Annual Report

2021

J.M. Burgerscentrum

Research School for Fluid Mechanics

Annual Report 2021

JM Burgerscentrum

Research School for Fluid Mechanics
TUD, TU/e, UT, RUG, WUR, UU

Correspondence for reproduction

JM Burgerscentrum, Mekelweg 2, 2628 CD Delft, The Netherlands

jmburgerscentrum@tudelft.nl

www.jmburgerscentrum.nl

Burgers Program for Fluid Dynamics (University of Maryland, USA) http://hydro.umd.edu

Preface

It is with pride that we can present the year 2021 Annual Report of the J.M. Burgerscentrum for Fluid Mechanics. 2021 was the second year of the Covid-19 pandemic. Despite the restrictions imposed by the pandemic, the members of the Burgerscentrum have performed at full strength. This is best demonstrated by the delivery of 79 PhD theses, including four that have received the predicate “Cum Laude”.

The present annual report of the J.M. Burgerscentrum provides an overview of the activities of our research school during the year 2021. The core of the report consists of a pointwise summary of the 2021 research initiatives and achievements within each of the participating JMBC groups. In addition, also seven research highlights are provided in the form of short articles, as prepared by junior JMBC members who received their PhD degree in 2021. 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 315). In addition, about 40 Postdocs are registered at the school. The work is supported by about 220 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 2021, seven JMBC courses were organised (including four that were given online due to the pandemic). The course on Machine Learning was given for the first time. Professor Federico Toschi of Eindhoven University of Technology, and very active within the Burgerscentrum, took the initiative for this. Very positive feedback from the large number of participants (mainly PhD students registered at the Burgerscentrum) 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 usually is a two-day gathering in Hotel de Werelt in Lunteren, but in 2021 this had to be organized fully virtual online, again due to the pandemic. Despite this, it was a great success with a large audience following the programme that included a number of lectures by well-known international fluid flow speakers. The programme also covered three presentations by fluid flow prize winners:

- Charles Hoogendoorn Fluid Dynamics Award 2019 (KIVI) by dr. ir. Cees Voesenek (WUR)
- Charles Hoogendoorn Fluid Dynamics Award 2020 (KIVI) by dr.ir. Anouk Bomers (UT)
- Leen van Wijngaarden Prize 2020 by dr. ir. Florian Muijres (WUR)

Mid 2021, an international panel evaluated the functioning of the Burgerscentrum (e.g., structure, management, organization of activities). In their evaluation report the panel mentioned that they were very impressed by the excellent achievements of the Burgerscentrum. They made a number of constructive novel recommendations to build on this success. The recommendations will be used to make a plan for implementation in the next period.

It is also worth mentioning that the agreement between the six universities (Delft, Eindhoven, Twente, Groningen, Wageningen, Utrecht), that formalizes the collaboration of the fluid flow groups within the Burgerscentrum, has been renewed for another 5 years till 2026. This underpins the high value perceived by the Boards of the Universities on academic collaboration on fluid mechanics.

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.

Organizing the mentioned external panel valuation and the renewal of the collaboration agreement were among the last tasks carried out by professor GertJan van Heijst, Scientific Director of the Burgerscentrum. On 1st August 2021, he ended his directorship after a seven year period. We are enormously grateful to him for the way in which he has led the centrum over the past years. Thanks to his efforts, the Burgerscentrum has remained its outstanding position, reflecting the power of fluid mechanics research 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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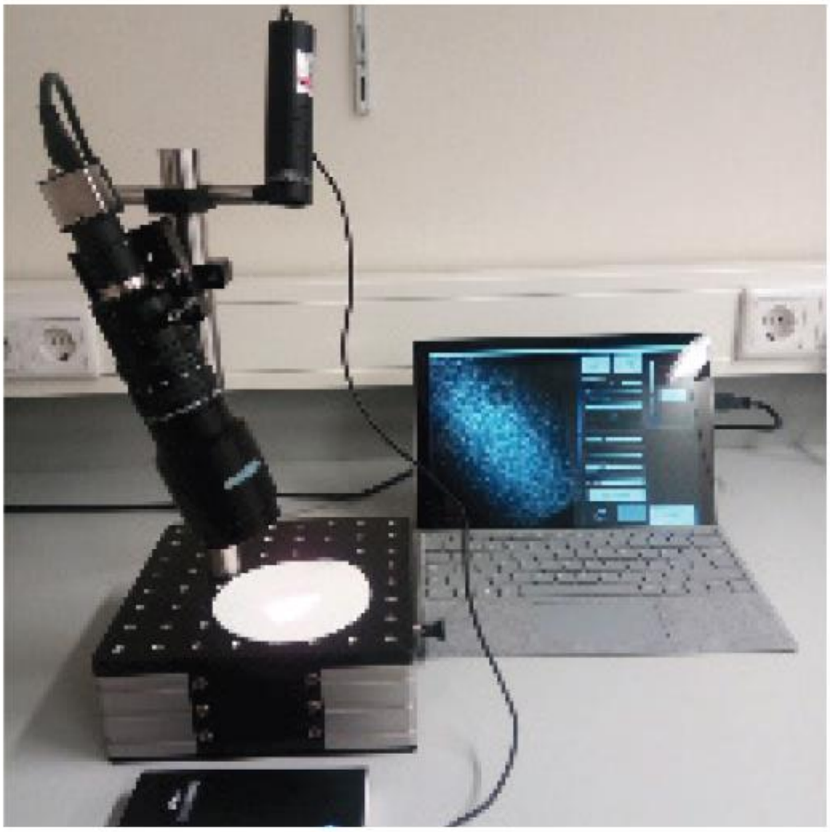

