhD Thesis, Delft University of Technology (Westerweel & Tam).

26 April 2022 – Jesse Buijs – *Simpler, faster, and softer: Towards broad application of Laser Speckle Imaging in art conservation and soft matter*, PhD Thesis, Wageningen University & Research, (Van der Gucht & Sprakel).

11 May 2022 – Prajakta Nakate – *Analysis of nitric oxide emissions from anode baking furnace through numerical modeling*, PhD Thesis, Delft University of Technology, (Vuik & Lahaye).

12 May 2022 – Miguel Rodríguez Olguín – *Nanostructured (electro)catalysts with electrospinning*, PhD Thesis, Twente University, (Gardeniers & Susarrey Arce).

24 May 2022 – Lijing Mu – *Geometry effect and scaling method for circulating fluidized riser: numerical study with discrete element methods*, PhD Thesis, Eindhoven University of Technology, (Kuipers, Deen, Buist).

31 May 2022 – Alberto Felipe Rius Vidales – *Influence of a forward-facing step on crossflow instability and transition*, PhD Thesis, Delft University of Technology, (Kotsonis & Scarano).

1 June 2022 – Balan Ramani – *Flash pyrolysis of tires: Process development for upcycling waste tires*, PhD Thesis, Twente University, (Brem & Bramer).

2 June 2022 – Sandrien Verloy – (joint degree VU Brussels) *Extending the microfabrication and particle handling toolbox for the development of ordered chromatography*, PhD Thesis, Twente University, (Gardeniers & DeSmet).

3 June 2022 – Maaike Rump – *Meniscus dynamics and evaporation in inkjet printing*, PhD Thesis, Twente University, (Lohse, Versluis, Segers).

3 June 2022 – Francesco Sabatino – *Direct air capture and methanation*, PhD Thesis, Eindhoven University of Technology, (Van Sint Annaland, Gallucci, Gazzani).

8 June 2022 – Fatma Ibis – *Kidney stone in a chip: Understanding calcium oxalate kidney stone formation,* PhD Thesis, Delft University of Technology, (Padding & Eral).

8 June 2022 – Anja Herrmann – *Pathways of diffusion through microelectronic packaging materials,* PhD Thesis, Eindhoven University of Technology, (Adan, Fan, Erich).

10 June 2022 – Duoc Tan Nguyen - *Development and validation of a three dimensional wave-current interaction formulation*, PhD Thesis, Delft University of Technology, (Roelvink & Reniers).

10 June 2022 – Dion Koeze - *Jamming in soft disk packings,* PhD Thesis, Delft University of Technology, (Vlugt & Tighe).

17 June 2022 – Jan-Sören Fischer – *Laminar wing design: A framework for transition delay using linear stability theory and adjoint optimization,* PhD Thesis, Twente University, (Venner, Soemarwoto, van der Weide).

20 June 2022 – Zeinab Zafar – *Suspended particulate matter formation and accumulation in the delta: from monitoring to modelling*, PhD Thesis, Delft University of Technology, (Chassagne & Pietrzak).

24 June 2022 – Bjorn Borgelink – *Microfluidic concepts for electrospinning,* PhD Thesis, Twente University, (Gardeniers & Tas).

27 June 2022 – Ahmad Shakeel – *Rheological analysis of mud: towards an implementation of the nautical bottom concept in the Port of Hamburg*, PhD Thesis, Delft University of Technology, (Pietrzak, Chassagne, Kirichek).

28 June 2022 – Elisa Bergkamp – *Computational modeling of skin and slip effects in fractured porous media*, PhD Thesis, Eindhoven University of Technology, (Verhoosel, Smeulders, Remmers).

30 June 2022 – Daoguan Ning – *Experimental investigation into single iron particle combustion*, PhD Thesis, Eindhoven University of Technology, (de Goey, Shoshyn, Finotello).

30 June 2022 – Harsha Mysore Prabhakara – *Sorption enhanced catalytic fast pyrolysis for the production of high-quality bio-oil from biomass,* PhD Thesis, Twente University, (Brem).

4 July 2022 – Vandana Dwarka – *Iterative methods for time-harmonic waves: Towards accuracy and scalability*, PhD Thesis, Delft University of Technology, (Vuik & van Gijzen).

4 July 2022 – Silke Tas – *Chenier dynamics*, PhD Thesis, Delft University of Technology, (Reniers).

7 July 2022 – Tim Hermans – *Understanding sea-level change using global and regional models*, PhD Thesis, Delft University of Technology, (Vermeersen & Katsman).

8 July 2022 – Piet Swinkels – *Colloidal Architectures: Atom-like Assembly of Patchy Particles*, PhD Thesis, University of Amsterdam (Schall & Coulais).

15 July 2022 – Vatsal Sanjay – *Viscous free surface flows*, PhD Thesis "Cum Laude", Twente University, (Lohse).

26 August 2022 – Yan Zhao – *Solid viscoelasticity in contact mechanics and elastohydrodynamic lubrication,* PhD Thesis, Twente University, (Venner, Morales-Espejel, Visser).

29 August 2022 – Jeremias Garay Labra – *On the analysis of inaccurate Phase-Contrast MRI and its assimilation into blood flow models*, PhD Thesis, University of Groningen, (Bertoglio, Verstappen).

30 August 2022 – Jorge Aguayo Araneda – *An inverse problem in fluid mechanics applied in biomedicine*, PhD Thesis, University of Groningen, (Bertoglio, Osses, Verstappen).

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26 September 2022 – Colin van Dercreek – *Improving Acoustic Measurements with Cavities in Closed Test Section Wind Tunnels*, PhD Thesis, Delft University of Technology, (Snellen, Ragni, Avallone).

28 September 2022 – Martin Sanders – *Aeroacoustic measurements of airframe components: in an open-jet, a hard-wall and a hybrid wind tunnel test section*, PhD Thesis, Twente University, (Venner & De Santana).

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29 September 2022 2 – Rick Sijs – *Droplet dynamics from sprays with and without additives*, PhD Thesis, University of Amsterdam, (Bonn).

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5 October 2022 – Julian Biesheuvel – *Sound propagation corrections in open jet wind tunnels*, PhD Thesis, Twente University, (Venner, De Santana, Tuinstra).

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17 October 2022 – Elin Vesper – *Modeling of continuous physical vapor deposition: from continuum to free molecular flow*, PhD Thesis, Delft University of Technology, (Kleijn & Kenjeres).

26 October – Thejas Hulikal Chakrapani – *Mesoscale modelling of multiphase flow and wetting,* PhD Thesis, Twente University, (Luding, den Otter).

26 October 2022 – Aswin Muralidharan – *Biomolecule electrotransfer to mammalian,* PhD Thesis, Delft University of Technology, (Kreutzer & Boukany).

26 October 2022 – Bas Nieuwboer – *Modelling spillage in rotating cutter suction heads: a combined Finite Volume and Discrete Element Model*, PhD Thesis, Delft University of Technology, (van Rhee & Keetels).

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3 November 2022 – Nestoras Antoniou – *Numerical and experimental investigation of urban microclimate in a real compact heterogeneous urban area,* PhD Thesis, Eindhoven University of Technology, (Blocken, Neophytou, Montazeri).

4 November 2022 – Martin Essink – *Soft Contact: from wetting to adhesion,* PhD Thesis, Twente University, (Snoeijer).

18 November 2022 – Jing Wang – *Transverse and longitudinal vibrations in axially moving strings,* PhD Thesis, Delft University of Technology, *(*van Horssen & Wang).

25 November 2022 – Boxin Deng – *Microfluidic analysis of dynamic processes occurring during bubble formation and stabilisation,* Wageningen University & Research, (Schroën & de Ruiter).

29 November 2022 – Mohammad Kojourimanesh – *System based thermo-acoustic design of central heating equipment*, PhD Thesis, Eindhoven University of Technology, (De Goey, Lopez Aetega, Kornilov).

30 November 2022 – Rezvan Shafirian – *Electrochemical oceanic carbon capture: using bipolar membrane electrodialysis*, PhD Thesis, Delft University of Technology, (Kleijn & Vermaas).

5 December 2022 – Jian Tan – *Improving the Techno-Economic Performance of Wave Energy Converters. From the Perspective of Systematic Sizing,* PhD Thesis, Delft University of Technology, (Miedema, Jarquin Laguna).

9 December 2022 – Saravana Kumar – *A study of complex solid-liquid interfaces by atomic force microscopy,* PhD Thesis, Twente University, (Mugele & Sîretanu).

9 December 2002 – Herehau Blais – *Innovative energy efficient membrane separation approaches for milk,* PhD Thesis, Wageningen University & Research, (Schroën & Tobin).

13 December 2022 – Bo Liu – *Morphology of liquid tin sheets formed by laser impact on droplets*, PhD Thesis, Vrije Universiteit Amsterdam, (Versolato & Gelderblom).

15 December 2022 – Keerthivasan Rajamani – *A magnetocaloric mixture based refrigerator - from material to system level analysis,* PhD Thesis, Twente University, (Pozarlik & Van der Meer).

22 December 2022 – Floris de Wit – *Wave shape prediction in complex coastal systems*, PhD Thesis, Delft University of Technology, (Reniers & Tissier).

REPORTS OF INDIVIDUAL RESEARCH GROUPS

TU Delft
Delft University of Technology

TU/e Technische Universiteit Eindhoven
University of Technology

UNIVERSITY OF TWENTE.

university of groningen

WAGENINGEN
UNIVERSITY & RESEARCH

Utrecht University

UNIVERSITY OF AMSTERDAM

Delft University of Technology

Faculty Mechanical Maritime and Material Engineering (3mE)

Department Process & Energy

Energy Technology & Thermal Fluids Engineering (TUD-3mE-ET)

Prof. dr. René Pecnik	Full prof.
Dr. ir. Willem Haverkort	Assistant prof.
Dr. ir. Jurriaan Peeters	Assistant prof.
Dr. eng. Pedro Costa	Assistant prof.

Group's research areas

- Turbulent heat and mass transfer
- Non-ideal fluid dynamics (supercritical fluids)
- Turbomachinery and rotating equipment
- Extreme-scale numerical simulations (GPGPU)
- Fluid mechanics for electrochemical applications
- Turbulent multiphase flows
- Urban flows and climate

Grant obtained in 2022

- NWO: E-Heat: understanding and controlling heat to enable large scale electrolyzers
- NWO Vidi Willem Haverkort 'hydrogen bubbles quantified'

Project started in 2022

- ECCM KICkstart DE-NL – NWO, Willem Haverkort, 'better electrodes for water electrolysis'
- Horizon-EIC Pathfinder, Willem Haverkort, Microfluidic wAstewater treatment and Creation of Green HYdrogen Via Electrochemical Reactions (MacGhyver).

Collaboration with other groups (inside or outside Burgerscentrum)

- Kawai, Tohoku University, Japan
- Larsson, University Maryland, US
- Pirozzoli, University Rome, Italy
- Woisetschlaeger, Graz University of Technology, Austria
- Fuchs, Wetsus, NL
- Neil Sandham, Southampton University, UK
- Roekaerts, TU Delft,
- Boersma, TU Delft,
- Hickel, TU Delft
- Rohde, TU Delft
- Halldór Pállson & Ásdís Helgadóttir, U. Iceland (Iceland)

- Francesco Picano, U. of Padova (Italy)
- Luca Brandt, KTH Mechanics (Sweden)
- Massimiliano Fatica, Josh Romero & Thorsten Kurth, NVIDIA Corporation (CA, USA)
- Soledad le Clainche, UP Madrid (Spain)
- Davide Modesti, TU Delft
- Nuclear Research and Consultancy Group
- McPhy
- HyET E-Trol
- Veco B.V.
- Magneto special anodes B.V.
- Shell
- Zero Emission Fuels B.V.
- RWTH-Aachen, group of Matthias Wessling
- Eden Tech Microfluidics

Delft University of Technology

Faculty Mechanical Maritime and Material Engineering (3mE)

Department Process & Energy

Fluid Mechanics (TUD-3mE-FM)

Prof. dr. ir. Jerry Westerweel	Full prof.
Prof. dr. ir. Ruud Henkes	Full prof. (part time)
Dr. ir. Gerrit Elsinga	Associate prof.
Dr. Daniel Tam	Associate prof.
Dr. ir. Mark Tummers	Assistant prof.
Dr. Abel-John Buchner	Assistant prof.

Group's research areas

- Turbulence
- Dispersed multiphase flow
- Biological flows
- Unsteady hydrodynamics
- Combustion

Grant obtained in 2022

- FlexFloat (NWO grant 19002): dr. S. Schreier (MTT/3mE/TUD)
- Data-driven identification and control of hydrodynamically coupled floating structures (3mE Cohesion grant): with dr. D. Boskos (DCSC/3mE/TUD)
- Modelling wake-structure interaction in unsteadily oscillating propulsors (departmental funding)
- HELIOS (EU Horizon CLEANH2): Dr. Mark Tummers en Prof. Sikke Klein (start project 1 March 2023)

Project started in 2022

- FlexFloat (NWO grant 19002): dr. S. Schreier (MTT/3mE/TUD)
- Hydrodynamics in Sport (NOC*NSF): dr.ir. A.J. Greidanus
- Data-driven identification and control of hydrodynamically coupled floating structures (3mE Cohesion grant): with dr. D. Boskos (DCSC/3mE/TUD)
- Modelling wake-structure interaction in unsteadily oscillating propulsors (departmental funding)
- HELIOS (EU Horizon CLEANH2

Collaboration with other groups (inside or outside Burgerscentrum)

- Prof. Tom van Terwisga / prof. Detlef Lohse in the AQUA project (NWO)
- Dr. Sebastian Schreier in FlexFloat (NWO)
- Dr. Ido Akkerman in Lift control for hydrofoil craft (NWO)
- Dr. Dimitris Boskos (DCSC/3mE/TUD)

- Prof. Florian Muijres (WUR)
- Prof. Sikke Klein (P&E/3mE/TUD)

Other 2022 highlights

- A.J. Greidanus, R. Delfos, S.J. Picken & J. Westerweel "Response regimes in the fluid-structure interaction of wall turbulence over a compliant coating", J. Fluid Mech. 952 (2022) A1.

PhD theses delivered in 2022

- 22 April 2022 – Ankur Kislaya – *Particle manipulation-on-chip: Using programmable hydrodynamic forcing in a closed loop*, PhD Thesis, Delft University of Technology (Westerweel & Tam).
- 19 September 2022 – Marieke Schenker – *Turbulent flow through a ribbed pipe: An experimental study,* PhD Thesis, Delft University of Technology, (Westerweel).

Delft University of Technology

Faculty Mechanical Maritime and Material Engineering (3mE)

Department Process & Energy

Multiphase Systems (TUD-3mE-MS)

Prof. dr. ir. Christian Poelma	Full prof.
Dr. ir. Wim-Paul Breugem	Associate prof.
Dr. Brian Tighe	Associate prof.
Dr. Angeliki Laskari	Assistant prof.

Group's research areas

- Flow of dense suspensions
- Flow measurement techniques for multiphase systems
- Turbulence and boundary layers near open surfaces
- Rheology
- (Transition to) Turbulence in multiphase systems

Grant obtained in 2022

- Wall-bounded turbulence: from the instantaneous to the statistical" (PI: Laskari; funding: AFOSR/EOARD)

Project started in 2022

- Data-driven control of gas bubble drag reduction in liquid wall bounded flows (PI: Laskari, internal funding)

Collaboration with other groups (inside or outside Burgerscentrum)

- Flow measurements using Magnetic Resonance Imaging (with University of Rostock)
- Fluid dynamics of flexible, floating structures (with MT&T, TU Delft)
- Urban Flow and Climate – large scale simulations for climate modeling (with CITG, TU Delft)

Other 2022 highlights

- Raaghav, S. K., Poelma, C., & Breugem, W. P. (2022). Path instabilities of a freely rising or falling sphere. International Journal of Multiphase Flow, 153, 104111; We found clearly different transition scenarios for moderately light versus heavy spheres. Some path instabilities were observed experimentally for the first time, including evidence for the existence of an intriguing bi-stable regime.
- Hogendoorn, W., Chandra, B., & Poelma, C. (2022). Onset of turbulence in particle-laden pipe flows. Physical Review Fluids, 7(4), L042301; We provide a scaling law to predict how and when the transition to turbulence occurs for neutrally-buoyant particles in pipe flow.

PhD theses delivered in 2022

- 10 juni 2022 – Dion Koeze - *Jamming in soft disk packings,* PhD Thesis, Delft University of Technology, (Vlugt & Tighe).
- 8 September 2022 – Amitosh Dash – *Opaque inertial suspensions*, PhD Thesis, Delft University of Technology, (Poelma & Breugem).