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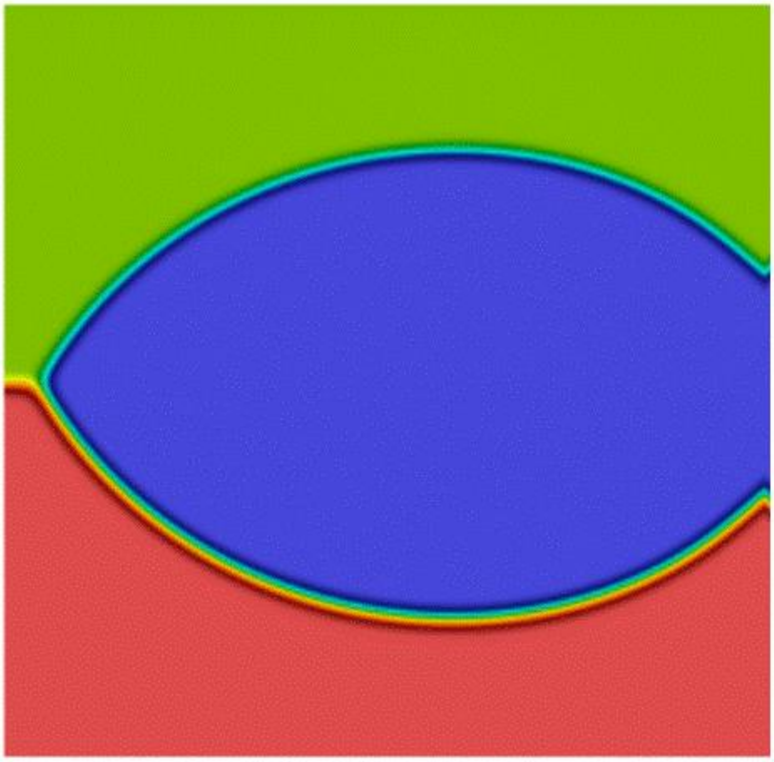


Introduction

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 more than 200 senior scientific staff members participate in the JMBC. The groups are located at the universities in Delft, Eindhoven, Twente, Groningen, Wageningen, and Utrecht. 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 2021, somewhat over 300 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 and Utrecht). 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.

Together with Engineering Mechanics (the Dutch research school on solid mechanics) the JMBC forms the 4TU Research Centre for Fluid & Solid Mechanics (FSM). This Research Centre has been recognized as a “centre of excellence” in The Netherlands and has in the past received significant funding by the Dutch Government for stimulating new research areas in fluid and solid mechanics.

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. In the year 2021, due to the Covid-19 pandemic, the Burgers Symposium was held on-line.

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 2021, Prof. GertJan van Heijst of Eindhoven University of Twente gave the Burgers Lecture at the 18th Annual Burgers Symposium. His (on-line) presentation (online due to the pandemic travel restrictions) was entitled: “Some Fascinating Aspects of Shallow Flows – Laboratory Experiments, Numerical Simulations, and Geophysical Applications”.

2021 Participation

The table shows the number of participants in the Burgerscentrum as per end 2021.

	TUD	TU/e	UT	RUG	WUR	UU	Total
Scientific staff	**82**	**65**	**67**	**5**	**5**	**2**	**226**
PhD students	**101**	**107**	**97**	**5**	**6**	**0**	**316**
Postdocs	**6**	**15**	**18**	**1**	**1**	**0**	**41**

2021 PhD Courses

18 – 22 January 2021 – Computational Fluid Dynamics 2 (CFD 2), Delft University of Technology, 20 participants, online (due to Covid).

29 March – 1 April 2021 – Macro- and Microfluidics, Eindhoven University of Technology, 22 participants, online (due to Covid).

19 – 22 April 2021, Shallow Flow, Von Karman Institute and JMBC, 45 participants, online (due to Covid).

28 June – 2 July 20221 – Machine Learning in Fluid Mechanics, Eindhoven University of Technology, 35 participants, online (due to Covid).

11 – 15 October 2021, Particle-Based Modelling Techniques, Eindhoven University of Technology, 17 participants.

3 – 4 November 2021, Solution Methods in Computational Mechanics Engineering Mechanics Graduate School and JMBC, Eindhoven University of Technology, 31 participants.

15 – 18 November 20221 – Experimental Techniques in Fluid Mechanics, University of Twente, 34 participants.

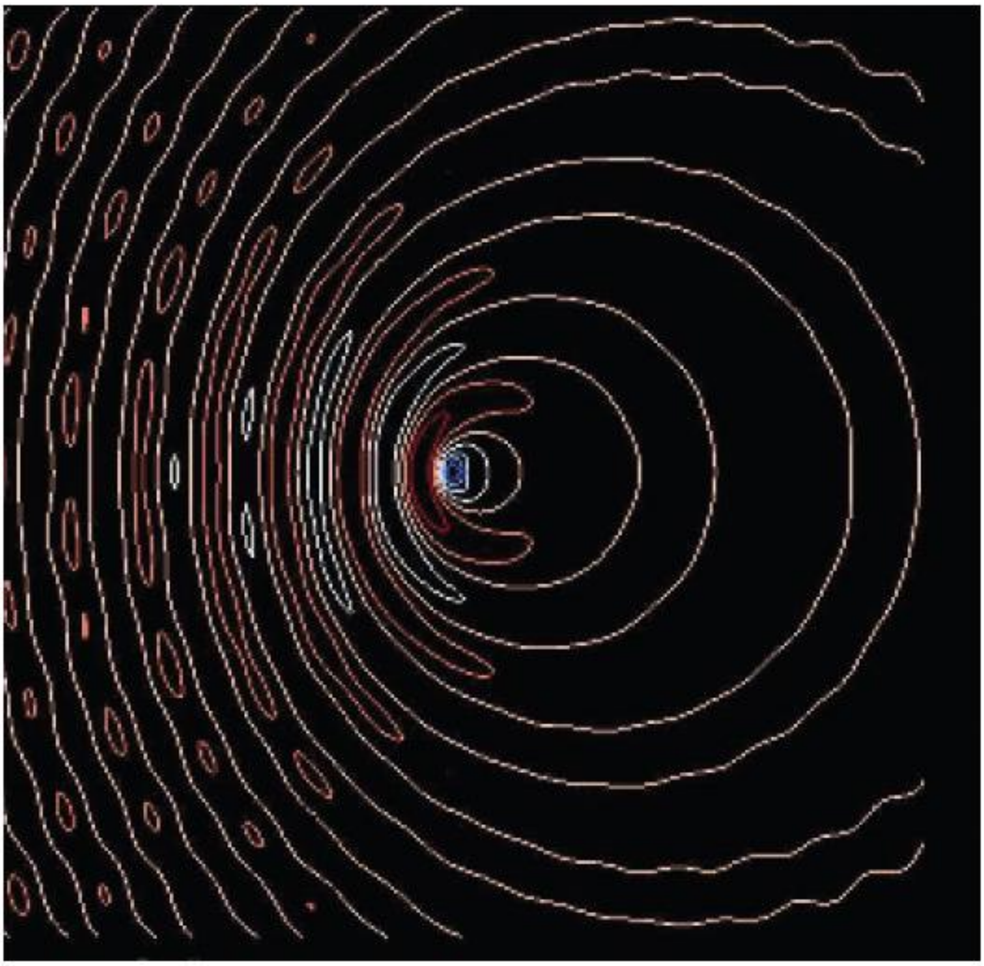
2021 Burgers Symposium

Due to the COVID 19 pandemic, the 2021 Burgers Symposium was given on-line in the afternoons of 26 and 27 May. The Symposium included:

- Burgers Lecture by prof. Howard Stone, Princeton University (USA)
- Lectures by
    - prof. Anne Juel (University of Manchester, UK)
    - prof. Wolfgang Schröder (RWTH Aachen, D)
    - prof. Matthew Juniper (University of Cambridge, UK)
    - prof. Jacques Magnaudet (IMFT Toulouse, F)
- Award session of prizes:
    - Charles Hoogendoorn Fluid Dynamics Award 2019 (KIVI) by dr. ir. Cees Voesenek (WUR)

- Charles Hoogendoorn Fluid Dynamics Award 2020 (KIVI) by dr.ir. Anouk Bomers (UT)
- Leen van Wijngaarden Prize 2020 by dr. ir. Florian Muijres (WUR)

HIGHLIGHTS



This highlight refers to the PhD Thesis by Sina Tajfirooz (2021)

Numerical methods for dynamics of particles in magnetized liquids

With applications in magnetic density separation of end-of life plastic

Sina Tajfirooz, Hans Kuerten, Jos Zeegers

Eindhoven University of Technology, Department of Mechanical Engineering, Power and Flow

In the wake of the ever-increasing worldwide production of plastic, now more than ever before, the inefficiency of our current plastic recycling strategies has become evident. Plastic pollution has become a major environmental, economic and societal concern. Different types of plastic (PET, PVC, PS, etc.) are inherently incompatible. Mixing different plastic types through the recycling process leads to the so-called “down-cycling” of high-quality plastic products to low-grade single-use products that cannot be recycled anymore. A main challenge in the plastic recycling industry is the efficient separation of different types of plastic.

Magnetic density separation (MDS) is a state-of-the-art mechanical separation technique that separates plastic particles of different types based on minute differences in their mass density (as low as 1 kilogram per cubic meter). MDS uses engineered magnets and a magnetically responsive liquid to create a non-linear pressure field inside the liquids. A schematic of an MDS system for separating plastic particles is shown in Figure 1. Once a mixture of plastic waste is injected, in the form of particles, into a continuous flow of a magnetic liquid, the combined effect of gravitational and magnetic buoyancy forces pushes the particles to heights unique to their mass density. Different mass density groups can then be continuously extracted from the system using separator plates mounted downstream of the flow at different heights.

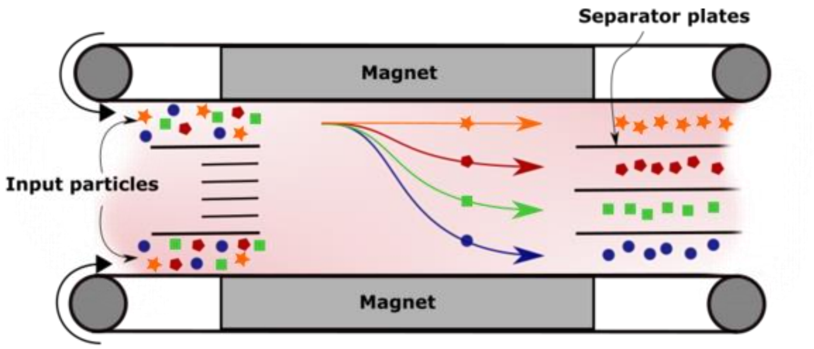
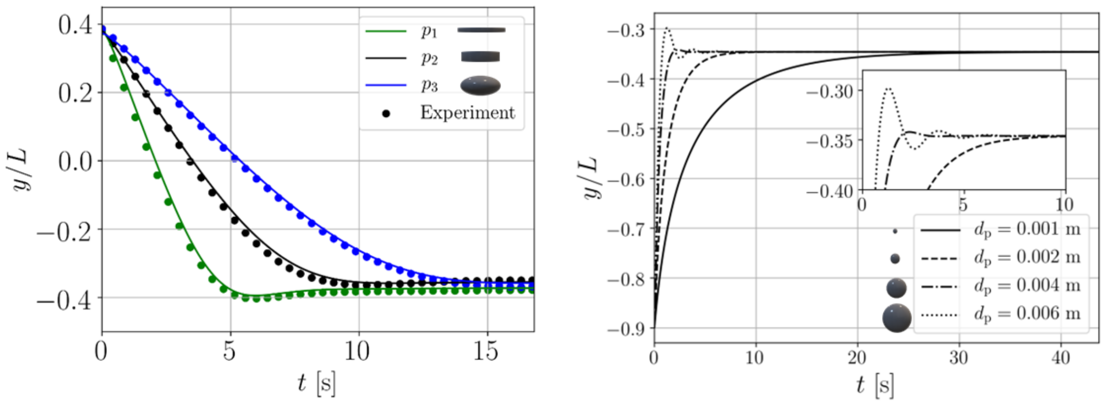


Figure 1: A sketch of the magnetic density separation system. Each marker (color) indicates a different mass density.

Optimizing MDS systems requires a fundamental understanding of the motion of millimeter-sized, arbitrarily-shaped particles in flows of magnetic liquids. This work develops an efficient computational framework to predict and understand particle-laden flows in MDS systems.

We use a point-particle Euler-Lagrange approach (PP-DNS) to capture the motions of magnetic fluid and immersed particles. Our computationally efficient point-particle method models the two-way fluid-particle momentum transfer by introducing local forces to the fluid momentum equation at the position of the particles. The collisions between the particles are also captured by accurate collision detection and response models. Moreover, to capture steady hydrodynamic interactions of highly non-spherical particles immersed in particle-laden flows, we combined a statistical-learning method with resolved CFD simulations to build accurate and versatile force and torque correlations for such particles.