Delft University of Technology

Faculty Mechanical Maritime and Material Engineering (3mE)

Department Process & Energy

Complex Fluid Processing (TUD-3mE-CFP)

Prof. dr. ir. Johan Padding	Full prof.
Prof. dr. Antoine van der Heijden	Full prof. (part time)
Dr. Lorenzo Botto	Associate prof.
Dr. Burak Eral	Assistant prof.
Dr. Remco Hartkamp	Assistant prof.

Group's research areas

- Electrochemical processes
- Electrokinetic transport
- Mesoscale transport phenomena
- Multiphase flows
- Viscoelastic flows
- Crystallization
- Solids processing
- Electrochemical separation processes
- Fluid dynamics of centrifugation of complex fluids
- Spray drying of 2D materials and rheology of complex fluid interfaces

Grants obtained in 2022

- NWO KIC grant "Electrically Driven Nonthermal Dewatering of Biomass" (Electrified)
- NWO-TTW OTP grant "CO2 into hexanoic acid using microbial electrosynthesis" (C1to6)
- NWO-TTW OTP grant "E-Heat: understanding and controlling heat to enable large-scale electrolysers"
- TKI + direct industry funding of "Modelling and experimental validation of HTW bubbling fluidized bed gasification"
- LTPPT-TREPS with direct industrial funding "Trace separations with external fields"
- MIT-MISTI collaboration grant extension "Shaking up laser induced nucleation"

Projects started in 2022

- Modelling of bubbling fluidized bed biomass and waste plastic gasification
- Gas-liquid flows in LOHC dehydrogenation reactors
- Modelling and experiments on hydrodynamics and crystallization phenomena in dehydrogenation reactors based on borohydrides
- Understanding mechanochemistry in high energy ball mills
- Effect of bubbles on electric conductivity of electrolytes

Collaboration with other groups (inside or outside Burgerscentrum)

- Electro-osmotic Drag and Thermodynamic Properties of Water in Hydrated Nafion Membranes from Molecular Dynamics, with Thijs J.H. Vlugt, Othonas Moultos, Mahinder Ramdin, David Dubbeldam (UvA), Alexey Lyulin (TUE)
- Surface protolysis and its kinetics impact the electrical double layer: with prof. Benoit Coasne (CNRS, UGrenoble)
- Scale-Dependent Friction-Coverage Relations and Non-Local Dissipation in Surfactant Monolayers, with prof. Martin H. Müser (USaarlandes), and prof. Daniele Dini (Imperial College London)
- Highly Efficient Water Desalination through Hourglass Shaped Carbon Nanopores, with prof. Sarith Sathian (IIT Madras)
- Binders for sustainable concrete: testing for dissolution and precipitation, with dr. Jeanette Visser (TNO)
- Electrochemical Conversion of CO2 to Synthetic Fuel Using 2D Electrode Materials, with dr. Peyman Taheri
- Design of suspension electrodes for CO2 electroconversion, with dr. David Vermaas (TUD)
- Bubble Dynamics in Electrolysis, with dr. Cor van Kruijsdijk (Shell), dr. James McClure (Virginia Tech) and dr. Zhe Li (Canberra National University)
- Hydrodynamic Drag, Lift and Torque Correlations for Ellipsoidal Particles, with dr. Yousef el Hasadi (TUD) and dr. Sathish Sanjeevi (National Energy Technology Laboratory, Morgantown, USA)
- Processing of Solid Borohydride Hydrogen Carriers, with dr. Dingena Schott, ir. Klaas Visser (TUD) and dr. Chris Slootweg (UvA)
- Transport phenomena in novel electric drying techniques, with dr. Maarten Schutyser (WUR)
- Viscoelastic Droplet Collisions for Spray Drying Applications, with dr. Alfred Jongsma (Tetrapak)
- Expanded Bed Adsorption for Production of Pharmaceuticals, with dr. Marcel Ottens and dr. Tim Nijssen (TUD)
- Design of Fluidized Bed Softening Reactors for Drinking Water Production, with dr. Onno Kramer (Waternet)
- Fluidized bed gasification of biomass and plastic waste, with dr. Wiebren de Jong (TUD) and dr. Elyas Moghaddam (GI Dynamics)
- Fundamentals of non-photochemical laser induced nucleation Allan Myerson (MIT), Andrew Alexander (University of Edinburgh)
- Recovery of rare earth elements with light induced crystallization Kerstin Forsberg (KTH,sweden)
- Battery recycling with eutectic freeze crystallization with dr. Pieter Verhees (Umicore)
- Light induced seed generation for industrial crystallization with Clemens Bothe (Bayer)
- Morphology control in antisolvent crystallization with Rob Geertman (J&J)
- Separations in e-refinery with R. Kortlever, D. Vermaas and Monique van der Veen (TUD)
- Rheology of suspensions of graphene nanoplatelets (with Prof. Hong Liang, Texas AM, USA)
- Buckling of elastic sheets in shear flow: comparison experiments/simulation (with Michael Graham, U. of Wisconsin at Madison, USA)

PhD thesis delivered in 2022

- 8 June 2022 – Fatma Ibis – *Kidney stone in a chip: Understanding calcium oxalate kidney stone formation,* PhD Thesis, Delft University of Technology, (Padding & Eral).

Delft University of Technology

Faculty Mechanical Maritime and Material Engineering (3mE)

Department Maritime and Transport Technology

Ship Hydromechanics (TUD-3mE-SH)

Prof. dr. ir. Bendiks Jan Boersma	Full. prof.
Prof. dr. ir. Gabe Weymouth	Full. prof.
Prof. dr. ir. T.C.J. van Terwisga	Full prof. (part time)
Dr. ir. Ido Akkerman	Assistant prof.
Dr. ing. Sebastian Schreier	Assistant prof.
Dr. ir. Peter Wellens	Assistant prof.
Dr. Harleigh Seyffert	Assistant prof.
Dr. Daniele Fiscaletti	Assistant prof.

Group's research areas

- Ship hydromechanics
- Multiphase flow: Cavitation, phase transition
- Multiphase flow: free surface waves
- Turbulence: separating turbulent boundary layers and wakes
- Fluid-structure-interaction: Large amplitude deformations and

Grants obtained in 2022

- NWO-KIC Maritime veiligheid: "FUSION: Smart Sensing for Informed Maintenance & Optimized Naval Design"
- European Defense Fund- Ship Structural Health Monitoring "dTHOR"

Collaboration with other groups inside and outside the Burgerscentrum

- In almost all projects we collaborate with the groups of Westerweel/Poelma/Henkes

Other 2022 highlights

- Gabe Weymouth started as new professor of Ship Hydromechanics

PhD thesis delivered in 2022

- 6 September 2022 – Pranav Doijode - *Application of machine learning to design low noise propellers*, PhD Thesis, Delft University of Technology, (Terwisga, Hickel, Visser).

Delft University of Technology

Faculty Mechanical Maritime and Material Engineering (3mE)

Department Maritime and Transport Technology

Dredging Engineering (TUD-3mE-DE)

Prof. dr. ir. Cees van Rhee	Full prof.
Dr. ir. Geert Keetels	Assistant prof.
Dr. ir. Rudy Helmons	Assistant prof.
Dr. ir. Arno Talmon	Assistant prof.
Dr. ir. Said Alhaddad	Assistant prof.
Dr. ir. Antonio Jarquin Laguna	Assistant prof.

Group's research areas

- Dredging Processes, including trenching of cables and pipelines
- Deep Sea Mining
- CFD of (multiphase) flows
- Turbidity currents, hyper concentrated sediment water flows
- Sedimentation and erosion of sediments
- Hydraulic and mechanical excavation
- Seabed interaction with fishing gear
- Wave energy
- Low head energy storage

Grant obtained in 2022

- StimTech - Fishery Research (Duurzame visserij)
- Mechanical cutting of Clay

Projects started in 2022

- PlumeFloc
- Menens

Collaboration with other groups (inside or outside Burgerscentrum)

- Blue Harvesting: collaboration with RWTH Aachen University, ICM Institute of Marine Sciences, Aarhus University, NIOZ, Jacobs University, University Politechnica of Catalunya , Royal IHC .
- PlumeFloc: NIOZ, IHC Mining, Allseas, Boskalis, Deltares
- Onderzoek Duurzame visserij: Marin, NIOZ, Wageningen Research
- SailFM : Marin, Port of Rotterdam

PhD thesis delivered in 2022

- 26 October 2022 – Bas Nieuwboer – *Modelling spillage in rotating cutter suction heads: a combined Finite Volume and Discrete Element Model*, PhD Thesis, Delft University of Technology, (van Rhee & Keetels).
- 5 December 2022 – Jian Tan – *Improving the Techno-Economic Performance of Wave Energy Converters. From the Perspective of Systematic Sizing,* PhD Thesis, Delft University of Technology, (Miedema, Jarquin Laguna).

Delft University of Technology

Faculty of Applied Sciences

Department Chemical Engineering

Transport Phenomena (TUD-CE-TP)

Prof. dr. ir. Chris Kleijn	Full prof.
Prof. dr. Saša Kenjereš	Full prof.
Prof. dr. ir. Harrie van den Akker	Full prof. (part time)
Dr. Valeria Garbin	Associate prof.
Dr. ir. David Vermaas	Associate prof.
Dr. Luis Portela	Assistant prof.
Dr. Bijoy Bera	Assistant prof.

Group's research areas

- Turbulent flow and transport phenomena
- Multiphase flow and interfacial transport phenomena
- Electrochemical flow and transport phenomena
- Bio-medical flow and transport phenomena
- Magnetohydrodynamic flow and transport phenomena
- Flow and Dynamics of Soft Matter

Grants obtained in 2022

- ERC Proof of Concept grant "ABuMic :Acoustic Bubble Microrheology" (V. Garbin)
- NWO-KIC project "ELECTRIFIED: Electrically driven non-thermal dewatering of biomass (V. Garbin)
- Joint Call TU Delft-IITD Collaborative project (B. Bera)
- E-Heat: controlling heat management in electrolyzers. Funded by NWO (OTP grant) in collaboration with TU Delft–Process&Energy department. Our group studies experimentally the temperature distribution and cooling strategies for water electrolyzers and CO_2 electrolyzers (D. Vermaas)
- OFFSET: Green hydrogen from seawater in floating electrolyzers. Funded by RVO, in collaboration with industrial partners SwitcH2, BW Offshore, Marin and Strohm. Our group investigates the impact of tilting/moving a flowing electrolyzer and developing an electrolyzer running on seawater (D. Vermaas)

Projects started in 2022

- "ABuMic :Acoustic Bubble Microrheology" (V. Garbin)
- Pore-scale to system level design of water desalination and water purification unit (B. Bera)
- "Numerical simulations of optimization of aerosol deposition in the patient-specific upper and central airways" (S. Kenjeres)
- "CFD simulation of blood flow in patient-specific geometry with machine learning optimization" (S. Kenjeres)

Collaboration with other groups (inside or outside Burgerscentrum)

- ELECTRIFIED: collaboration with FPE group at WUR (JMBC), CFP group at TUD (JMBC) and RUG, TU/e, UT.
- Smart Tomographic Sensors for Advanced Industrial Process Control: collaboration with Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany, Lodz University of Technology (LUT), Poland, and Institut de Mécanique des Fluides de Toulouse (IMFT), France.
- Computation for Rational Design of Bioreactors: collaboration with Department of Biotechnology, Delft University of Technology (TU Delft).
- Two-Phase Gas-Liquid Flows in Pipelines: collaboration with University of Campinas (UNICAMP), Brazil.
- Sediment Transport: collaboration with National University of Asuncion, Paraguay and State University of Rio de Janeiro, Brazil.
- CO2 Cooling for Particle Detectors: collaboration with European Organization for Nuclear Research (CERN), Switzerland.
- X-Ray Tomography: collaboration with Centrum Wiskunde & Informatica (CWI).
- LUMC - Leiden University Medical Centre: Department of Radiology; Department of Pediatric Surgery; Department of Cardiology and Anatomy and Embryology; Department of Cardiothoracic Surgery;
- MUMC+ - Maastricht University Medical Centre: Department of Radiology & Nuclear Medicine; Cardiovascular Research Institute;
- AMC - Amsterdam University Medical Centre: Department of Radiology and Nuclear Medicine;
- EMC - Erasmus Medical Centre Rotterdam: Department of Cardiology; Department of Biomedical Engineering;
- University of Ghent, Belgium - Institute of Biomedical Technology;
- AGH Krakow University of Science and Technology, Poland - Faculty of Energy and Fuels, Department of Fundamental Research in Energy Engineering;
- SCK-CEN - Belgian Nuclear Research Centre, Mol, Belgium
- Vinca Institute of Nuclear Sciences, University of Belgrade, Serbia
- Tata Steel, IJmuiden, The Netherlands
- Philips, Department of MR R&D Clinical Science, Best, The Netherlands
- Pie Medical Imaging, Maastricht, The Netherlands

Other 2022 highlights

- First Prize in the Flow Visualization Competition of the ASME Fluids Engineering Division Summer Meeting (FEDSM), held in August 3-5, 2022, in Ontario, Canada, attributed to *Swirl Effects on Gas-Liquid Upward Vertical Pipe Flow*, by Matheus M. Garcia and Luis M. Portela.
- Jorrit Bleeker (PhD) and David Vermaas (PI) won a prizes for the best poster and best presentation, respectively, at the E3C conference for their work on flow dynamics in electrochemical cells.
- The work of Rezvan Sharifian (PhD, currently postdoc) and David Vermaas, about CO_2 capture from seawater in electrodialysis flow cells, was broadcasted at BNR radio, Radio 2, De Volkskrant and Algemeen Dagblad.

PhD theses delivered in 2022

- 30 March 2022 – Amin Ebrahimi – *Molten metal oscillatory behaviour in advanced fusion-based manufacturing processes,* PhD Thesis, Delft University of Technology, (Richardson & Kleijn).

- 15 September 2022 – Artem Blishick - *Numerical modeling of conjugate magnetohydrodynamic flow phenomena*, PhD Thesis, Delft University of Technology, (Kenjeres, Kleijn).
- 17 October 2022 – Elin Vesper – *Modeling of continuous physical vapor deposition: from continuum to free molecular flow*, PhD Thesis, Delft University of Technology, (Kleijn & Kenjeres).
- 30 November 2022 – Rezvan Shafirian – *Electrochemical oceanic carbon capture: using bipolar membrane electrodialysis*, PhD Thesis, Delft University of Technology, (Kleijn & Vermaas).

Delft University of Technology

Faculty of Applied Sciences

Department Chemical Engineering

Product and Process Engineering (TUD-CE-PPE)

Prof. dr. ir. Ruud van Ommen	Full prof.
Dr. ir. Volkert van Steijn	Associate prof.
Dr. Pouyan Boukany	Associate prof.

Group's research areas

- Droplet microfluidics
- Interfaces, bubbles, droplets, emulsions and interfaces
- Granular matter, (nano)particle processing, fluidization
- Application of fluid mechanics in health technology

Grant obtained in 2022

- ENW_M2: The role of the actin cortex in membrane electroporation and cargo translocation (ROCKET)

Collaboration with other groups (inside or outside Burgerscentrum)

- Collaboration with a wide range of groups, including Kuipers (TU/e), Luding (UT), Padding (TUD), Quax & Kruyt (LUMC), Van Beusekom (EMC), Ten Dijke (LUMC)

PhD theses delivered in 2022

- 26 October 2022 – Aswin Muralidharan – *Biomolecule electrotransfer to mammalian,* PhD Thesis, Delft University of Technology, (Kreutzer & Boukany).

Delft University of Technology

Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS)

Delft Institute of Applied Mathematics (DIAM)

Numerical Analysis (TUD-EEMC-NA)

Prof. dr. ir. Kees Vuik	Full prof.
Prof. dr. Martin van Gijzen	Full prof.
Dr. ir. Matthias Möller	Associate prof.
Dr. ir. Deepesh Toshniwal	Assistant prof.
Dr. Alexander Heinlein	Assistant prof.

Group's research areas

- Discretization methods for Partial Differential Equations: Isogeometric analysis (IgA), Boundary Element Method (BEM), Multiscale methods for porous media flow.
- Fast and Robust solvers: Domain Decomposition methods, Preconditioned and Deflated Krylov methods, Multigrid methods, Scalable methods
- High Performance computing: methods for GPU and Quantumcomputing, parallel iterative methods
- Machine Learning methods combined with Partial Differential Equations

Grants obtained in 2022

- NWO OTP project FlexFloat, Matthias Moller
- EU ITN ProposalSafe underground Hydrogen storage IN porous subsurface rEservoirs (SHINE), Kees Vuik and Hadi Hajibeygi

Collaboration with other groups (inside or outside Burgerscentrum)

- Group of Prof. J. Westerweel
- Group of Dr. H. Hajibeygi

Other 2022 highlights

- On Wednesday 5 October 2022, the National Agenda for Computational Sciences was presented, by Kees Vuik, to the Director of Innovation and Knowledge at the Ministry of Economic Affairs and Climate Policy, Michiel Sweers. https://www.dutchcomputational.science/national-agenda/
- The art of scientific computing, an event to celebrate the launch of the DelftBlue supercomputer and the 5th anniversary of the TU Delft Institute for Computational Science & Engineering, took place on September 30, in the Prinsenhof in Delft. https://www.tudelft.nl/evenementen/2022/dcse/the-art-of-scientific-computing

PhD theses delivered in 2022

- 11 May 2022 – Prajakta Nakate – *Analysis of nitric oxide emissions from anode baking furnace through numerical modeling*, PhD Thesis, Delft University of Technology, (Vuik & Lahaye).
- 4 July 2022 – Vandana Dwarka – *Iterative methods for time-harmonic waves: Towards accuracy and scalability*, PhD Thesis, Delft University of Technology, (Vuik & van Gijzen).