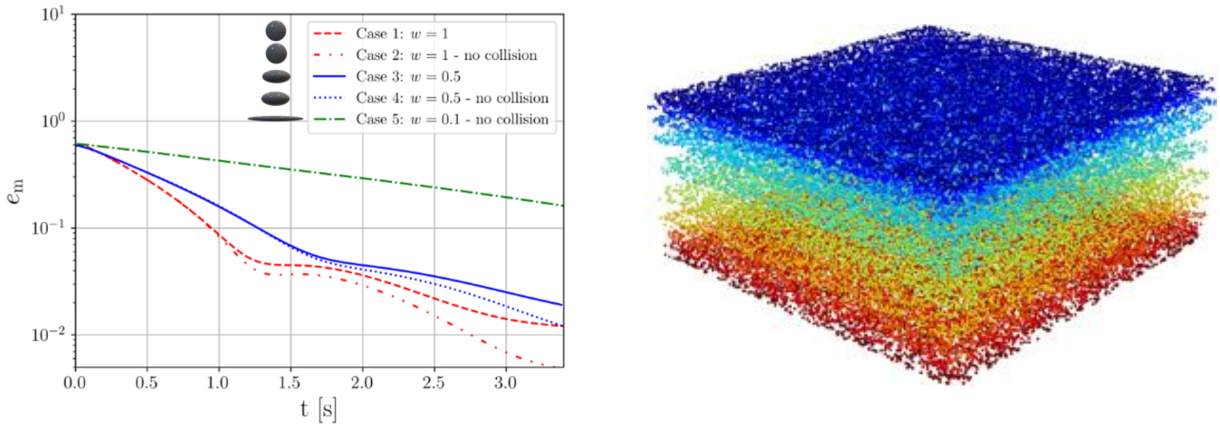
We first validated different elements of our model by comparing the numerical results with detailed experiments performed in a lab-scale MDS setup consisting of one or two particles. Next, we employed the model to investigate large MDS systems. We quantified the effects of particle size, shape, and collisions on the MDS performance. Figure 2 shows the effects of particle shape and size on the motion of single spherical particles in a magnetized liquid. Larger particles separate more quickly. In addition, spherical particles are separated faster than thin disk-shaped particles.



(a) *(b)*

Figure 2: Effects of (a) particle shape and (b) size on the traveling time of a single particle inside a magnetized liquid. Particles p_1, p_2, and p_3 particles have aspect ratio 0.1, 0.2 and 0.5 respectively.

The effects of particle shape and collisions on the separation efficiency of large MDS systems are shown in Figure 3a. Separation performance is quantified by separation error e_m, defined as root-mean-square of particle distances from their theoretical equilibrium points. Figure 3b shows a snapshot of spherical particles (case 1) after 3 seconds. In large MDS systems, the hampering effect of collisions is larger for more spherical particles. However, overall, the spherical particles exhibit a better separation performance. Hence, it would be beneficial if the particles could be pre-processed to be roughly spherical. The findings of this work can be effectively used to optimize future MDS systems.



(a) *(b)*

Figure 3: (a) Effects of particle aspect ratio, w and collisions on the separation error e_m. (b) A snapshot of spherical particles consisting of ten mass density groups after 3 seconds. Each colour represents a mass density.

Reference

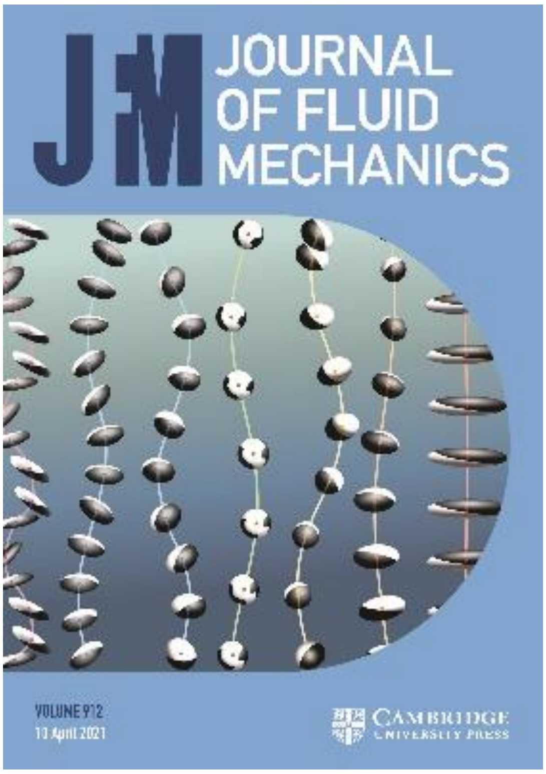
Tajfirooz, S. 2021. Numerical methods for dynamics of particles in magnetized liquids, PhD Thesis, Eindhoven University of Technology.

This highlight refers to the PhD Thesis by Jelle Will (2021)

Wake-induced dynamics of buoyancy-driven and anisotropic particles

Jelle Will, Dominik Krug , Detlef Lohse

Physics of Fluids, Faculty of Science and Technology, University of Twente



A picture from this study appeared on the front cover of Volume 912 of Journal Fluid Mechanics (11 April 2021)

One of the classical problems in fluid dynamics is the motion of an unrestrained body rising (bubbles in your favourite beverage) or settling/falling (rain, hail, or the big rock you threw in a lake) in a fluid otherwise at rest under the effect of its own effective **buoyancy**. Investigations of this problem date back at least as far as Leonardo da Vinci who documented, and questioned the reason for, the non-vertical paths of small bubbles rising in water. Later on, Sir Isaac Newton dropped solid spheres and hog's bladders inside St. Paul's cathedral in London. Both found that, even when correcting for buoyancy, the particles do not always experience the same aerodynamic or hydrodynamic **drag**. Surprisingly, this deceivably simple system can behave in remarkably complex ways. For large enough Reynolds numbers, the ratio of inertial to viscous forces, the flow around the body will begin to separate resulting in periodic shedding of vortices akin to the famous von Kármán vortex street. For these cases, the periodic forcing by the flow and the particle rotation and translation will interact with each other; the particle motion affecting the flow and vice versa resulting in complex and sometimes chaotic particle motion. This coupling makes the system extremely sensitivity to both particle and fluid properties. For this reason it is, to this day, still impossible to predict the dynamics and kinematics of freely rising and settling bodies. However, understanding the fundamental origins and nature of the differences in particle drag and the observed paths is a key question in many fields of research such as meteorology, sedimentology, as well as in many practical, industrial applications where, particle induced mixing is present. Therefore, in the present work we focus on identifying key parameters or characteristics of particles by means of controlled experiments that can be used to model and predict their behaviour. We specifically focus on **body rotation,** which has been a largely overlooked but nevertheless important parameter, as we find.