Delft University of Technology

Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS)

Delft Institute of Applied Mathematics (DIAM)

Mathematical Physics (TUD-EEMC-MP)

Prof. dr. ir. Henk Schuttelaars	Full prof.
Prof. dr. ir. Arnold Heemink	Full prof. (em.)
Prof. dr. ir. Martin Verlaan	Full prof. (part time)
Prof. dr. ir. Hai Xiang Lin	Full prof.
Dr. ir. Wim van Horssen	Associate prof.
Dr. Johan Dubbeldam	Associate prof.
Dr. Bernard Meulenbroek	Assistant prof.
Dr. Domenico Lahaye	Assistant prof.
Dr. Yoeri Dijkstra	Assistant prof.
Dr. ir. Ramses van der Toorn	Assistant prof.

Group's research areas

- Modelling and analysis of partial differential equations, with applications in coastal sea dynamics, vibrating structures, and petroleum reservoirs.
- Data assimilation and Inverse modelling, with application in tidal model calibration, reservoir history matching, emission estimation in atmospheric-chemistry transport models, and closed-loop degaussing for ships
- Complex networks, Dynamics on/of complex networks
- Development of mathematical methods in perturbation theory, difference equations, differential-delay equations, and fractional differential equations, with applications in mechanical engineering

Collaboration with other groups (inside or outside Burgerscentrum)

- Forecast Arctic Surges and Tides for the Netherlands: collaboration with dr. Slobbe, department of geosciences and remote sensing
- Versatile Hydrodynamics - A synergistic development of tomorrow's marine navigation products: collaboration with dr. Slobbe, Geosciences and remote sensing, CiTG, and with prof. J. Pietrzak, Environmental Fluid Mechanics, CiTG
- SaltiSolutions: collaboration with Prof. Dr. T. Hoitink, Environmental Fluid Mechanics, WUR
- Morphodynamic evolution of tidal basins: collaboration with Prof. Dr. Ir. T. De Mulder, Faculty of Engineering and Architecture, Ghent University
- IFlow, three dimensional modeling of sediment trapping in estuaries: collaboration with Dr. G.P. Schramkowski and Dr. S. Kaptein, Flanders Hydraulics Research
- Collaboration with Katerina Stankova (TPM at TU Delft)
- Collaboration with NAS group of Piet van Mieghem (EEMCS at TU Delft)
- Towards Exascale Computing for Large Scale Groundwater Simulation, collaboration with Prof.dr. M. Bierkens, Utrecht University, and Dr. G.H.P. Oude Essink, Deltares.
- Air quality forecast by integrating learning with data assimilation, collaboration with Dr.ir. A. Segers and Dr. A.M. Manders-Groot, TNO Climate, Air and Sustainability

- ML and DA for improving air quality forecast of chemical transport models, collaboration with Dr. J. Jin, Nanjing University of Information Science & Technology.
- Collaboration with the Departments of Mathematics at ITB and at UGM (Indonesia).

Other 2022 highlights

- The Mathematics of Marine Modelling (Water, Solute and Particle Dynamics in Estuaries and Shallow Seas), Eds. Henk Schuttelaars, Arnold Heemink and Eric Deleersnijder. Volume 9 in the Springer Series 'Mathematics of Planet Earth', ISBN 978-3-031-09558-0

PhD theses delivered in 2022

- 25 January 2022 – Xiaohui Wang – Improving global tide and storm surge forecasts with parameter estimation, PhD Thesis, Delft University of Technology, (Lin and Verlaan).
- 3 March 2022 – Koen Reef – *Exploratory modelling of barrier coast dynamics*, PhD Thesis, University of Twente (Hulscher, Roos, Schuttelaars).
- 11 May 2022 – Prajakta Nakate – *Analysis of nitric oxide emissions from anode baking furnace through numerical modeling*, PhD Thesis, Delft University of Technology, (Vuik & Lahaye).
- 18 November 2022 – Jing Wang – *Transverse and longitudinal vibrations in axially moving strings,* PhD Thesis, Delft University of Technology, *(*van Horssen & Wang).
- November 2022 – Aditya Firman Ihsan – *Two time-scales perturbation methods for moving boundary problems*, PhD Thesis, ITB-Indonesia, (Tuwankotta, van Horssen, Gunawan).

Delft University of Technology

Faculty of Aerospace Engineering

Department Flow Physics and Technology

Aerodynamics (TUD-AE-AD)

Prof. dr. Stefan Hickel	Full prof.
Prof. dr. Fulvio Scarano	Full prof.
Dr. ir. Bas van Oudheusden	Associate prof.
Dr.ir. Marc Gerritsma	Associate prof.
Dr. Richard Dwight	Associate prof.
Dr. ir. Marios Kotsonis	Associate prof.
Dr. Andrea Sciacchitano	Associate prof.
Dr. ir. Sander van Zuijlen	Assistant prof.
Dr. ir. Ferry Schrijer	Assistant prof.
Dr. Ahn Khoa Doan	Assistant prof.
Dr. Steven Hulshoff	Assistant prof.
Dr. Davide Modesti	Assistant prof.
Dr. ir. Woutijn Baars	Assistant prof.
Dr. Morgan Li	Assistant prof.

Group's research areas

- Aircraft aerodynamics, flapping-wing and animal flight aerodynamics, Wind turbine aerodynamics, Sports aerodynamics
- Compressible flows and high-speed aerodynamics
- Unsteady aerodynamics and aeroelasticity
- Boundary layers: flow stability and laminar-turbulent, turbulence
- Bluff body aerodynamics and wakes
- Reactive flows
- Climate effects; aircraft emissions, control by aerosols
- Flow measurement and flow visualization techniques
- Particle Image Velocimetry (PIV)
- Fluid-Structure interaction (FSI)
- CFD with DNS/LES/RANS
- High-order mimetic methods for continuum mechanics
- High performance computing, Quantum computing, Data assimilation, Machine learning
- Active and passive flow control

Grants obtained in 2022

- CHRONOS: OVERHEAT–fOrced conVEction in Rectangular ducts with nonuniform HEATing, 68M CPU hours, Piz Daint Supercomputer.
- EuroHPC: META, Mach number Effects in Turbulent flows over Acoustic liners, 4M CPU hours, Meluxina Supercomputer.
- NWO: Effect of steps on crossflow-induced transition, 22M CPU hours, SURFsara Snellius.
- NWO: Role of steps on laminar-turbulent transition, 21M CPU hours, SURFsara Snellius
- NWO: Metamaterials for control of transitional flows, Open Competition Domain Science M

- NWO: Holi-Doctor: Flow diagnostics for wind turbine blades, KIC Wind energy technologies
- Horizon Europe Clean Aviation: HERWING-T
- Horizon Europe Clean Aviation: FASTER-H2
- AFOSR-EOARD: A-SURF
- ESA: Nonintrusive Unsteady Pressure Loads Measurement Techniques in Wind Tunnels for Launchers

Projects started in 2022

- Flow separation control over sharp-cornered and smooth-curve backward facing steps, mimicking morphing wings
- Effect of non-adiabatic wall conditions on transitional and turbulent boundary layers
- Launcher fairing aerodynamics: large-eddy simulations, quantitative flow visualization and non-intrusive pressure determination
- Deep Learning Techniques for Extreme Events Detection in Turbulence
- Advancement of three-dimensional and scalable velocimetry by helium filled bubble tracking and data assimilation
- Aerodynamics and aeroacoustic analysis of emergent eVTOL technology for Urban Air Mobility
- Dielectric Barrier Discharge actuators for transition control on industrial scale wings (FASTER-H2, collaboration with Airbus)
- Pulsed jet actuators for separation control on morphing flaps (HERWING-T, collaboration with Leonardo SPA)
- Deployable metamaterials for aerodynamic flow control

Collaboration with other groups (inside or outside Burgerscentrum)

- Iso-geometric methods: TU Delft / Mathematics
- Sports aerodynamics: TU Delft / 3ME / Fluid Mechanics
- Uncertainty Quantification: TU Delft / 3ME / Systems and Control; DLR; Sorbonne Université
- Port-Hamiltonian systems: TU Twente
- Heat transfer by forced convection: La Sapienza University of Rome
- Supersonic flows over rough walls: La Sapienza University of Rome
- Drag reduction by riblets: University of Melbourne
- Aerodynamics of multi-rotor air vehicles & large-scale PIV systems: NLR
- PIV: Volkswagen AG; LaVision GmbH; F1 teams.
- Aeroacoustics: von Karman Institute
- Dynamic control of wind turbine wakes: TU Delft / 3mE
- Bluff-body aerodynamics: Norwegian University of Science & Technologies; University of Sheffield; University of Calgary; University of Durham
- Physics-constrained autoencoders for the prediction of extreme events: Imperial College London; The Alan Turing Institute
- Physical quantities reconstruction in puffing pool fire with physics-informed machine learning: Siemens Mobility Austria GmbH
- Data-driven reaction rate modelling for MILD combustion: Tokyo Institute of Technology
- Development of a hybrid deep-learning reacting flow solver: TU Munich
- Reconstruction of acoustic fields with physics-aware neural networks: TU Munich
- GPU-accelerated large-eddy simulations for eVTOL aerodynamic analysis: Lilium GmbH
- Wall-pressure measurements in high-Reynolds-number wall-turbulence: University of Bologna, Forli, Italy

- Non-intrusive sensing of wall temperature fluctuations beneath turbulent boundary layers: Universidad Carlos III de Madrid, Spain
- Instabilities in multi-phase mixing layers: U. Napoli, Italy
- Temperature Sensitive Paints for transition detection: DLR, Germany
- Micro-hollow cathode discharge actuators for flow control: CERTH, Greece
- Roughness effects on rotating disk flows: KTH, Sweden

Other 2022 highlights

- Patent application "Device to increase laminar flow on wings" (co-inventors: Kotsonis, Michelis, Zoppini, Casacuberta, Rius Vidales, Westerbeek)

- APS/DFD Gallery of Fluid Motion winner:
  F. Salvadore, A. Memmolo, D. Modesti, G. Della Posta, M. Bernardini, V0037
  Direct numerical simulation of a micro-ramp in a high-Reynolds number supersonic turbulent boundary layer. https://doi.org/10.1103/APS.DFD.2022.GFM.V0037

PhD theses delivered in 2022

- 20 January 2022 – Yi Zhang – *Mimetic spectral element method and extensions toward higher computational efficiency*, PhD Thesis, Delft University of Technology, (Gerritsma, Hickel, Hulshoff).
- 18 February 2022 – Alexander Spoelstra – *Ring of fire as a novel approach to study cycling aerodynamics*, PhD Thesis, Delft University of Technology, (Scarano & Sciacchitano)
- 16 March 2022 – Constantin Jux – *Development of robotic volumetric PIV*, PhD Thesis, Delft University of Technology, (Scarano & Sciacchitano).
- 31 May 2022 – Alberto Felipe Rius Vidales – *Influence of a forward-facing step on crossflow instability and transition*, PhD Thesis, Delft University of Technology, (Kotsonis & Scarano).
- 6 September 2022 – Pranav Doijode - *Application of machine learning to design low noise propellers*, PhD Thesis, Delft University of Technology, (Terwisga, Hickel, Visser).

Delft University of Technology

Faculty of Aerospace Engineering

Department Flow Physics and Technology

Wind Energy (TUD-AE-WE)

Prof. dr. Damiano Casalino	Full prof.
Prof. dr. Simon Watson	Full prof.
Prof. dr. Dominic von Terzi	Full prof.
Prof. dr. ir. Carlos Simao Ferreira	Full prof.
Dr. Daniele Ragni	Associate prof.
Dr. Axelle Vire	Associate prof.
Dr. ir. Delphine de Tavernier	Assistant prof.
Dr. Francesco Avallone	Assistant prof.
Dr. Daniele Fiscaletti	Assistant prof.

Group's research areas

- Porous materials for noise reduction, modelling of new trailing and leading edges for both aircraft and wind-energy applications
- Urban air mobility, new single and multi-rotor propulsive systems, integration with airframe and aeroacoustic propagation
- Liner design and impedance evaluation with both experimental and numerical methods
- PIV and CFD derived aeroacoustic analogies for dense data processing

Grants obtained in 2022

- Clean Aviation Herwingt project: Hybrid Electric Regional Wing Integration Novel Green Technologies – HERWINGT
- Holi-DOCTOR: Holistic framework for DiagnOstiCs and moniTORing of wind turbine blades
- Colossus: Collaborative System of Systems Exploration of Aviation Products, Services and Business Models

Projects started in 2022

- Colossus: first vehicle for wild-fire suppression under design and preparation.
- GARTEUR AG-26 "Noise Radiation and Propagation for Multirotor System Configurations"
- Turbo-air group for Scaled Flight Testing project, encompassing the full measurement and numerical chain for scaled models: https://www.tudelft.nl/lr/tu-delft-advanced-air-mobility-ta2m/projects/drones-turbo-air

Collaboration with other groups (inside or outside Burgerscentrum)

- European Academy of Aeroacoustics: Professional School with Von Karman Institute of Fluid Dynamics and University of Bristol;

- Among others: INVENTOR and ENODISE consortia with benchmarking activities across institutes (e.g. VKI, Achen, Ecole Centrale de Lyon, Onera, DLR, NLR).

PhD theses delivered in 2022

- 7 February 2022 – Gianluca Romani – *Computational aeroacoustics of rotor noise in novel aircraft configurations: A lattice-boltzmann method-based study*, PhD Thesis, Delft University of Technology, (Casalino).
- 10 March 2022 – Christopher Teruna – *Aerodynamic noise reduction with porous materials: aeroacoustics investigations and applications*, PhD Thesis, Delft University of Technology, (Casalino, Ragni, Avallone).
- 13 September 2022 – Leandro Rego – *Aeroacoustics of Jet-Surface Interaction and Passive Solutions for Mitigating Jet-Installation Noise*, PhD Thesis, Delft University of Technology (Casalino, Ragni, Avallone).
- 26 September 2022 – Colin van Dercreek – *Improving Acoustic Measurements with Cavities in Closed Test Section Wind Tunnels*, PhD Thesis, Delft University of Technology, (Snellen, Ragni, Avallone).
- 14 October 2022 – Salil Luesutthiviboon – *Assessing and improving trailing-edge noise reduction technologies for industrial wind-turbine applications*, PhD Thesis, Delft University of Technology, (Snellen, Simons, Ragni).

Delft University of Technology

Faculty of Civil Engineering and Geosciences

Department Hydraulic Engineering

Environmental Fluid Mechanics (TUD-CEG-EFM)

Prof. dr. ir. Wim Uijttewaal	Full prof.
Prof. dr. Caroline Katsman	Full prof.
Prof. dr. Julie Pietrzak	Full prof.
Prof. dr. ir. Ad Reniers	Full prof.
Dr. ir. Claire Chassagne	Associate prof.
Dr. Ton den Bremer	Associate prof.
Dr. ir. Bram van Prooijen	Associate prof.
Dr. ir. Marcel Zijlema	Assistant prof.
Dr. ir. Robert Jan Labeur	Assistant prof.
Dr. Marion Tissier	Assistant prof.

Group's research areas

- Physical Oceanography
- Coastal and Estuarine dynamics
- River dynamics
- Sediment dynamics
- Turbulence and transport in environmental flows

Projects started in 2022

- Start of development of the Delta Transport Processes Laboratory to examine the fluid mechanics of transport processes in the coastal environment

Collaboration with other groups (inside or outside Burgerscentrum)

- Hydrodynamical interaction with submerged floating tunnels: University of Michigan, USA
- Turbidity currents triggered by jets: Karlsruhe Institute of Technology, Germany
- The fluid mechanics of marine litter pollution in the coastal zone: TU Eindhoven.
- Plastic accumulation in water systems: Bandung Institute of Technology, Indonesia
- Mangrove restoration: University Diponegoro University Semarang, Indonesia
- Hydrodynamics and sediment transport in estuaries: NIOZ-Yerseke
- Characteristics of currents in the subpolar North Atlantic Ocean – NIOZ-Texel
- Hydrodynamics and sediment transport in estuaries: SKLEC Shanghai China
- Wave Breaking in Crossing Seas, Universities of Oxford, Edinburgh, Manchester and University College Dublin.