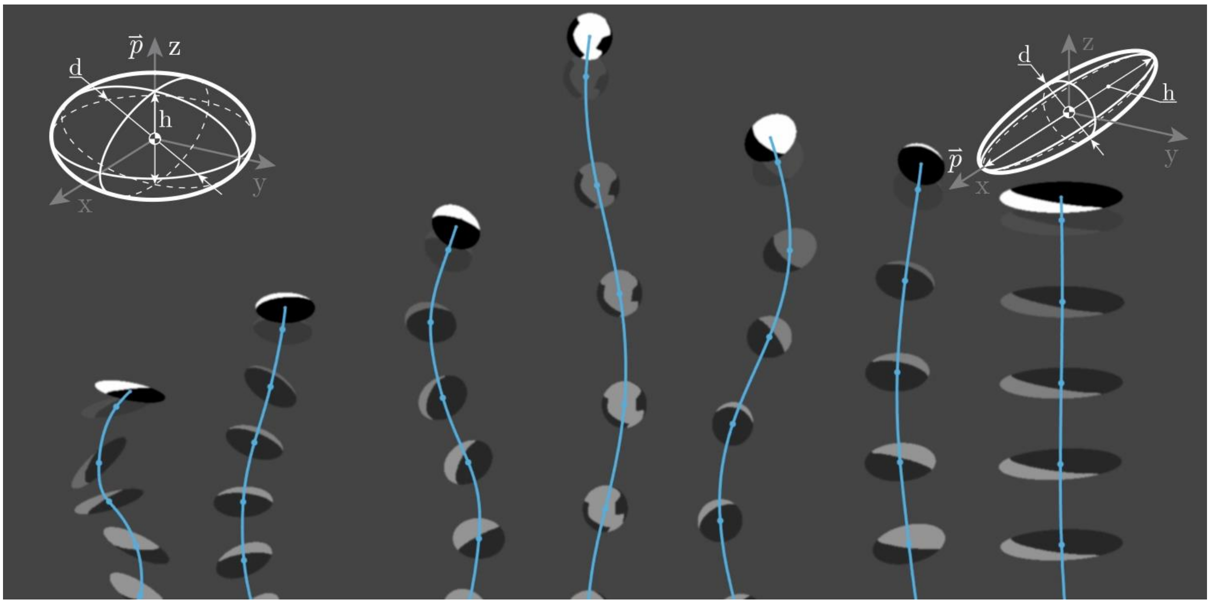


Figure 1: Seven rising particles with different geometries but identical volume and density, all released at the same moment in time. In the centre we observe the fastest (lowest drag): a rising sphere, to its left are 3 oblate (disk shaped) ellipsoids with the furthest left being the most anisotropic and to its right 3 prolate (needle shaped) ellipsoids. The black and white pattern on these bodies is used for rotational tracking.

Effects of geometry

A very fundamental but from a fluid dynamic perspective crucially important distinction is that between a sphere (isotropic) and any shape besides that (anisotropic). We experimentally investigated the effect of **geometry** by studying ellipsoids ranging from oblate (disk shaped) to prolate (needle shaped) (Will et al., 2021). The reason for this distinction is rotation and the driving thereof. For a sphere, any body rotation is induced by the thin layer of fluid close to the surface **shearing** the surface resulting in a torque and rotation, however for any other shape the fluid will also 'push' against the surface resulting in a **pressure** induced torque. We found that for anisotropic bodies the vortex shedding, which results in significant pressure asymmetries on the body's surface, will in general result in large torques resulting in a more rotationally active particle. More importantly, even a small amount of anisotropy was enough to induce a tumbling mode, where the body continuously flips (for visualization particle motion see supplementary videos to Will et al., 2021) accompanied by a significant increase in drag compared to the sphere. Surprisingly, this flipping behaviour does not persist as anisotropy increases, in fact for the explored parameter range six unique regimes of motion were uncovered. A number of these regimes are visualised in Figure 1, where path and orientation are shown from left-to-right for 3 oblate, one spherical, and 3 prolate geometries of identical volume and weight which are released simultaneously. For oblate bodies the motion becomes extremely regular and periodic, this is accompanied by a strong increase in drag. For prolate bodies on the other hand the two cross-flow dimensions result in more chaotic and surprising behaviour. In general, the drag tends to increase the further the geometry deviates from spherical, however for some prolate particles the trend was the opposite due to a reduction in body rotation and the absence of path-oscillation under certain conditions, see the right most particle in Figure 1. The differences between oblate and prolate clearly show that a simple measure of 'sphericity' as often employed in literature and modelling can never be sufficient to predict behaviour in any sensible way.

Effects of moment of inertia

Besides changing the shape of a body, it is also possible that there is an **internal inhomogeneity**, a small pocket of air inside the material or a body made up of two or more materials. This can result in changes in the **rotational inertia** of the body without affecting what the flow 'sees'. In the past, many experiments with rising bodies used hollow shells; not too dissimilar from a ping-pong ball. It was recently suggested that resulting changes in the rotational inertia could explain the large variation of the measured drag coefficients in literature (see black dots in Figure 2d). To test this, we systematically varied the moment of inertia for spherical bodies of several particle-to-fluid density ratios (Will and Krug, 2021a,b). The idea again relies on body rotation, the coupling to the particle path, and vortex shedding being important aspects of the measured drag coefficient. While we did observe that the mean rotation rate reduces for increased inertia and this did result in a gradual increase in the drag no variations were observed to the extend as those found in literature, thus rotational inertia alone cannot explain these aberrant findings. The reason for this is that, although the body responds more strongly to the fluid induced torques when the inertia is lower, it still only gets rotated by **shearing** forces on the particle shell, which at higher Reynolds numbers are relatively weak compared to the pressure forces that rotate the previously described anisotropic bodies. We did however show the direct correlation between moment of inertia and drag and amplitude of the path oscillations of rising particles which is a valuable fundamental insight in the coupled dynamics of rising spheres as well as in interpreting previous work.

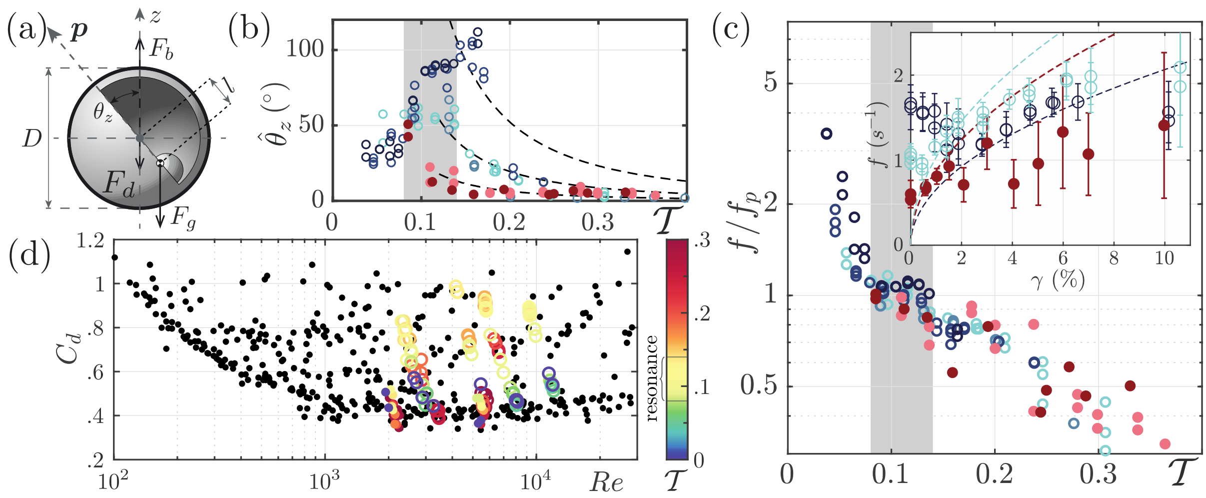


Figure 2: (a) Schematic of a sphere used in the experiments, by moving an internal metal ball radially outwards inside the shell the COM is displaced from the geometric centre. (b) Amplitude of the rotational oscillations of the sphere as a function of the dimensionless COM offset. (c) Inset: Frequency of the path oscillations vs. COM offset, the dashed lines show the pendulum frequency of the system. Main panel: frequency ratio vs. dimensionless offset. (d) Drag coefficient vs. Reynolds number, the coloured markers indicate the present results, compared to the spread in literature (black dots).

Effects of centre of mass offset

Another, completely unexplored, way to affect the internal mass distribution is by changing the location of the **centre of mass** (COM) with respect to the geometric centre, see Figure 2a. This does not affect the geometry that the flow encounters. Due to the offset, however, there is stronger coupling between the translational and rotational dynamics. In Figure 2b, where we plot the rotational amplitude versus the dimensionless offset ($\mathcal{T}$) we find that the rotational amplitude increases for a subset of offsets, the so-called **resonance** phenomenon. To explain this behaviour, we considered the rotational equation of motion as a driven harmonic oscillator with a pendulum frequency (f_p). When the driving (vortex shedding/path oscillation) frequency (f) is equal to this pendulum frequency, as is shown in Figure 2c, then the system is in resonance and we observe a maximum enhancement of rotational dynamics as well as of the drag. The change of the resonance frequency with COM offset is shown for different particle densities by the coloured dashed lines in the inset of Figure 2c, for a subset of offsets the observed path oscillation frequency is found to 'lock-in' with this pendulum frequency and the as a consequence the frequency ratio in the main panel of Figure 2c equals one. This region is indicated by the grey area in the figure. Note, that this is indeed the range where the rotational amplitude is at its peak in Figure 2b. Notably, this resonance behaviour only works for rising particles due to an asymmetry in the equations of motion, this can be seen in Figure 2b where the blue markers indicate rising and red settling particles and the rotational amplitude is only increased for the blue cases. Finally, in Figure 2d we show the drag coefficient versus the Reynolds number and compare these results to those from literature, the black markers. The range of drag coefficients observed with COM offset appears to match that observed in literature and offers a plausible explanation for previous findings that do not match more recent attempts to reproduce them; a small offset might have been present during the original experiment that might have gone unnoticed. The effects of offset on rising bodies are very significant, causing drag to more than double for small offsets of a couple of percent of the radius making this parameter one that should be carefully considered.

Conclusion

The dynamics and kinematics of rising and settling particles are complex, many parameters affect what will happen when you throw that rock into a pond. The shape of the rock will matter a lot, if it is perfectly ellipsoidal based on this work you can more accurately predict what will happen but if it deviates a little, things might already begin to vary. If the rock is hollow, we have learned that this will have marginal effect, rotations will be enhanced a little and so with the path oscillations and drag, but no significant regime changes are expected. If the centre of mass of the rock is different than its geometric centre rotational resonance with the vortex shedding might occur greatly increasing the rotational amplitude and drag, but this is only if the rock is rising instead of sinking!

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This highlight refers to the PhD Thesis by Antoine Cribellier (2021, Cum Laude)

Biomechanics of the capture and escape of malaria mosquitoes

Antoine Cribellier and Florian T. Muijres

Experimental Zoology Group, Wageningen University & Research

Haematophagous female mosquitoes need to interact with their hosts in order to get a blood meal necessary for egg production. Many dangerous pathogens such as the malaria parasite and the dengue virus take advantage of this mosquito–vertebrate interaction to spread themselves. This is what makes mosquitoes the most dangerous animal in the world. Malaria alone kills more than 400,000 people – mostly young children – every year (WHO, 2020), and killed many more in the past.