PhD theses delivered in 2022

- 2 March 2022 – Pengxu Zou – *Dynamic response of a submerged floating tunnel subject to hydraulic loading: numerical modelling for engineering design*, PhD Thesis, Delft University of Technology, (Uijttewaal & Bricker).
- 10 June 2022 – Duoc Tan Nguyen - *Development and validation of a three dimensional wave-current interaction formulation*, PhD Thesis, Delft University of Technology, (Roelvink & Reniers).
- 20 June 2022 – Zeinab Zafar – *Suspended particulate matter formation and accumulation in the delta: from monitoring to modelling*, PhD Thesis, Delft University of Technology, (Chassagne & Pietrzak).
- 27 June 2022 – Ahmad Shakeel – *Rheological analysis of mud: towards an implementation of the nautical bottom concept in the Port of Hamburg*, PhD Thesis, Delft University of Technology, (Pietrzak, Chassagne, Kirichek).
- 4 July 2022 – Silke Tas – *Chenier dynamics*, PhD Thesis, Delft University of Technology, (Reniers).
- 7 July 2022 – Tim Hermans – *Understanding sea-level change using global and regional models*, PhD Thesis, Delft University of Technology, (Vermeersen & Katsman).
- 29 September 2022 – Alejandra Gijón Mancheño – *Restoring mangroves with structures: Improving the mangrove habitat using local materials*, PhD Thesis, Delft University of Technology, (Uijttewaal & Reniers).
- 22 December 2022 – Floris de Wit – *Wave shape prediction in complex coastal systems*, PhD Thesis, Delft University of Technology, (Reniers & Tissier).

Eindhoven University of Technology

Department of Applied Physics

Fluids & Flows (TUE-AP-FF)

Prof. dr. Herman Clercx	Full prof.
Prof. dr. ir. GertJan van Heijst	Full prof. (em.)
Prof. dr. Federico Toschi	Full prof.
Prof. dr. Anton Darhuber	Full prof.
Dr. ir. Rudie Kunnen	Associate prof.
Dr. Matias Duran Matute	Assistant prof.
Dr. Alessandro Corbetta	Assistant prof.
Dr. ir. Hanneke Gelderblom	Assistant prof.
Dr. ir. Jos Zeegers	Assistant prof.
Dr. Nicolae Tomozeiu	Assistant prof.

Group's research areas

- Turbulence
- Environmental Fluid Mechanics
- Multiphase and Complex Fluids
- Micro- and Nanohydrodynamics

Grants obtained in 2022

- Pandemic and Disaster Preparedness Center Frontrunner project Predicting, measuring and quantifying airborne virus transmission, 1 joint PhD position with Erasmus MC (Gelderblom)
- AICrowds: AI-Based Pedestrian Crowd Modelling and Management (TU/e-EAISI-EMDAIR grant (Corbetta)
- NWO-TTW-Perspectief Program "Mitigation Strategies for Airborne Infection Control – MIST", 1 joint PhD position with BPS-BE at TU/e (Duran Matute)

Projects started in 2022

- *Flow-assisted shaping of polymer surfaces for steering cell behavior* (Gelderblom; PhD: Jorn Kloosterman)
- *Experiments on magnetically actuated particles in turbulence* (Clercx, Kunnen & Toschi; PhD: Chunlai Wu) – part of NWO-Groot "Shaping turbulence with small particles"
- *Simulation of chiral and magnetically actuated particles in turbulence* (Toschi, Clercx & Kunnen; PhD: Xander de Wit) – part of NWO-Groot "Shaping turbulence with small particles"
- *The physics of inkjet printing – fast multicomponent transport in porous media* (Darhuber; PhD: Karimnejad)

Collaboration with other groups (inside or outside Burgerscentrum)

- “Shaping turbulence with small particles” NWO-Groot (Toschi, Clercx & Kunnen): Twente University (PoF-group), Università di Roma (Tor Vergata; Verzicco)
- “Fundamental fluid dynamics challenges in inkjet printing (FIP)” NWO-Canon-UT-TU/e program (Darhuber & Toschi): Canon Production Printing, Twente University (PoF-group), Utrecht University, TU/e (ET-group, Mech. Eng.)
- “SaltiSolutions: Data and CFD for solutions” NWO-TTW Perspectief (Clercx & Duran Matute): Delft University (Civil Eng.; Pietrzak), UCSB-USA (Meiburg), Flanders Hydraulics (Kaptein, Lopez Castaño), Hydro-Key (Uittenboogaard)
- "UMO: Urban Mobility Observatory" NWO-Apparatuur Groot (Toschi). Delft University (Civil Eng.; Daamen)
- “Transport in rarefied gases in next generation phot-lithography machines (RARETRANS)” TTW-OTP (Toschi & Clercx): ASML (Arlemark), TU/e (ET-group, Mech. Eng.), Flow Matters (Di Staso)
- "Understanding and Controlling the Flow of Human Crowds" NWO-VENI (Corbetta): TU/e (MCS-SCI; Schilders & IE&IS-HTI group), RUG (de Jong), Univ. Tokyo (Feliciani), ITT Madras (Panachagnula, Thampi), Naturalis Leiden, Eindhoven municipality.
- "HTCrowd: a high-tech platform for human crowd flows monitoring, modeling and nudging" NWO-HTSM (Toschi & Corbetta). TU/e (IE&IS-HTI group), ProRail, Eindhoven municipality.
- “Active contamination control for equipment and substrates: Particle transport (ACCESS)” VDL-TU/e Impuls Program (Clercx, Kunnen & Toschi): VDL (Shestakov (VDL), Flow Matters (Di Staso), TU/e (AP-EPG; Beckers)
- "Unravelling Neural Networks with Structure-Preserving Computing" NWO-Groot (Toschi & Corbetta). Sissa, Trieste (Rozza), Los Alamos (Gyria, Livescu)
- “Capillary shaping of structured surfaces for steering cell behavior” TU/e-AP (Gelderblom): TU/e (AP-SMB), TU/e (OBM-Biomed. Eng.; Foolen)
- “Plasma-induced flow in the liquid phase” TU/e-ICMS (Gelderblom): TU/e (AP-EPG; Sobota)
- “Self-organization of particles under an oscillating flow” TU/e-AP (Duran Matute & Clercx): Delft University (3ME-LAH; Breugem), Genova (Mazzuoli), TU/e (AP-SMB; Ellenbroek, Meijer)
- “The Dutch Wadden Sea as an event-driven system” NWO-ENW-Klein2 (Duran Matute): NIOZ (Gerkema, Donatelli), IOW-Germany (Gräwe)
- “Dispersion statistics in confined quasi-2D turbulence” CONACyT (Clercx & Duran Matute): Delft University (3ME-MTT; Keetels)
- “Thinning, fragmenting and rupture of a liquid tin sheet from laser impact on a droplet” project at ARCNL (Gelderblom): ARCNL (Versolato)
- "SRCrowd: Individual and collective agency in Socially Responsible nudging of Crowds" NWO-HTSM-MVI (Toschi & Corbetta): TU/e (IE&IS-HTI group), ProRail
- “Predicting, measuring and quantifying airborne virus transmission”, PDPC Frontrunner (Gelderblom): TU/e (P&F-group, Mech. Eng.; Homan), Erasmus MC (Herfst, Fouchier)
- “AICrowds: AI-Based Pedestrian Crowd Modelling and Management”, EMDAIR - EAISI Exploratory Multidisciplinary AI Research Program (Corbetta): TU/e (CS-EE; Schoukens), TU/e (Stat-M&CS; Castro)
- “Fighting malaria mosquitoes using smart turbulence flow fields” (Zeegers): Wageningen University (Exp. Zoology group; Muijres)
- “Magnetic Density Separation” (Zeegers): Umincorp Rotterdam (Van Grootheest)
- “Mitigation Strategies for Airborne Infection Control – MIST” (Duran Matute): TU/e (BPS-BE; Van Hooff)

Other 2022 highlights

- Shell MSc Thesis Award for Physics. Recipient: Xander de Wit for his thesis *“The transition towards a large-scale vortex in fluid turbulence”* – results also published as *J. Fluid Mech.* 936, A43 (2022).

PhD theses delivered in 2022

- 13 April 2022 – Riccardo Madonia – *Laboratory study of rotation-dominated convective turbulence*, PhD Thesis, Eindhoven University of Technology, (Clercx & Kunnen).
- 13 December 2022 – Bo Liu – *Morphology of liquid tin sheets formed by laser impact on droplets*, PhD Thesis, Vrije Universiteit Amsterdam, (Versolato & Gelderblom).

Eindhoven University of Technology

Department of Applied Physics

Transport in Permeable Media (TUE-AP-TPM)

Prof. dr. ir. Olaf Adan (part-time)	Full prof. (part time)
Dr. ir. Leo Pel	Associate prof.
Dr. ir. Henk Huinink	Associate prof.

Group's research areas

- Transport and phase changes in permeable media (to support various technology domains, such as high-tech materials, petrophysics and thermal energy storage)
- Interaction between transport of fluids and solutes, phase changes and material response on different scale levels (micrometre to millimetre range)
- Thermo-Chemical Materials
- Experimental techniques (such as MRI)

PhD theses delivered in 2022

- 18 March 2022 – Yesim Koca – *Optimal decision making under uncertainty in biomanufacturing*, PhD Thesis, Eindhoven University of Technology, (Adan & Martagan).
- 8 June 2022 – Anja Herrmann – *Pathways of diffusion through microelectronic packaging materials,* PhD Thesis, Eindhoven University of Technology, (Adan, Fan, Erich).

Eindhoven University of Technology

Department of Applied Physics

Elementary Processes in Gas Discharges (TUE-AP-EPG)

Prof. dr. ir. Gerrit Kroesen	Full prof.
Dr. ir. Jan van Dijk	Associate prof.
Dr. Dipl.-Ing. Ana Sobota	Associate prof.

Group's research areas

- Non-thermal atmospheric pressure plasmas and their interaction with substrates

Collaboration with other groups (inside or outside Burgerscentrum)

- Plasma-induced flow in the liquid phase (Sobota (PI) and Gelderblom; PhD: Ryan)

PhD theses delivered in 2022

- 8 February 2022 – Tim Staps – *Towards experimental characterization of nanoparticle charging in plasmas*, PhD Thesis, Eindhoven University of Technology, (Beckers & Kroesen).

Eindhoven University of Technology

Department of Mechanical Engineering

Energy Technology (TUE-ME-ET)

Prof. dr.ir. David Smeulders	Full prof.
Prof. dr. ir. Harald van Brummelen	Full prof.
Prof. dr. ir. Rick de Lange	Full prof.
Prof. dr. ir. Anton van Steenhoven	Full prof. (em.)
Prof. dr. ir. Hans van Duijn	Full prof. (em.)
Prof. dr. ir. Herman Wijshoff	Full prof. (part time)
Prof. dr. Herbert Zondag	Full prof. (part time)
Prof. dr. Angèle Reinders	Full prof. (part time)
Dr. ir. Camilo Rindt	Associate prof.
Dr. ir. Michel Speetjens	Associate prof.
Dr. ir. Clemens Verhoosel	Associate prof.
Dr. ir. Arjan Frijns	Assistant prof.
Dr. Silvia Gaastra-Nedea	Assistant prof.
Dr. Maja Rücker	Assistant prof.
Dr. ir. Michael Abdelmalik	Assistant prof.
Dr Azahara Luna-Triguero	Assistant prof.

Group's research areas

- Thermal energy storage
- Thermo-mechanical fluid-structure interactions
- Micro-thermofluidics

Projects started in 2022

- PPS-project 'DACCLET - Dynamics of air entrapment in cooling circuits for lithographic exposure tools' – RVO referentienummer TKI2212P08
- ORACLE project: Operational Readiness in Adverse Conditions that Limit Endurance
- 4TU 'Heritage' Programme

Collaboration with other groups (inside or outside Burgerscentrum)

- "Fundamental fluid dynamics challenges in inkjet printing (FIP)" NWO-Canon-UT-TU/e program (TU/e-AP-FF group, Darhuber & Toschi): Canon Production Printing, Twente University (PoF-group), Utrecht University, TU/e (ET-group, Mech. Eng.)
- "Transport in rarefied gases in next generation phot-lithography machines (RARETRANS)" TTW-OTP (TU/e-AP-FF group, Toschi & Clercx): ASML (Arlemark), TU/e (ET-group, Mech. Eng.), Flow Matters (Di Staso)
- Mat4Heat NWO program: Radboud University (Vlieg), TU/e-AP-FF group (Huinink, Adan), TU/e (ET-group, Mech. Eng.)
- Dr. Roeland Diltz (TU/e-Electrical Engineering) on AI and solvers of Boltzmann equation
- Dr Yoeri van de Burgt and Dr Nick Jaensson (TU/e-Microsystems group, Mech. Eng.) on machine learning for multi-physics modelling and design

- Prof. Aldo Frezzotti, Politecnico di Milano on kinetic modelling for micro/nano fluidics
- Prof Luiza Cabeza, Lleida University on heat transfer and heat storage
- TUDelft, Dept. Civil Engineering and Geosciences (Bertotti, Barnhoorn, Vardon) on subsurface energy and storage.

Other 2022 highlights

- Prof. Reinders appointed Director Solliance Solar Research Centre

PhD theses delivered in 2022

- 18 March 2022 – Sali Chandana Divi – *Scan-based immersed isogeometric analysis*, PhD Thesis, Eindhoven University of Technology, (Verhoosel, Reali, Van Brummelen).
- 28 June 2022 – Elisa Bergkamp – *Computational modeling of skin and slip effects in fractured porous media*, PhD Thesis, Eindhoven University of Technology, (Verhoosel, Smeulders, Remmers).

Eindhoven University of Technology

Department of Mechanical Engineering

Power & Flow (TUE-ME-PF)

Prof. dr. ir. Niels Deen	Full prof.
Prof. dr. Philip de Goey	Full prof.
Prof. dr. Hans Kuerten	Full prof.
Prof. dr. ir. Jeroen van Oijen	Full prof.
Prof. dr. Benedicte Cuenot	Full prof. (part time)
Prof. dr. ir. Bert Vreman	Full prof. (part time)
Prof. dr. ir. Frank Willems	Full prof. (part time)
Dr. ir. Rob Bastiaans	Associate prof.
Dr. Nico Dam	Associate prof.
Dr. Bart van Esch	Associate prof.
Dr. ir. Bart Somers	Associate prof.
Dr. Marie-Aline van Ende	Associate prof. (part time)
Dr. Giulia Finotello	Assistant prof.
Dr. Tess Homan	Assistant prof.
Dr. ir. Noud Maes	Assistant prof.
Dr. Xiaocheng Mi	Assistant prof.
Dr. Yali Tang	Assistant prof.
Dr. ir. Nijso Beishuizen	Assistant prof. (part time)
Dr. ir. Xander Seykens	Assistant prof. (part time)

Group's research areas

- Complex Multiphase Flows
- Metal Fuels as dense CO2-free Energy Carriers
- Combustion Systems and their Fuels

Grants obtained in 2022

- HELIOS - Stable high hydrogen low NOx combustion in full scale gas turbine combustor at high firing temperatures, Horizon Europe - HORIZON-JTI-CLEANH2-2022-1, Start date 1 March 2023
- Understanding of wet agglomeration of non-spherical particles in fluidized beds, NWO TTW OTP, presumable start date second semester 2023
- Production of metal powder via dendritic electrodeposition, EuroTech PhD, presumable start first semester 2023
- ViPERS - Virtual Product Engineering for Reliability and Safety, TKI HTSM, start date
- MECII - Iron fuel: a clean and circular energy carrier, TKI Chemie, 1 June 2022

Projects started in 2022

- Numerical simulation of evaporation and absorption of inkjet-printed droplets
- ADOPT - Automatic design optimization of process equipment for chemically reacting flows, TKI Chemie, start date 01-01-2022
- ViPERS - Virtual Product Engineering for Reliability and Safety, TKI HTSM, start date

- X-ray computed tomography measurement of the 3D gas distribution in zero-gap electrolysers, ECCM KICkstart DE-NL, start date 2022
- ATAtechNoise - Acoustics and Thermo-Acoustics Design of Low-Carbon Technologies and reducing Noise Pollution by applying Innovative Compressed Low-Frequency Broadband Mufflers, NWO Faculty of Impact, start date 2022
- MECII - Iron fuel: a clean and circular energy carrier, TKI Chemie, 1 June 2022

Collaboration with other groups (inside or outside Burgerscentrum)

- Chemical Process Intensification (van Sint Annaland, TU/e)
- Multi-scale Modeling of Multiphase Flows (Kuipers, TU/e)
- Complex Fluid Processing (Padding, TUD)
- On the topic of recycling of plastic particles by magnetic density separation (Fluids and Flows, Applied Physics, TU/e)
- On the topic of evaporation of droplets on porous substrates (Smeulders, Energy Technology, Mechanical Engineering, TU/e)
- On the topic of evaporation of droplets on porous substrates (Lohse, Physics of Fluids, UT)
- On the topic of hydrogen bubbles in electrolysis (Lohse, Physics of Fluids, UT)
- Delft University (Klein)
- Thomassen Energy
- Delft University (de Vos)
- Delft University (Roekaerts, Gangoli Rao)
- Dutch Section of the Combustion Institute (DSCI) en Nederlandse Vereniging voor Vlamonderzoek (NVV)

Other 2022 highlights

- XMECRE workshop on metal fuels, https://www.tue.nl/en/our-university/calendar-and-events/31-10-2022-workshop-metal-enabled-cycle-of-renewable-energy-mecre

PhD theses delivered in 2022

- 27 January 2022 – Ruben Van Gaalen – *Evaporation and absorption of inkjet printed droplets with surfactants*, PhD Thesis, Eindhoven University of Technology, (Kuerten & Wijshoff).
- 24 May 2022 – Lijing Mu –. *Geometry effect and scaling method for circulating fluidized riser: numerical study with discrete element methods*, PhD Thesis, Eindhoven University of Technology, (Kuipers, Deen, Buist).
- 30 June 2022 – Daoguan Ning – *Experimental investigation into single iron particle combustion*, PhD Thesis, Eindhoven University of Technology, (de Goey, Shoshyn, Finotello).
- 29 November 2022 – Mohammad Kojourimanesh – *System based thermo-acoustic design of central heating equipment*, PhD Thesis, Eindhoven University of Technology, (De Goey, Lopez Aetega, Kornilov).

Eindhoven University of Technology

Department of Mechanical Engineering

Microsystems (TUE-ME-MS)

Prof. dr. ir. Jaap den Toonder	Full prof.
Dr. Regina Lüttge	Associate prof.
Dr. ir. Yoeri van de Burgt	Associate prof.
Dr. Hans Wyss	Associate prof.
Dr. Ye Wang	Assistant prof.

Group's research areas

- Microfluidics & microactuation
- Organ-on-a-chip
- Biomedical microdevices
- Microfluidics & soft matter
- Neuromorphic engineering

Grants obtained in 2022

- NWO Gravitation Grant "Interactive Polymeric Materials (IPM) Research Center, Grant No. 024.005.020; collaboration with various TU/e research groups
- OrChESTRA "Organ-on-a-Chip Focused Strategic Partnership", Horizon Europe Twining action project, grant 101079473; collaboration with ODTÜ MEMS, IMEC and UFR
- Eurostars/RVO Grant "AbET-UTI: Antibiotic Efficiency Testing (AbET) to enable evidence-based and personalized antibiotic administration for Urinary Tract Infections (UTI)", Grant No. ESTAR 22119.
- NWA Grant "LS-NeoCarE (Large-Scale Neo-Cartilage Engineering: regenerative treatment technologies for osteoarthritis)", Grant No. NWA.1389.20.192.

Projects started in 2022

- NWO Gravitation Grant "Interactive Polymeric Materials (IPM) Research Center, Grant No. 024.005.020; collaboration with various TU/e research groups
- OrChESTRA "Organ-on-a-Chip Focused Strategic Partnership", Horizon Europe Twining action project, grant 101079473; collaboration with ODTÜ MEMS, IMEC and UFR
- Eurostars/RVO Grant "AbET-UTI: Antibiotic Efficiency Testing (AbET) to enable evidence-based and personalized antibiotic administration for Urinary Tract Infections (UTI)", Grant No. ESTAR 22119.

Collaboration with other groups (inside or outside Burgerscentrum)

- OrChESTRA "Organ-on-a-Chip Focused Strategic Partnership", Horizon Europe Twining action project, grant 101079473; collaboration with ODTÜ MEMS, IMEC and UFR

- NWO Gravitation Grant “Interactive Polymeric Materials (IPM) Research Center, Grant No. 024.005.020; collaboration with various TU/e research groups
- Eurostars/RVO Grant “AbET-UTI: Antibiotic Efficiency Testing (AbET) to enable evidence-based and personalized antibiotic administration for Urinary Tract Infections (UTI)”, Grant No. ESTAR 22119. Collaboration with ShanX Medtech, Microfluidic Chipshop.
- NWO-TTW-Perspectief Grant “SMART Organ-on-Chip” collaboration with TUD, UT, UMCU, WUR, MU, MUMC+, AMC, UL.
- H2020-NMBP Grant “Tumor-LN-oC: Tumor and Lymph Node on Chip for cancer studies”, collaboration with National Technical University of Athens, Abo Akademi University, ALPES, Rayfos, TU Wien, Alvesys, Phosprint, Asphalion, Amkres.
- NWO-TTW-OTP Grant “SEDAS: Sweat sensing device and data analytics for semi-continuous sepsis monitoring”, collaboration with Signal processing group at TU/e.
- Penta-Aeneas Grant “Sentinel: A hybrid patch for early warning”, collaboration with Signal processing group, TU/e, Philips Research, Micronit, Verhaert, Catharina ZH, Tegema
- NWO-OC-GROOT Grant “The Active Matter Physics of Collective Metastasis”, collaboration with U Leiden, Radboud UMC, TUD, UMCU.
- H2020-ECSEL Grant “Moore4Medical Accelerating Innovation in Microfabricated Medical Devices “, collaboration with TUD, Philips Research, INESC.
- NWO-GDST Grant, “Electro-optical full colour display based on nano-particle dispersions”, collaboration with DIRM group at TU/e, TU/e, South China Normal University
- InSciTe - Trial for Smart, Easy and Accurate Minimally invasive Glaucoma Surgery, collaboration with DIRM group at TU/e, Biomedical Engineering at TU/e, MUMC+, Santen.
- RAAK pro + ICMS Grant “Printing makes Sense”, collaboration with Fontys, Biomedical Engineering at TU/e.
- NWO-TTW Research Grant “Locate: Integrated platform to design novel cancer localization strategies by ultrasound microvasculature imaging”, collaboration with Signal processing group at TU/e.
- Philips – Brainbridge: “Microfluidic device for pollen detection”, collaboration with Zhejiang University, Philips Research

Other 2022 highlights

- Our group published a comprehensive review paper on “Microscopic Artificial Cilia” in the journal Lab on a Chip (DOI: 10.1039/d1lc01168e)

PhD thesis delivered in 2022

- 12 April 2022 – Andreas Pollet – *In vitro models for investigating vascular flow: A toolbox for recreating the vasculature on chip,* PhD Thesis, Eindhoven University of Technology, (den Toonder & Mischi).

Eindhoven University of Technology

Department Chemical Engineering and Chemistry

Multi-scale Modelling of Multi-phase Flows (TUE-CEC-MMM)

Prof. dr. ir. Hans Kuipers	Full prof.
Dr. ir. Maike Baltussen	Assistant prof.
Dr. ir. Kay Buist	Assistant prof.
Dr. ir. Frank Peters	Assistant prof.

Group's research areas

- Fundamentals of chemical reaction engineering
- Transport phenomena with fluid flow and with chemical transformations in multiphase chemical reactors and in porous media
- Multiphase Reactor Modelling
- Advanced Experimental Techniques for multiphase flow
- CFD with multifluid models and with discrete element models

Grants obtained in 2022

- Understanding of wet agglomeration of non-spherical particles in fluidized beds, Y. Tang, N.G. Deen (TUE-ME-PF) and J.A.M. Kuipers, M.W. Baltussen (TUE-CEC-SMM), OTP2022 19951.
- Modelling of three-phase flows with catalytic particles, J.A.M. Kuipers, ERC-AdG MOD3CAT 101054459
- Novel packings for gas-liquid packed bed reactors, A. Ambekar, EuroTech Postdoc 2, E.A.J.F. Peters and J.A.M. Kuipers

Projects started in 2022

- Novel packings for gas-liquid packed bed reactors, Aniket Ambekar

Collaboration with other groups (inside or outside Burgerscentrum)

- Chemical Process Intensification, Sint Annaland, TUE-CEC-CPI
- Sustainable Process Engineering, Neira d'Angelo, TUE-CEC
- Power and Flow, Deen, TUE-ME-PF
- Physics of Fluids, Lohse, UT-TNW-POF
- Multi Scale Mechanics, Luding, Thornton, UT-ET-MSM
- Product and Process Engineering, van Ommen, TUD-CE-PPE
- Complex Fluid Processing, Padding, TUD-3mE-CFP
- Inorganic Materials and Catalysis, Hensen, TUE
- Transport Engineering and Logistics, Schott, TUD
- Inorganic Chemistry and Catalysis, Weckhuysen, UU
- Soft Condensed Matter, van Blaaderen, UU
- Chemical Technology, van Geem, Ghent University, Belgium
- Multiphase Flows, Schlüter, TUHH, Germany

- Solid Processing Engineering and Particle Technology, Heinrich, TUHH, Germany
- Particulate Flow Modelling, Pirker, JKU, Austria
- Chemical Engineering, Buwa, IIT Dehli, India
- Technical Chemistry, Hinrichsen, TUM, Germany
- Mechanical Engineering, Weiner, Braunschweig University of Technology, Germany

Other 2022 highlights

- Best poster award, NPS 2022, Noah Romijn

PhD theses delivered in 2022

- 24 May 2022 – Lijing Mu – *Geometry effect and scaling method for circulating fluidized riser: numerical study with discrete element methods*, PhD Thesis, Eindhoven University of Technology, (Kuipers, Deen, Buist).

Eindhoven University of Technology

Department Chemical Engineering and Chemistry

Chemical Process Intensification (TUE-CEC-CPI)

Prof. dr. ir. Martin van Sint Annaland	Full prof.
Dr. ir. Ivo Roghair	Assistant prof.

Group's research areas

- Process intensification
- Reactive adsorption / Direct air capture and activation
- Electrification of industrial processes
- Catalyst structuring and heat integration using additive manufacturing
- Novel experimental techniques and numerical methods in reactive multiphase flows

Grant obtained in 2022

- DISCO (Downstream Isolation of high-value COmponents) (EngD)

Projects started in 2022

- TNO: Transient WGS/rWGS kinetics of K-HTC under SEWGS working conditions (postdoc, 1 yr)
- Totally Nuts (Circular Biobased thermosets from cashew nutshells) (postdoc, 2 yr)

Collaboration with other groups (inside or outside Burgerscentrum)

- THOR: collaboration with TNO, Ambrell, TotalEnergies, Hybrid Catalysis
- Zeocat: collaboration with VITO, Hybrid Catalysis, a.o.
- Totally nuts: collaboration with Avans
- Emissi0n: collaboration with TNO

PhD thesis delivered in 2022

- 3 June 2022 – Francesco Sabatino – *Direct air capture and methanation*, PhD Thesis, Eindhoven University of Technology, (Van Sint Annaland, Gallucci, Gazzani).

Eindhoven University of Technology

Department Mathematics and Computer Science

Centre for Analysis, Scientific Computing and Applications (TUE-MCS-CASA)

Prof. dr. ir. Barry Koren	Full prof.
Prof. dr. Mark Peletier	Full prof.
Dr. ir. Bas van der Linden	Associate prof.
Dr. ir. Jan ten Thije Boonkkamp	Associate prof.
Dr. ir. Arris Tijsseling	Associate prof.

Group's research area

- Computational Fluid Dynamics

Grants obtained in 2022

- Grant for two PhD students from Eindhoven Artificial Intelligence Systems Institute, on project *Neural Green's Operators as Surrogates for Parametric Solutions of Partial Differential Equations: application to first-principle models for magnetic confinement fusion energy systems*.

Collaboration with other groups (inside or outside Burgerscentrum)

- Unravelling Neural Networks with Structure-Preserving Computing (NWO-XL project): Toschi Group, TUE (Giulio Ortali, Alessandro Corbetta and Federico Toschi); Data Mining Group, TUE (Vlado Menkovski); Numerical Astrodynamics Group, Leiden University (Veronica Saz Ulibarrena and Simon Portegies Zwart); Scientific Computing Group, CWI, Amsterdam (Toby van Gastelen and Benjamin Sanderse)
- Numerical Simulation of Internal Turbulent Flows with Heat Transfer: CFD Group, NRG, Petten (Ed Komen)
- Mechanistic Modelling of Slug Forces on Pipe Bends: Equinor, Oslo (Arnout Klinkenberg)
- Parallel Solution Methods for Large Dense Linear Systems: CFD Group, MARIN, Wageningen (Rik Hoekstra and Auke van der Ploeg)
- Enforcing Physical Behaviour in Neural Networks for Use in Closure Models: Scientific Computing Group, CWI, Amsterdam (Hugo Melchers, Daan Crommelin and Benjamin Sanderse)
- Implementing a Discrete Double de Rham Complex on 2D Simplices: Modeling & Inference Group, ASML, Veldhoven (Twan Moises, Artur Palha, Martijn Zaal and Henk-Jan Smilde)

Other 2022 highlights

- Margot Gerritsen (Stanford University): honorary doctor TU/e with Barry Koren as honorary promoter

PhD thesis delivered in 2022

- 18 January 2022 – Yous Van Halder – *Efficient sampling and solver enhancement for uncertainty quantification*, PhD Thesis, Eindhoven University of Technology, (Koren & Sanderse).

Eindhoven University of Technology

Department of the Built Environment

Building Physics (TUE-BE-BP)

Prof. dr. ir. Bert Blocken	Full prof.
Dr. ir. Twan van Hooff	Associate prof.
Dr. Hamid Montazeri	Assistant prof.
Dr. Stefanie Gillmeier	Operational wind tunnel manager
Dr. Alessio Ricci	Senior Research Fellow

Group's research areas

- Building aerodynamics
- Indoor/outdoor ventilation
- Pollutant/aerosol dispersion
- Wind comfort
- Automotive aerodynamics
- Maritime aerodynamics
- Urban wind energy
- Building-integrated photovoltaics
- Wind effects on PV panels
- Urban microclimate
- Sports aerodynamics

Grants obtained in 2022

- NWO Perspectief research grant: MIST: MItigation STrategies for Airborne Infection Control (WP3, van Hooff T, Loomans MGLC, Blocken B, Duran Matute M (Applied Physics; TU/e))
- TKI Holland Health: "Clean Air for Everyone (CLAIRE). WP3 and WP4: (Blocken B, Loomans MGLC, van Hooff T)
- EWUU Seed fund for course: Global Summer School-Food for Mars and Moon (Liu Z, Wamelink W (WUR); Kuramae EE (UU); van Hooff T (TU/e))

Projects started in 2022

- P3Venti "Program Pandemic Preparedness and Ventilation Program" – part 1 (PIs: Loomans MGLC, van Hooff T)
- ERIES (Engineering research Infrastructures for European Synergies). TU/e contributes with the Atmospheric Boundary Layer Wind Tunnel. (PI: Gillmeier, S.)
- "Wind Effects on Building-Integrated Photovoltaic Systems in Urban Areas (PI: Montazeri H)"

Collaboration with other groups (inside or outside Burgerscentrum)

- Fluids and Flows, Applied Physics, Eindhoven University of Technology
- Physics of Fluids, Faculty of Science and Technology, University of Twente
- Faculty of Architecture and the Built Environment, Delft University of Technology

- Faculty of Aerospace Engineering, Delft University of Technology
- Institute for Risk Assessment Sciences (IRAS), Utrecht University
- Faculty of Science, University of Amsterdam
- Department of Civil Engineering, KU Leuven, Belgium
- Energy and Materials in Infrastructure and Buildings, University of Antwerp, Belgium
- Department of Architecture and Urban Planning, Ghent University, Belgium
- Civil Engineering, National University of Ireland, Galway, Ireland
- Environmental and Hydraulic Engineering, Sapienza University Rome
- Department of Particulate Flow Modelling, Johannes Kepler University, Linz, Austria
- Department of Civil, Chemical and Environmental Engineering, University of Genoa, Italy
- IUSS School for Advanced Studies, Pavia, Italy
- School of Civil Engineering, University of Leeds, UK
- School of Civil Engineering, University of Birmingham, UK
- Meteorological Institute, Environmental Boundary Layer Wind Tunnel Laboratory, University of Hamburg, Germany
- Wind Engineering, Energy and Environment Research Facility, Western University, Canada
- Jules Verne climatic wind tunnels, The Scientific and Technical Center for Building, CSTB, France
- Research Institute for Occupational Health and Safety (INRS), France
- Digital Twin Cities Centre, Chalmers University of Technology, Sweden
- Big Data for Smart Society (GATE) Institute, Sofia University, Bulgaria
- Mathematics and Computer Science, Intelligent Electrical Power Grids, Delft University of Technology
- Royal Meteorological Institute of Belgium
- The Electronics – ICT department, University of Antwerp, Belgium
- Izmir Institute of Technology, Turkey

Other 2022 highlights

Josip Žužul, PhD Student at Eindhoven University of Technology and University of Genoa, has been awarded the "Giovanni Solari Award for Research Innovation" at the 8th European-African Conference on Wind Engineering that took place in Bucharest, Romania, 20-23 September 2022. The award was given for his submitted and presented research work entitled "LES simulations of a downburst immersed in an ABL-like wind".