To get a blood meal, female mosquitoes must seek a vertebrate host (see Figure 1). For this, they can detect CO_2 and volatiles that signal the presence of a nearby host upwind (Cardé et al. 2010, Cardé 2015). Then, they will rely on visual cues to find the source of the odour plume (Van Breugel et al. 2015, Vinauger et al. 2019). Up until this point, the host-seeking flight behaviour of mosquitoes has been studied extensively, most often in wind-tunnel experiments (Kennedy 1940, Cooperland and Cardé 2006, Hawkes and Gibson 2016). Finally, mosquitoes will use additional cues, so-called short-range cues such as heat and humidity, to decide whether and where it will land (Hawkes and Gibson 2016, Beeuwkes et al. 2008. The importance of these cues is also well established but the flight dynamics of mosquitoes and the role of airflow – another important cue used by mosquitoes – in close vicinity of their hosts is still relatively poorly understood.

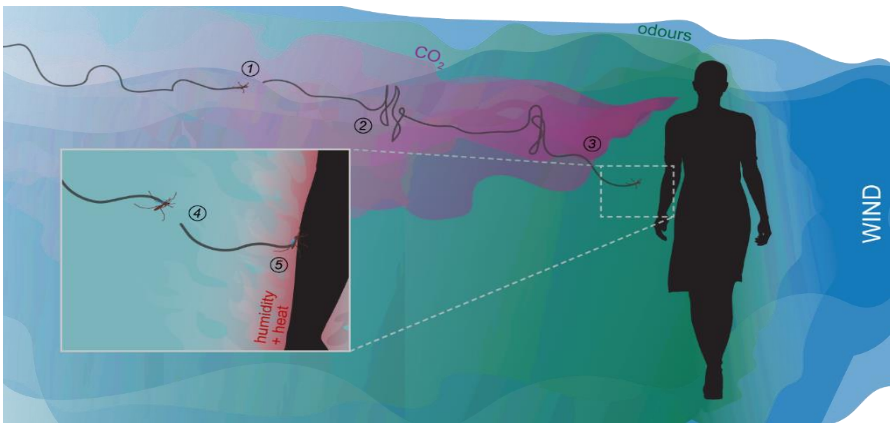

Figure 1: Infographic on how mosquitoes detect and fly towards a blood host (Cribellier 2021). (1) A flying female mosquito encounters CO_2 and odour plumes. (2) The mosquito will surge upwind and cast crosswind to find the source. (3) The mosquito will inspect visually interesting objects, and then (4) will use cues such as heat and humidity to select a spot to land (5).

Counter-flow odour-baited traps have been developed (Kline 2002, Kawada et al. 2007, Bhalala and Arias 2009). These traps use counter-flows generated by a fan to, first, diffuse a human-mimicking odour blend and CO_2, thus attracting host seeking mosquitoes in their vicinity, and second, capture mosquitoes that would have approached it by sucking them inside the trap (Kröckel et al., 2006). Until recently, odour-baited traps were exclusively used as tools for monitoring mosquito populations. However, they are now being considered as insecticide-free vector control tools that could effectively reduce mosquito populations when combined with bed nets (Homan et al., 2016).

A study was made on how mosquitoes behave around counter-flow odour-baited traps (Cribellier et al., 2018). We recorded thousands of three-dimensional flight tracks of female malaria mosquitoes (*Anopheles coluzzii*) around a well-known trap, the BG-Suna, in opposite orientations to represent two widely used traps. We visualized the average behaviour of mosquitoes and flight dynamics around the traps on two-dimensional heat maps. This allowed us to identify that mosquitoes were following stereotypical behaviours: when approaching the traps, by flying downward, and when close to the inlet of the traps, by accelerating upward. These behaviours led to very different capture dynamics of mosquitoes, and consequently to contrasting short-range attractiveness and capture mechanisms of the two traps. For example, the standing BG-Suna was more attractive than the hanging BG-Suna, while being also the only trap that triggered escape-like responses of mosquitoes.

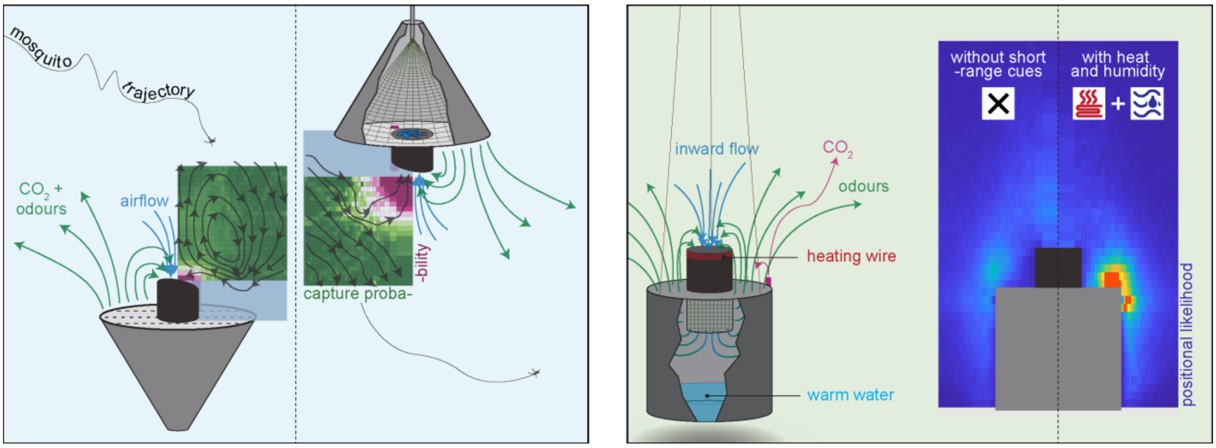

Figure 2: Graphical summary of the first (left) and second (right) studies [10]. First, we studied how flying mosquitoes behaved around an odour-baited trap either standing or hanging. Then, we tested whether adding heat and humidity to a newly designed trap resulted in improved trapping performance, and how this impacted mosquito flight behaviour.

Based on our findings, integrated with the literature, we developed a new counter-flow odour-baited trap: the M-Tego (PreMal b.v.). One specificity of this trap is that it can generate two additional host cues that have been found to attract mosquitoes at short range, namely heat and humidity. Then, we tested this new trap against the BG-Suna in laboratory and semi-field conditions (Cribellier et al., 2020). In both conditions, the M-Tego without additional short-range cues was found to capture more than twice as many malaria mosquitoes than the standing BG-Suna. And when the M-Tego generated heat and humidity, it captured around 4.5 times as many mosquitoes as the BG-Suna. By recording the flight tracks of mosquitoes around this new trap, we showed that mosquitoes are more attracted to the M-Tego and spent more time close to it when the trap generates heat and/or humidity. Additionally, we did not observe escape-like responses of mosquitoes near the M-Tego, which explains why the M-Tego captures more mosquitoes than the standing BG-Suna even when they produce the same host cues.