PhD thesis delivered in 2022

- 3 November 2022 – Nestoras Antoniou – *Numerical and experimental investigation of urban microclimate in a real compact heterogeneous urban area,* PhD Thesis, Eindhoven University of Technology, (Blocken, Neophytou, Montazeri).

University of Twente

Faculty of Science and Technology

Physics of Fluids (UT-ST-POF)

Prof. dr. Detlef Lohse	Full prof.
Prof. dr. Devaraj van der Meer	Full prof.
Prof. dr. Jacco Snoeijer	Full prof.
Prof. dr. Michel Versluis	Full prof.
Prof. dr. ir. Chris de Korte	Full prof. (part time)
Prof. dr. Andrea Prosperetti	Full prof. (part time)
Prof. dr. Chao Sun	Full prof. (part time)
Prof. dr. Roberto Verzicco	Full prof. (part time)
Prof. dr. Xuehua Zhang	Full prof. (part time)
Prof. dr. Marjolein van der Linden	Full prof. (part time)
Prof. dr. ir. Leen van Wijngaarden	Full prof. (em.)
Dr. Alvaro Marin	Associate prof.
Dr. ir. Richard Stevens	Associate prof.
Dr. Corinna Maaß	Associate prof.
Dr. Dominik Krug	Associate prof.
Dr. ir. Martin van der Hoef	Associate prof. (part time)
Dr. ir. Sander Huisman	Assistant prof.
Dr. Guillaume Lajoinie	Assistant prof.

Group's research areas

- Turbulence
- Wind Energy
- Computational Fluid Dynamics
- Multiphase flows with bubbles, drops, and particles
- Melting and dissolution
- Microbubble physics
- Ultrasound
- Blood flow characterization
- Heat and mass transfer
- Deep learning
- Fully developed turbulence and in particular thermally driven turbulence
- Micro- and nanofluidics
- Inkjet printing
- Surface nanobubbles and nanodroplets, colloidal science
- Bubble dynamics and cavitation
- Granular matter
- Acoustics

Grants obtained in 2022

- ERC Proof of Concept grant for Alvaro Marin - Novel technology for detecting and identifying traces of micro- and nanoplastics in consumable water
- ERC starting grant for Guillaume Lajoinie, Ultrasound with Super-Resolution
- NWO M grant for Sander Huisman and Claas Willem Visser — Turbulence with custom-made fibers
- ERC starting grant for Sander Huisman - Melting dynamics in turbulent flows
- NWO Grant (PI Detlef Lohse) - MItigation STrategies for Airborne Infection Control (MIST)
- NWO ECCM KICKstart DE-NL (PIs Detlef Lohse and Dominik Krug) - Towards upscaling alkaline electrolysis: Pushing the limits of interfacial transport

Projects started in 2022

- NWO Grant Detlef Lohse - MItigation STrategies for Airborne Infection Control (MIST)
- ERC starting grant Sander Huisman - Melting dynamics in turbulent flows
- ARC-CBBC "New Chemistry for a Sustainable Future: Growth of electrolytic bubbles in the electrochemical reduction of CO2: experiments"

Collaboration with other groups (inside or outside Burgerscentrum)

- Max Planck Center Twente for Complex Fluid Dynamics: collaboration with MPI-DS in Göttingen and with MPI-Polymere in Mainz
- Tsinghua University, Group of Professor Chao Sun
- Collaboration with PIN group of Prof. Harold Zandvliet in Twente
- Collaboration with group of Prof. Daniel Bonn and Dr. Mazi Jalaal at UvA
- Collaboration with group of Prof. Federico Toschi, TUE.
- Collaboration with group of Prof. Albert van den Berg, UT
- Collaboration with groups of Profs. Rob Lammertink, Han Gardeniers, Guido Mul, UT
- Collaboration with groups of Prof. Stefan Luding, Cees Venner, CW Visser, UT, CTW
- Collaboration with Canon, Venlo
- Thyrosonics project, collaboration with the INRIA institute in France
- HIFU-induced immunotherapy with the University of Ghent (Faculty of Pharmacy)
- Luminescent ultrasound detectors with the University of Ghent (Solid-state Physics)
- 4TU Precision Medicine, collaboration with the universities of Twente, Delft, Wageningen, and Eindhoven
- UCOM project, Ultrasound Cavitation in Soft Materials with City University of London, TU Munich, EPFL Lausanne, UPMC Sorbonne University, Institute of Cancer Research UK
- NWO OTP VORTECS on blood flow characterization with Radboud UMC
- NWO Perspective 3D ultrasound in vascular surgery (ultra-X-treme) with Radboud UMC
- TU/e, Rijnstate Hospital, CZ Eindhoven, Erasmus MC, and TU Delt.
- Water and fire: A new intumescent coating based on heat-induced vaporization of water-filled microcapsules (NWO VENI Guillaume Lajoinie) - with PPG Coatings.
- ADEAR - Aorta aneurysm dynamics and aortic endograft outcome. Top Technology Twente: University of Twente Connecting Industry program - with Terumo Aortic.

- reMIND - Regenerative Medicine Innovative products as enabling technologies for the treatment of Alzheimer and other Neurological Diseases. REACT-EU European Commission - consortium with UT groups, Demcon, and local SMEs (Micronit, LocSense).
- NWO OTP ULTIMO – liver vascular flow: understanding liver treatment to improve microsphere optimal distribution – with UT, Radboud UMC, Terumo Querem.
- Microbubbles and ultrasound to guide radioembolization therapy: implementation of a patient-specific treatment strategy (NWO VENI Erik Groot Jebbink) – with Terumo Querem.
- Mono-RAILS monodisperse microbubbles - Top Technology Twente: Connecting Industry - with Bracco Suisse S.A.
- NWO OTP SOUND-CHECK on bubble-mediated local drug delivery with Utrecht UMC, TU Delft, Bracco Suisse SA, Bruker, and FELIXrobotics BV

Other 2022 highlights

- Devaraj van der Meer elected as fellow American Physical Society
  Devaraj van der Meer, Professor in Physics of Fluids at the UT's Science & Technology faculty, has been elected Fellow of the American Physical Society. He is the eighth UT researcher receiving this prestigious distinction.
- Carola Seyfert and Alvaro Marin did win an American Physics Society, Division of Fluid Dynamic's Gallery of Fluid Motion prize for the video "Yarning Droplets"
  https://doi.org/10.1103/APS.DFD.2021.GFM.V007. Published Nov. 2022, https://doi.org/10.1103/PhysRevFluids.7.110509.

PhD theses delivered in 2022

- 18 February 2022 – Carola Seyfert – *Shaping droplets,* PhD Thesis, Twente University, (Marin & Lohse).
- 2 March 2022 – Diana Garcia Gonzalez – *Capillary interaction on soft and textured surfaces*, PhD Thesis, Twente University, (Snoeijer).
- 23 March 2022 – Stefan Engelhard – *Blood flow quantification in the aortoiliac arteries: from bench to bedside*, PhD Thesis, Twente University, (Reijnen, Versluis, Groot Jebbink).
- 3 June 2022 – Maaike Rump – *Meniscus dynamics and evaporation in inkjet printing*, PhD Thesis, Twente University, (Lohse, Versluis, Segers).
- 15 July 2022 – Vatsal Sanjay – *Viscous free surface flows*, PhD Thesis "Cum Laude", Twente University, (Lohse).
- 1 September 2022 – Martin Assen – *Wake-induced dynamics of anisotropic particles in homogeneous and shear flows,* PhD Thesis, Twente University, (Lohse, Verzicco, Stevens).
- 30 September 2022 – Anja Stieren – *Large-eddy simulations of the interaction between wind farms and mesoscale effects,* PhD Thesis, Twente University, (Lohse & Stevens).
- 4 November 2022 – Martin Essink – *Soft Contact: from wetting to adhesion,* PhD Thesis, Twente University, (Snoeijer).

University of Twente

Faculty of Science and Technology

Physics of Complex Fluids (UT-ST-PCF)

Prof. dr. Frieder Mugele	Full prof.
Dr. Michael Duits	Associate prof.
Dr. Igor Siretanu	Assistant prof.

Group's research areas

- (Electro)wetting and droplet dynamics
- Microfluidic two-phase flow
- Interfacial physical chemistry
- (Interfacial) rheology
- CO2 fixation
- Photocatalysis

Collaboration with other groups (inside or outside Burgerscentrum)

- Ferrofluid-infused surfaces as microfluidic platform (Jun Gao, Chin. Academ. Sci. Qingdao; Xi Yao, City Univ. Hongkong)
- Polymer-based enhanced oil recovery (Julius Vancso, Univ. Twente)
- CO2 absorption in clays (Wim Brilman, Univ. Twente)
- Ultrasensitive graphene oxide-based Raman spectroscopy (Cees Otto, Univ. Twente)
- Facet-dependent surface properties of photocatalysts (Guido Mul, Univ. Twente)

PhD thesis delivered in 2022

- 9 December 2022 – Saravana Kumar – *A study of complex solid-liquid interfaces by atomic force microscopy,* PhD Thesis, Twente University, (Mugele & Sîretanu).

University of Twente

Faculty of Science and Technology

Cluster Membrane Science and Technology (MST)

Soft Matter, Fluidics and Interfaces (UT-ST-SFI)

Prof. dr. ir. Rob Lammertink	Full prof.
Prof. dr. ir. Karin Schroën	Full prof.
Dr. Jeff Wood	Assistant prof.

Group's research areas

- Interfacial transport phenomena
- Membranes
- Ion transport
- Microfluidics

Grants obtained in 2022

- ECCM Kickstart "Towards upscaling alkaline electrolysis: Pushing the limits of interfacial transport"
- MIST, "Mitigation strategies for airborne infection control", NWO Perspectief

Collaboration with other groups (inside or outside Burgerscentrum)

- Combining Cake and Membrane Filtration for Removal of Micropollutants from Concentrate Streams in Reverse Osmosis Treated Drinking Water (Membrane Technology and Engineering for Water Treatment, UT)
- Electroconvection in Water Electrolysis (PoF and PCS, UT)
- New membrane coatings and process designs for selective ion removal (WUR)

PhD theses delivered in 2022

- 31 August 2022 – Xiuqin Wang – *Poly(arylene piperidinium)-based anion exchange membranes for water electrolysis,* PhD Thesis, Twente University, (Lammertink).
- 2 September 2022 – Nicole Timmerhuis – *Turn on the light: Diffusio-osmosis induced by photocatalytic reactions,* PhD Thesis, Twente University, (Lammertink).

University of Twente

Faculty of Science and Technology

Mesoscale Chemical Systems (UT-ST-MS)

Prof. dr. Han Gardeniers	Full prof.
Prof. dr. ir. David Fernandez Rivas	Full prof.
Dr. ir. Niels Tas	Associate prof.
Dr. Jimmy Faria Albanese	Associate prof.
Dr. Arturo Susarrey Arce	Assistant prof.

Group's research areas

- Mass transport and reaction kinetics in systems with 3D nanostructured photo/electrolytic surfaces
- Inorganic nanostructures fabricated with additive manufacturing and their application in functional devices
- Microfluidic devices for chemical analysis & synthesis, molecule/particle separation, and liquid parameter measurement
- Bubble generation, growth, and collapse, and their interaction with soft and solid surfaces
- Microfabricated devices for liquid jetting and (electro)spinning, with applications in drug delivery and additive manufacturing
- Silicon-based 3D nanofabrication

Grants obtained in 2022

- Horizon Europe EIC Pathfinder "Chiralforce" (Chiral separation of molecules enabled by enantioselective optical forces in integrated nanophotonic circuits)
- Horizon Europe "ALCYONE" (Autonomous Living Cell analYsis ON-chip for Evaluation of space Environment Effects: low-power integrated lab-on-chip for the assessment of radiation damage on living systems in nanosatellite missions)

Projects started in 2022

- per 1 December: Horizon Europe EIC Pathfinder "Chiralforce" (PI Gardeniers)
- per 1 October: NWO OTP "AMBIFAlent" (PI Tas)

Collaboration with other groups (inside or outside Burgerscentrum)

- Microflow magnetic resonance: collaboration with Makinwa (TUD)
- Continuous sensing and flow with bubbles: collaboration with Lohse / van der Meer (UT)
- CREAM4 - Chemical Reaction Engineering by Additive Manufacturing of Mesoscale MetaMaterials: collaboration with Sotthewes / Moralis-Masis (UT), Ruiz-Zepeda (Nat Inst Chem Ljubljana), Bartling (Leibniz Inst Catalysis Rostock), De Leon (Tec de Monterrey MX), Torres-Martinez (UA Nuevo León MX), Vandichel (U Limerick), Boscher (LIST Luxembourg), Aguirre (UNL Santa Fe Argentina), Cabriel / Izeddin (ESPCI Paris), Gabel / Merle (FAU Erlangen), Flox / Kallio (Aalto U), Takeuchi (UNAM MX)

- BuBble Gun - Penetrating microjets in soft substrates: towards controlled needle-free injections: towards controlled needle-free injections: collaboration with van der Meer / Lohse (UT), Hunter (MIT Cambridge MA, USA)
- Development of a high P, high T microfluidic chip for water-flooding oil recovery: collaboration with Mugele / Duits (UT)
- PrintPack - Arranging the Particles: Step Changing Chemical Measurement Technology (ERC AdG Desmet): collaboration with Desmet (VU Brussels), Sotthewes / van der Meer (UT)
- Microfluidic approaches for particle generation and handling: collaboration with De Malsche (VU Brussel)
- Continuous retention-based enrichment of small molecules in liquid phase: collaboration with De Malsche (VU Brussel)
- Micro-GC - Chiral MS via micro-de Laval nozzle: collaboration with Horke (RU Nijmegen)
- Field electron emission in organic solvents for biomass conversion: collaboration with van Housselt / Zandvliet (UT)
- UCOM - Ultrasound cavitation in soft materials: collaboration with Versluis (UT) and 15 other research-oriented organisations in the EU, Switzerland, US, Japan, and China
- NeuroChip - Intracellular recording of human neurons on a chip: collaboration with le Gac (UT) and Cornelisse (VU Amsterdam)
- SERSing - Handheld device to detect chemical hazards anywhere: collaboration with Garcia Blanco (UT) and 8 other research-oriented organisations in Denmark, Czech Republic, Sweden and Spain
- Nanomachining of 3D race-track memories: collaboration with Parkin (MPI Halle)

PhD thesis delivered in 2022

- 12 May 2022 – Miguel Rodríguez Olguín – *Nanostructured (electro)catalysts with electrospinning*, PhD Thesis, Twente University, (Gardeniers & Susarrey Arce).
- 2 June 2022 – Sandrien Verloy – (joint degree VU Brussels) *Extending the microfabrication and particle handling toolbox for the development of ordered chromatography*, PhD Thesis, Twente University, (Gardeniers & DeSmet).
- 24 June 2022 – Bjorn Borgelink – *Microfluidic concepts for electrospinning,* PhD Thesis, Twente University, (Gardeniers & Tas).

University of Twente

Faculty of Engineering Technology

Engineering Fluid Dynamics (UT-ET-EFD)

Prof. dr. ir. Kees Venner	Full prof.
Prof. dr. ir. Harry Hoeijmakers	Full prof. (em.)
Dr. ir. Rob Hagmeijer	Associate prof.
Dr. ir. Edwin van der Weide	Associate prof.
Dr. ir. Claas Willem Visser	Associate prof.
Dr. ir. Ysbrandt Wijnant	Assistant prof.
Dr. Ir. M.P.J. Sanders	Assistent prof.
Dr. Kartik Jain	Assistant prof.
Dr. ir. Franciscus de Jongh	Assistant prof.
Dr. ir. Arne van Garrel	Assistant prof.
Dr. Huseyin Ozdemir	Assistant prof.

Group's research areas

- Aerodynamics & Aeroacoustics
- Computational Fluid Dynamics Algorithms and Design
- Thin Layer Flow and Lubrication
- Fluid Mechanics of Functional Materials
- Biomedical Fluid Mechanics

Grants obtained in 2022

- Rolling Contact Fatigue Life and Material Optimization for Micro drop/dosage high speed bearings, M2i, PhD position
- EngD position
- Sustainable Solvent-free microencapsulation, "Crazy-Research grant", UT
- Direct Bubble Writing – A new Horizon for Customized Foams. NWO Take-off phase 1 Feasibility study WO.
- Tailoring large-scale turbulence with bespoke small-scale fibers, NWO-OTP (with UT-physics of Fluids)

Projects started in 2022

- Aeroacoustics of Disruptive Aerodynamic Designs.
- Sustainable Solvent-free microencapsulation
- Direct Bubble Writing – A new Horizon for Customized Foams

Collaboration with other groups (inside or outside Burgerscentrum)

- Thermal Engineering (UT-ET), Multi-Scale Mechanics (UT-ET), Physics of Fluids (UT-TNW), Robotics and Mechatronics (UT-EEMCS)
- Flow physics and technology, TUDelft

- LAMCOS INSA-Lyon, France
- Von Kármán Institute, Belgium
- Royal Dutch Aerospace Center NLR
- German Dutch Wind tunnel DNW, SKF RTD

Other 2022 highlights

- HiSST Best overall paper award "Schlieren Visualisation of Dual Injection in Supersonic Cross Flow

PhD theses delivered in 2022

- 17 June 2022 – Jan-Sören Fischer – *Laminar wing design: A framework for transition delay using linear stability theory and adjoint optimization,* PhD Thesis, Twente University, (Venner, Soemarwoto, van der Weide).
- 26 August 2022 – Yan Zhao – *Solid viscoelasticity in contact mechanics and elastohydrodynamic lubrication,* PhD Thesis, Twente University, (Venner, Morales-Espejel, Visser).
- 28 September 2022 – Martin Sanders – *Aeroacoustic measurements of airframe components: in an open-jet, a hard-wall and a hybrid wind tunnel test section*, PhD Thesis, Twente University, (Venner & De Santana).
- 5 October 2022 – Julian Biesheuvel – *Sound propagation corrections in open jet wind tunnels*, PhD Thesis, Twente University, (Venner, De Santana, Tuinstra).

University of Twente

Faculty of Engineering Technology

Thermal Engineering (UT-ET-TE)

Prof. dr. ir. Gerrit Brem	Full prof.
Prof. dr. ir. Wilko Rohlfs	Full prof.
Prof. dr. ir. Theo van der Meer	Full prof. (em.)
Dr. ir. Jim Kok	Associate prof.
Dr. ir. Artur Pozarlik	Associate prof.
Dr. Mina Shahi	Associate prof.
Dr. ir. Amir Mahmoudi	Assistant prof.
Dr. Canan Acar	Assistant prof.
Dr. Yashar Hajimolana	Assistant prof.
Dr. Abhishek Singh	Assistant prof.
Dr. Mohammad Mehrali	Assistant prof.
Dr. Tingting Zhu	Assistant prof.
Dr. ir. Keerthivasan Rajamani	Assistant prof.

Group's research areas

- Energy efficient processes
- Heat conversion and storage
- Heat pumps and district heating systems
- Hydrogen production, storage and end-use
- Material science for heat transfer applications
- Thermal management of electrical components
- Gaseous and liquid fuel combustion in gas turbine engines and furnaces
- Combustion dynamics and acoustics interaction
- Nitric oxide and soot emission in combustors
- Energy Systems Integration
- Biomass conversion
- CO2 capture from ambient air

Projects started in 2022

- ABraytCSPfuture: Air-Brayton cycle concentrated solar power future plants via redox oxides-based structured thermochemical heat exchangers/thermal boosters (EU Horizon Europe)
- BALANS - Biogrondstoffen van niet-houtige oorsprong als ALternatief voor houtige biomassa in bio-energie ANndijk voor de opwekking van duurzame warmte en Stroom (Her+)
- CCEP: A novel reactor for CO_2-capture from ambient air (Coca-Cola Europacific Partners)
- CR4HEAT: A continuous reactor for thermochemical heat storage (Sector plan)
- DIVAC: Digital twin of a vacuum based heat battery (TKI- EU)
- HERMES - Highly Efficient Super Critical ZERO eMission Energy System (Horizon Europe)
- HERCULES: High-temperature Thermochemical Heat Storage Powered by Renewable Electricity for Industrial Heating Applications (EU Horizon Europe)

- TechUPGRADE :Thermochemical Heat Recovery and Upgrade for Industrial Processes (EU Horizon Europe)
  -

Collaboration with other groups (inside or outside Burgerscentrum)

- ABraytCSPfuture: DLR Germany, CERTH Greece, Fraunhofer Germany, OPRA NL, CENER Spain, Techniker Spain, Landson, Kraftblock, COBRA Spain
- Alliance International Catalyst Program: National Sciences and Engineering Research Council of Canada, University of Windsor
- Coca Cola Europacific Partners
- DIVAC: ARES and Saxion
- DYNAF: TUE, Oxford university, Barcelona Supercomputing Centre, IFTA, Duiker Combustion Engineers, Danieli Corus, DNVGL, Bosch Nefit.
- Engender: ISPT, UCLouvain, Avebe, Corbion, Givaudan
- HERMES (National Technical University of Athens, Exergia, Tec4Fuels, OWI Science for Fuels, Imperial College, CERFACS, Paul Scherrer Institute, OPRA, Swiss Federal Institute of Technology Lausanne, Wroclaw University of Science and Technology
- HERCULES: DLR Germany, CERTH Greece, TATA Steel NL, Alucha NL, Kraftblock Germany, Landson Denmark, RISE Sweden, COBRA Spain, TMS Greece
- Heat Land: De Kleijn Energy Consulting, FPsim, Ennatuurlijk B.V., Twence holding B.V.
- HeatQuiz: Digital Teaching, RWTH Aachen University
- HoSt, HVC, Bio-energie Andijk
- Hydrogen Systems and Enabling Technologies Joint Master's Program: Politechnico di Torino, Politechnico di Milano, SNAM S.P.A., Repsol SA, Universiti Teknologi Malaysia, The Norwegian Hydrogen Forum
- Kickstart- Industrial Heat Pump: TNO, TU Delft, TU Eindhoven, IBK, Smurtfit Kappa, Corbion, Reco, KWA Advisors, Farm Frites, De Kleijn Energy Consulting, Kiremko, Yeagar Energy
- RECOWATDIG: WUST, AGH, KTH, HoSt, GAC
- TechUPGRADE: DTU Denmark, DLR Germany, TU Wein, COWI Denmark, IED Greece, Greenlab Denmark, Quanterall Ltd, TMEC Ukraine, MG Sustainable Sweden, Absolicon Sweden, RISE Sweden, University in Klaipėda, Lithuania, NTUA Greece

PhD theses delivered in 2022

- 1 June 2022 – Balan Ramani – *Flash pyrolysis of tires: Process development for upcycling waste tires*, PhD Thesis, Twente University, (Brem & Bramer).
- 30 June 2022 – Harsha Mysore Prabhakara – *Sorption enhanced catalytic fast pyrolysis for the production of high-quality bio-oil from biomass,* PhD Thesis, Twente University, (Brem).
- 2 November 2022 – Umair Jamil Ur Rahman – *Towards a multizone vortex dryer for dairy sprays,* PhD Thesis, Twente University, (Brem & Pozarlik).
- 15 December 2022 – Keerthivasan Rajamani – *A magnetocaloric mixture based refrigerator - from material to system level analysis,* PhD Thesis, Twente University, *(*Pozarlik & Van der Meer).

University of Twente

Faculty of Engineering Technology

Multi Scale Mechanics (UT-ET-MSM)

Prof. dr. Stefan Luding	Full prof.
Prof. dr. Anthony Thornton	Full prof.
Dr. Thomas Weinhart	Associate prof.
Dr. ir. Wouter den Otter	Associate prof.
Dr. Igor Ostanin	Assistant prof.

Group's research areas

- Multiscale Mechanics: Particle Systems
- Multiscale Methods: Bridging the gaps (from small to large, from discrete to continuum, from fast to slow, from fluid to solid (state transitions), …)
- Open-source software MercuryDPM: https://www.mercurydpm.org
- Open-source software oomph-lib https://oomph-lib.github.io/oomph-lib/doc/html/
- Molecular Modeling of Complex Fluids
- Virtual Prototyping of Particulate Processes
- Shaping segregation: Multiscale modelling of segregation in industrial processes
- Flow rheology for complex, non-Newtonian fluids (e.g. capillary suspensions)
- Mechanical wave propagation applied to non-invasive exploration/sensing
- Multiscale modelling of agglomeration: Applications tabletting, powder bed 3D-printing
- EU_ETN TUSAIL: Upscaling and Multiscale analysis of particle processes in industry
- Merging fluid AND solid mechanics for granular solid hydrodynamics
- Mathematical network analysis and advanced machine learning particle systems

Collaboration with other groups (inside or outside Burgerscentrum)

- Industrial Dense Granular Flows IDGF (with profs. Schott TUD, Kuipers TU/e, van Ommen, TUD)
- Modelling the imbibition and flow of fluids in porous media (with Canon, Venlo, and prof. Darhuber TU/e) – ended 2022
- TUSAIL (EU-ETN with: University of Edinburgh, TU Hamburg Harburg, TU Braunschweig, University of Salerno + several industrial partners, e.g., JM, PG, BASF, SACMI, DCS, mercuryLAB)
- Modeling the dynamics of electrolyte in supercapacitors (with UU)
- Aeolian sand transport (sector plan PhD with K Wijnberg, UT)
- Segregation and non-spherical particles (with RC Hidalgo, Navarra)
- Segregation in industrial problems (with L. Orefice from RCPE, Graz)
- Dynamics of proteins in mitochondria (with Radboud University Medical Center)
- Colloidal suspensions (with A. Jarray and E. Scholten, WuR)

Other 2022 highlights

- Published coupled DEM-FEM solver for volume- and surface-coupled problems, available open-source at https://www.mercurydpm.org/
- Publication in Nature Communications on tail-flipping lipids to target drugs-carrying liposomes.

PhD thesis delivered in 2022

- 26 October – Thejas Hulikal Chakrapani – *Mesoscale modelling of multiphase flow and wetting,* PhD Thesis, Twente University, (Luding, den Otter).

University of Twente

Faculty of Engineering Technology

Marine and Fluvial Systems (UT-ET-MFS)

Prof. dr. Suzanne Hulscher	Full prof.
Prof. dr. Kathelijne Wijnberg	Full prof.
Dr. Jord Warmink	Associate prof.
Dr. ir. Pieter Roos	Associate prof.
Dr. ir. Jebbe van der Werf	Associate prof.
Dr. ir. Bas Borsje	Associate prof.
Dr. ir. Anouk Bomers	Assistant prof.
Dr. ir. Geert Campmans	Assistant prof.
Dr. Trang Duong	Assistant prof.
Dr. Vasileios Kitsikoudis	Assistant prof.
Dr. ir. Erik Horstman	Assistant prof.

Group's research areas

- Nature-based Flood Protection
- Biogeomorphology
- Vegetated flows
- Intertidal ecosystems
- Offshore seabed patterns
- Coastal sediment transport
- River modelling
- Barrier coasts
- Tidal inlets
- Coastal hazards including erosion and flooding
- Climate Change impacts on coast
- Environmental Fluid Mechanics
- Aeolian sediment transport
- Machine learning for flood prediction
- Hydraulic river modelling

Grants obtained in 2022

- SEDIMARE Sediment transport and morphodynamics in marine and coastal waters with engineering solutions, EU Project, Horizon Europe Framework Programme
- Future FRM Tech: Future food risk management technologies for rivers and coasts FRM technologies, NWO Perspectief

Projects started in 2022

- Project 1: MELODY project: physical sand transport processes in the lower shoreface, Philippe Frankemölle (PhD) funding NWO
- Project 2: MELODY project: Scale interactions of sand waves on the lower shoreface, Laura Portos Amil (PhD), funding NWO

- Project 3: Development of Machine Learning Applications for Real-Time River Flood Forecasting, Leon Besseling (PhD), funding NWO Simon Stevin Meester
- Project 4: Living on the edge: Biogeomorphic evolution of salt marshes under wave and tidal forcing, Sarah Dzimballa (PhD), funding NWO, part of VIDI project Living on the edge
- Project 5: Wave damping, sediment trapping and salt-intrusion mitigation by estuarine ecosystem engineering species, Jesse Bootsma (PhD), funding NWO Perspectief programme, SALTISolutions
- Project 6: Living dikes: stability of saltmarshes under extreme hydrodynamic forcing, Jos Muller (PhD), funding NWO, part of the Living Dikes programme
- Project 7: Nature-Based Flood Protection by Living Dikes: Modelling Salt Marsh Dynamics and Coastal Safety, Elien Sipma (PhD), funding NWO, part of the Living Dikes programme

Collaboration with other groups (inside or outside Burgerscentrum)

- Project 1: Deltares, University of Copenhagen, Ghent University, University of Nottingham
- Project 2: Deltares, University of Copenhagen, Ghent University, University of Nottingham
- Project 3: none
- Project 4: none (it is all University of Twente)
- Project 5: TUDelft Hydraulic Engineering and TUDelft Ports and Waterways
- Project 6: TUDelft Hydraulic Engineering
- Project 7: none (it is all University of Twente)

Other 2022 highlights

- The Professor De Winter Award, for a high-impact publication by an outstanding female scientist at the University of Twente, went to Anouk Bomers for her publication in the Journal of Hydrology: ‘Predicting Outflow Hydrographs of Potential Dike Breaches in a Bifurcating River System Using NARX Neural Networks’’.

PhD theses delivered in 2022

- 3 March 2022 – Koen Reef – *Exploratory modelling of barrier coast dynamics*, PhD Thesis, University of Twente (Hulscher, Roos, Schuttelaars).
- 1 April 2022 – Vera van Bergeijk – *Over the dike top: Modelling the hydraulic load of overtopping waves including transitions for dike cover erosion*, PhD Thesis, Twente University, (Hulscher & Warmink).
- 8 April 2022 – Daan Poppema – *Morphological effects of buildings in a sandy beach environment,* PhD Thesis, Twente University, (Wijnberg, Hulscher, Mulder).

University of Twente

Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS)

System Analysis and Computational Science (SACS)

Multiscale Modelling and Simulation (UT-EEMCS-3MS)

Prof. dr. ir. Bernard Geurts Full prof.

Group's research areas

- Computational modeling of multiscale problems in multiphase flows, environmental flows and flows in complex domains
- Novel algorithms, with error quantification, immersed boundary methods and time-parallel integration
- Computational models for application in the fields of energy and biofluid mechanics

University of Groningen

Faculty of Science and Engineering

Computational and Numerical Mathematics (RUG-SE-CNM)

Prof. dr. ir. Roel Verstappen	Full prof.
Prof. dr. Arthur Veldman	Full prof. (em.)
Prof. dr. Cristóbal Bertoglio	Associate and adjunct full prof.
Dr. ir. Fred Wubs	Associate prof.
Dr. Julian Koellermeier	Assistant prof.

Group's research areas

- CFD methods for numerical simulation (LES, DNS) of turbulent flows
- Inverse problems in (coupled) fluid and solid models
- Modeling, numerical analysis and simulation of blood flows
- Magnetic Resonance Imaging
- Numerical bifurcation analysis of fluid flows
- Structure-preserving discretization methods for fluid flows
- Numerical simulation methods for multi-phase flows
- Model reduction of rarefied gases and geophysical flows

Collaboration with other groups (inside or outside Burgerscentrum)

- Heat and Mass Technology Center, Universitat Politecnica de Catalunya
- Delft Institute of Applied Mathematics,TUD
- Netherlands eScience Center
- UMCG: Oral and Maxillofacial Surgery, BRIDGE, Pediatric Cardiology & Radiology
- Center for Mathematical Modeling, University of Chile
- Cardiovascular MRI group, Amsterdam AMC
- Center for Biomedical Imaging, Pontificia Universidad Católica de Chile
- Charité University Hospital, Berlin, Germany
- Computational Biophysics, RUG
- Scientific Computing, CWI
- ComFLOW User Group: collaboration with MARIN, TUD + several shipyards/offshore companies
- Institute for Marine and Atmospheric Research (IMAU)
- CogniGron - Groningen Cognitive Systems and Materials Center
- Numerical Analysis and Applied Mathematics, KU Leuven
- Department of Energy and Power Engineering, Tsinghua University
- Differential Equations, Numerical Analysis and Applications group, University of Málaga
- Turbulence in Fusion Plasmas group, TU Eindhoven

PhD thesis delivered in 2022

- 29 August 2022 – Jeremias Garay Labra – *On the analysis of inaccurate Phase-Contrast MRI and its assimilation into blood flow models*, PhD Thesis, University of Groningen, (Bertoglio, Verstappen).
- 30 August 2022 – Jorge Aguayo Araneda – *An inverse problem in fluid mechanics applied in biomedicine*, PhD Thesis, University of Groningen, (Bertoglio, Osses, Verstappen).

University of Groningen

Faculty of Science and Engineering

Computational Mechanical and Materials Engineering (RUG-SE-CMME)

Dr. Antonis Vakis Associate prof.

Group's research areas

- Tribology
- Advanced manufacturing
- Renewable energy
- Biomechanics

Projects started in 2022

- Dynamics of a floating offshore platform for hybrid wind and wave energy conversion (see below)

Collaboration with other groups (inside or outside Burgerscentrum)

- Dynamics of a floating offshore platform for hybrid wind and wave energy conversion (D. Bernal, PhD project, Jan. 2022), with E. Mendoza (UNAM, Mexico): double doctorate with the student spending two years in Groningen (Jun. 2023-May 2025)
- Fluid flows through dense wave energy converter arrays (A.T. Asiikkis, PhD project, Sep. 2021-), with D.G.E. Grigoriadis (UCy, Cyprus): double doctorate with the student spending two years in Groningen (Sep. 2023-Aug 2025)
- CFD investigations of dense wave energy converter arrays (C. Wang, PhD project, Jan. 2021-), with A.E.P. Veldman (RUG-SE-CNM)
- Multi-phase CFD simulations for supercritical CO_2-assisted extrusion (T.M. Kousemaker, PhD project, Jul. 2019-), with F. Picchioni (RUG-SE-PT)

Other 2022 highlights

- KIVI Prins Friso Award 2022 awarded to CMME alumnus, drs. M. van Rooij

Wageningen University & Research (WUR)

Department of Animal Sciences

Experimental Zoology (WUR-ASG-EZO)

Prof. dr. ir. Florian Muijres	Full prof.
Prof. dr. ir. Johan van Leeuwen	Full prof. (em.)
Dr. Guillermo J. Amador	Assistant prof.

Group's research areas

- Bio-fluid mechanics of animal flight
- Bio-fluid mechanics of fish swimming
- Bio-inspired soft robotics
- Novel fishing methods

Grants obtained in 2022

- NWO Vidi *Functional morphology of cuttlefish suction cups*
- WU-WIAS Postdoc Talent Programme *Hydrodynamics and biomechanics of cuttlefish locomotion and prey capture*
- WU-WGS Africa Talent Programme *In-flight mating in sympatric swarms of Anopheles malaria mosquitoes and their hybrids*

Projects started in 2022

- NWO-TTW *New stimulation techniques for flatfish trawling (StimTech)*
- NWO Vidi *Functional morphology of cuttlefish suction cups*
- WU-WIAS Postdoc Talent Programme *Hydrodynamics and biomechanics of cuttlefish locomotion and prey capture*
- WU-WGS Africa Talent Programme *In-flight mating in sympatric swarms of Anopheles malaria mosquitoes and their hybrids*

Collaboration with other groups (inside or outside Burgerscentrum)

- 4TU Soft Robotics: collaboration with TU Delft, TU/e, and U Twente
- NWO Vidi Aerodynamics and control of Diptera flight: collaboration with TU Delft.
- HFSP Swarming and in-flight mating of malaria mosquitoes: collaboration with TU Delft.
- Alliance EWUU Preventing malaria disease spreading by smart turbulence flow fields: collaboration with UU and TU/e.
- WU-WIAS PhD Talent Program Escape flights of moths as greenhouse pests: collaboration with TU Delft.
- NWO-TTW StimTech: Collaboration with Wageningen Marine Research (WMR), TU Delft, Visserij-Innovatiecentrum Zuidwest Nederland.
- NWO Vidi Functional morphology of cuttlefish suction cups: collaboration with Karlsruhe Institute of Technology (Germany), University of Kiel (Germany), TU Delft, U Twente, TU/e.

- WU-WIAS Postdoc Talent Programme Hydrodynamics and biomechanics of cuttlefish locomotion and prey capture: collaboration with University of Antwerp (Belgium), TU Delft.

Other 2022 highlights

- 2022 key publications by the group:
    - van Veen, W. G., van Leeuwen, J. L., van Oudheusden, B. W., & Muijres, F. T. (2022). The unsteady aerodynamics of insect wings with rotational stroke accelerations, a systematic numerical study. *Journal of Fluid Mechanics* **936**, A3 1-45. doi.org/10.1017/jfm.2022.31
    - Cribellier, A., Straw, A. D., Spitzen, J., Pieters, R. P. M., Leeuwen, J. L. van, & Muijres, F. T. (2022). Diurnal and nocturnal mosquitoes escape looming threats using distinct flight strategies. *Current Biology* **32**, 1–15. doi.org/10.1016/j.cub.2022.01.036
    - Goyal, P., van Leeuwen, J. L., & Muijres, F. (2022). Bumblebees Land Rapidly by Intermittently Accelerating and Decelerating Towards the Surface During Visually Guided Landings. *iScience* **25**(5), 104265. doi.org/10.1016/j.isci.2022.104265
    - Olejnik, D. A., Muijres, F. T., Karásek, M., Honfi Camilo, L., de Wagter, C., & de Croon, G. C. H. E. (2022). Flying Into the Wind: Insects and Bio-Inspired Micro-Air-Vehicles With a Wing-Stroke Dihedral Steer Passively Into Wind-Gusts. *Frontiers in Robotics and AI* **9**, 1–17. doi.org/10.3389/frobt.2022.820363
    - Le Roy, C., Silva, N., Godoy-diana, R., Debat, V., Llaurens, V., & Muijres, F. T. (2022). Divergence of climbing escape flight performance in Morpho butterflies living in different microhabitats. *Journal of Experimental Biology* **225**. doi.org/10.1242/jeb.243867
    - Liao, C., Amador, G. J., Liu, X., Wu, Z. & Wu, J., (2022) Trichoid sensilla on honey bee proboscises as inspiration for micro-viscometers. *Bioinspiration & Biomimetics* **18**, 1, 016012.
    - van den Boogaart, L.M., Langowksi, J.K.A., & Amador, G. J. (2022) Studying stickiness: Methods, trade-offs, and perspectives in measuring reversible biological adhesion and friction. *Biomimetics.* 7, 3, 134.
    - Hagmayer, A., Lankheet, M. J., Bijsterbosch, J., Van Leeuwen, J. L. & Pollux, B. J. A. (2022) Maternal food restriction during pregnancy affects offspring development and swimming performance in a placental live-bearing fish. *Journal of Experimental Biology*. **225**, 2, jeb242850.

PhD thesis delivered in 2022

- 26 January 2022 – Goyal Pulkit – *How bees land: Visual guidance and sensorimotor control of landing maneuvres in bees*, Wageningen University & Research, (Muijres, Van Leeuwen, de Croon).

Wageningen University & Research (WUR)

Department of Agrotechnology and Food Sciences

Food Process Engineering (WUR-AFS-FPE)

Prof. dr. ir. Karin Schroën Full prof.

Group's research areas

- Emulsions
- Foams
- Microfluidics
- Separation systems

Grant obtained in 2022

- PICKFOOD; Marie Curie innovative training network

Project started in 2022

- PICKFOOD

Collaboration with other groups inside and outside the Burgerscentrum

- Within the ReCoVR project we work together with University of Twente, Delft University of technology, Eindhoven Technical University and various industrial partners.
- Within PICKFOOD we work together with the PCC group of Wageningen University, and various international partners that are all interested in Pickering emulsions.

Other 2022 highlight

- Construction of a number of Sectorplans together with the deans of technology of all TU's and RUG, that will help technical education and research in the Netherlands in the long run.

PhD theses delivered in 2022

- 1 April 2022 – Jilu Feng – *Maillard-reaction based routes for stable food emulsions ,* Wageningen University & Research, (Vicenzo, Schroën, Benron-Carabin).
- 25 November 2022 – Boxin Deng – *Microfluidic analysis of dynamic processes occurring during bubble formation and stabilisation,* Wageningen University & Research, (Schroën & de Ruiter).
- 9 December 2002 – Herehau Blais – *Innovative energy efficient membrane separation approaches for milk,* PhD Thesis, Wageningen University & Research, (Schroën & Tobin).

Wageningen University & Research (WUR)

Department of Agrotechnology and Food Sciences

Physical Chemistry and Soft Matter (WUR-AFS-PCSM)

Prof. dr. ir. Jasper van der Gucht	Full prof.
Dr. Uddalok Sen	Assistant prof.

Group's research areas

- Polymer materials, gels, coacervates
- Rheology of complex fluids
- Film formation in colloidal systems
- Granular materials

Project started in 2022

- ITN Pickfood; PhD student Xuefeng Shen

Collaboration with other groups (inside or outside Burgerscentrum)

- Controlling multiphase flow (with TUD, UvA, Unilever, Shell, Evodos)
- Participation in two ITNs: Nanpaint (capillary suspensions), Pickfood (Pickering emulsions)

PhD theses delivered in 2022

- 8 April 2022 – Sven Boots – *The strong and the weak: Nucleating insight into the role of mechanical heterogeneity on material failure*, PhD Thesis, Wageningen University & Research, (van der Gucht & Kodger).
- 26 April 2022 – Jesse Buijs – *Simpler, faster, and softer: Towards broad application of Laser Speckle Imaging in art conservation and soft matter*, PhD Thesis, Wageningen University & Research, (Van der Gucht & Sprakel).
- 31 August 2022 – Riahna Kembaren – *Stuck inside: Strategies for improving the stability of enzyme-containing complex coacervate core micelles*, PhD Thesis, Wageningen University & Research, (van der Gucht, Borst, Kleijn, Kamperman).

Utrecht University

Institute for Meteorology and Oceanography (UU-IMAU)

Prof. dr. Henk Dijkstra	Full prof.
Dr. Anna von der Heydt	Associate prof.

Group's research areas

- Physical Oceanography
- Climate Dynamics

Grants obtained in 2022

- ERC-AdG, NWO-M1, NWO-NLeSC (Dijkstra)

Collaboration with other groups (inside or outside Burgerscentrum)

- ERC-AdG, NWO-M1, NWO-NLeSC (Dijkstra)

Projects started in 2022

- ERC-AdG (Dijkstra): Tipping of the Atlantic Ocean Circulation
- NWO-M1 (Dijkstra): Skillful El Nino prediction beyond predictability barriers
- NWO-Vici (Von der Heydt): Tipping cascades in the climate system

PhD thesis delivered in 2022

- 21 February 2022 – Peter Nooteboom – *There and back again: The journey of sinking marine microplankton and its implication for past, present and future climate*, PhD Thesis, University Utrecht, (Dijkstra & Von der Heydt).
- 7 March 2022 – André Jüling – *Climate variability and rresponse in high-rresolution earth system models*, PhD Thesis, University Utrecht, (Dijkstra & Von der Heydt).

University of Amsterdam

Faculty of Science - Van der Waals-Zeeman Institute for Experimental Physics

Soft Matter Group (UVA-SMG)

Prof. dr. Daniel Bonn	Full prof.
Prof. dr. Noushine Shahidzadeh	Full prof.
Prof. dr. Peter Schall	Full prof.
Dr. Joshua Dijksman	Associate prof.
Dr. Corentin Coulais	Associate prof.
Dr. Maziyar Jalaal	Assistant prof.
Dr. Sara Jabbari-Farouji	Assistant prof.
Dr. Antoine Deblais	Assistant prof.

Group's research areas

- Flow behaviour of surfactant, polymer, granular and colloidal systems
- Wetting, complex fluids and hydrodynamics
- Crystallization and self-assembly
- Friction and interfaces
- Complex media and metamaterials
- Soft active matter
- Chaos and Dynamical Systems
- Biological Physics
- Environmental/ecological/geophysical fluid mechanics
- Computational continuum mechanics
- Light-matter interaction
- Active filaments in porous media
- Microswimmers in external fields
- Drying of gels in porous media
- Mechanics of glassy and semicrystalline polymers

Grants obtained in 2022

- *Scaling-up SuperLubricity into Persistence* (SSLiP), European Innovation Center (EIC) Pathfinder project; coordinated by Trinity College Dublin (PI: Schall).
- *Shaping the solar spectrum for enhanced crop yields in agriculture*, ZonMw TakeOff grant (PI: Schall).
- *CAVITation in Ultrasoft Solids* (CAVITUS), SNF/NWO grant (PI: Jalaal).
- *MItigation STrategies for Airborne Infection Control* (MIST), NWO Perspectief grant, coordinated by U Twente (PIs: Bonn, Jalaal)
- Achieving animate properties with odd robotic matter (NWO ENW, VIDI, 800k), PI: Coulais

Projects started in 2022

- *Scaling-up SuperLubricity into Persistence* (SSLiP), European Innovation Center (EIC) Pathfinder project; coordinated by Trinity College Dublin (PI: Schall).
- *Shaping the solar spectrum for enhanced crop yields in agriculture*, ZonMw TakeOff grant (PI: Schall).
- *CAVITation in Ultrasoft Solids* (CAVITUS), SNF/NWO grant (PI: Jalaal).
- *MItigation STrategies for Airborne Infection Control* (MIST), NWO Perspectief grant, coordinated by U Twente (PIs: Bonn, Jalaal)

Collaboration with other groups (inside or outside Burgerscentrum)

- Industrial collaborations such as with Michelin, SKF and Unilever, Shell, DSM, Akzo Nobel, ASML, Tata steel, ATG Europe, BASF, SACMI, Zetadec, Ocean Cleanup, Ultimaker, Renolit, Chemtrix, Photanol
- AMOLF, Leiden, Utrecht, Delft, Eindhoven, UTwente, Wageningen,
- U Munster, DLR, esa, ETH, U Erlangen, INSA Lyon, University of Warsaw, University of Chicago, ENS Lyon, Georgia Tech, University of Milan, Osaka University, Can Tho University

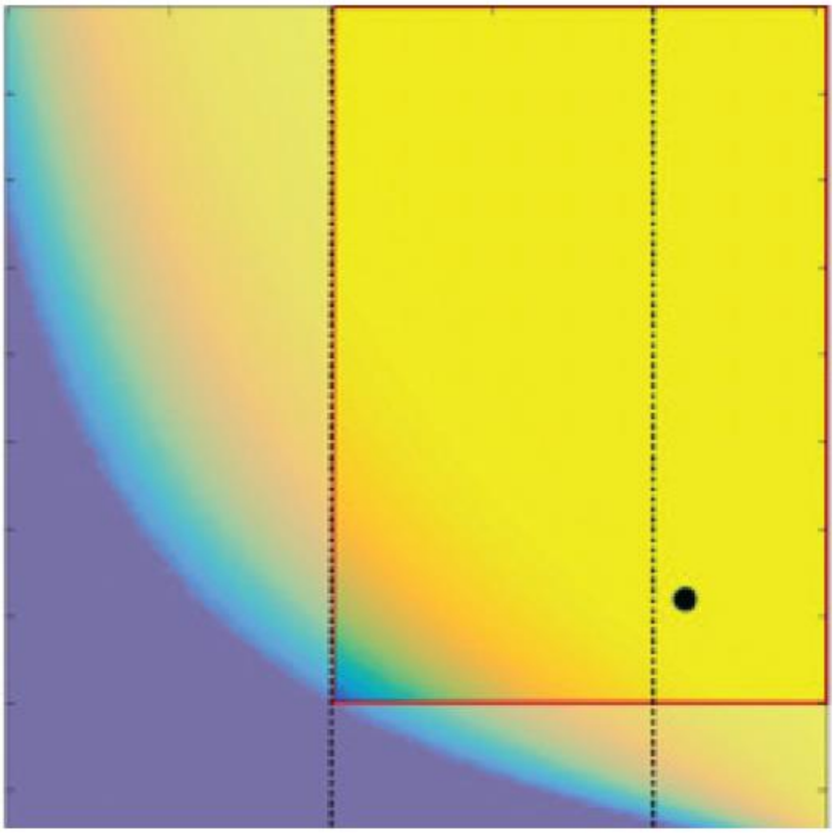
Other 2022 highlights

- Joshua Dijksman joined in September 2022 (with 1 day per week part-time appointment at Wageningen University for the first year).
- Huge media impact on the research about edible metamaterials

PhD theses delivered in 2022

- 9 March 2022 – Riande Dekker – *Emulsion stability and rheology*, PhD Thesis, University of Amsterdam, (Bonn).
- 8 July 2022 – Piet Swinkels – *Colloidal Architectures: Atom-like Assembly of Patchy Particles*, PhD Thesis, University of Amsterdam (Schall & Coulais).
- 29 September 2022 2 – Rick Sijs – *Droplet dynamics from sprays with and without additives*, PhD Thesis, University of Amsterdam, (Bonn).
- 12 October 2022 – Marius Bittermann – *New light on soft matter; Spectroscopic and microscopic studies of complex fluids, active matter and supercooled fluids*, PhD Thesis, University of Amsterdam, (Bonn & Woutersen).

ORGANISATION



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Contact Groups

- Biological Fluid Mechanics
- Combustion
- Computational Fluid Dynamics (CFD)
- Experimental Techniques
- Lattice-Boltzmann Techniques
- Microfluidics
- Multiphase Flow
- Turbulence

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