Following this, we focused on the escape manoeuvres of flying mosquitoes. To study those, we built a new experimental setup where mosquitoes were tracked in three dimensions and in real time

(Cribellier et al., 2022). Based on the real-time position of a mosquito, a mechanical swatter was then automatically triggered to simulate an attack towards it. This allowed us to study the escape performance of day-active and night-active mosquitoes (Aedes aegypti and An. coluzzii, respectively). For that, we recorded the flight behaviour of these two species when attacked by the swatter in four light intensities ranging from dark to overcast daylight conditions. Using Bayesian generalized linear models (B-GLM), we discovered that these mosquitoes exhibited enhanced escape performances in their respective natural light conditions (overcast for Aedes and dark for Anopheles). Furthermore, the high escape performance of Anopheles in the dark was mostly explained by its increased flight unpredictability in this light condition, whereas the higher escape performance of Aedes in overcast daylight compared with sunrise was due to its fast visually induced escapes.

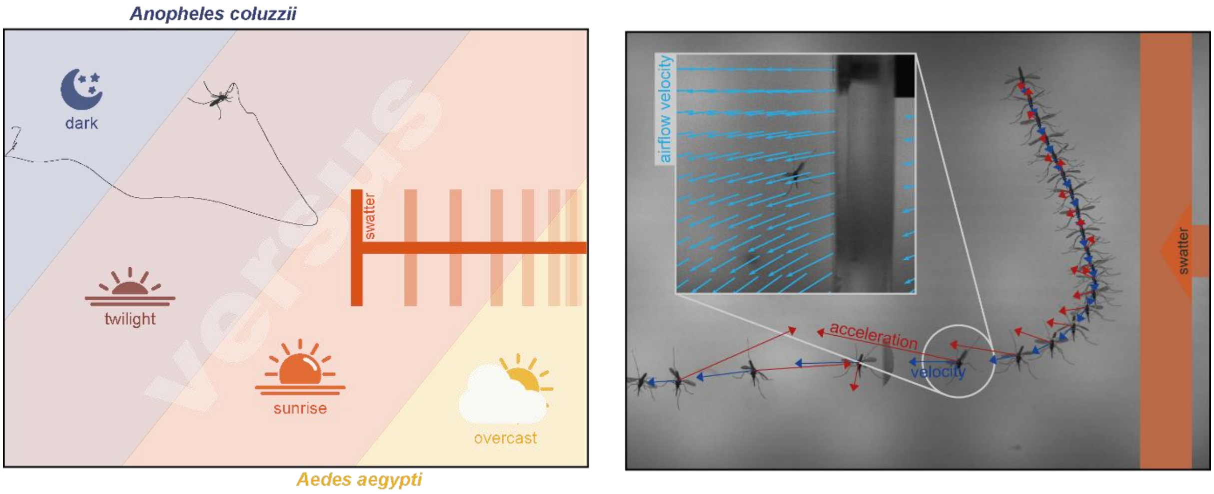

Figure 3: Graphical summary of the third (left) and forth (right) studies [10]. We investigated how the escape performance of diurnal (Aedes) and nocturnal (Anopheles) mosquitoes varied with light conditions, as well as what were their respective escaping strategies. We also examined how mosquitoes performed escape manoeuvres and what was the role of the airflow induced by the attacker in their escape success.

Finally, we zoomed in on the escape manoeuvres of *An. coluzzii* mosquitoes with the aim to understand whether they rely on the airflow induced by the attacker to escape successfully. First, we compared the escape performance of mosquitoes when attacked by either a solid or a perforated swatter, in both dark and low-light conditions. We showed that the faster the air movements induced by the attack, the fewer mosquitoes that were hit by the swatter. This demonstrates that airflow plays an important role in the escapes of these mosquitoes. However, at this point, it was still unknown whether mosquitoes are using the airflow passively or actively. Then, using high-speed video cameras (12500 fps) and a newly developed neural-network-based tracker, we recorded the kinematics of the body and wings of flying mosquitoes when escaping. By combining this with results from a CFD simulation of the airflow induced by the attack, we estimated the aerodynamic forces involved during mosquito manoeuvres. We discovered that these mosquitoes, although seemingly moving passively with the airflow, were actively moving with the bow wave induced by the swatter. Moreover, we found that, despite that mosquitoes contributed actively to most of their escape acceleration, the passive effect of the airflow also significantly contributed to their success.

Competing interests

A.C. and F.M. are part of the scientific supervisory board of PreMal b.v., but have no financial competing interests.

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This highlight refers to the PhD Thesis by Kartik Totlani (2021)

Droplet based microfluidic platforms for bioprocess engineering

Kartik Totlani[1], Michiel Kreutzer[1], Walter van Gulik[2], Volkert van Steijn[1]

[1] Department of Chemical Engineering, Faculty of Applied Sciences, TU Delft, Netherlands
[2] Department of Biotechnology, Faculty of Applied Sciences, TU Delft, Netherlands

Challenges in bioprocess development

A critical challenge during the initial stages of bioprocess development is that tools used to screen microorganisms and optimize cultivation conditions do not represent the environment imposed at the industrial scale. Inside an industrial-scale bioreactor, microorganisms are often cultivated under fed-batch conditions, where nutrients are supplied during the culture. Additionally, microorganisms continuously keep crossing zones with low and high concentrations of substrate and dissolved oxygen. However, during the initial stages of bioprocess development, growth and productivity of microorganisms are evaluated under batch conditions due to the difficulty of dynamically controlling nutrient and dissolved oxygen concentrations in screening equipment such as micotiter plates (Totlani 2021, Totlani et al. 2021a). This inconsistency in cultivation conditions often leads to selection of strains that fail to perform at industrial scale. Droplet microfluidics holds the potential to address this inconsistency with fidelity by offering high-throughput experimentation and excellent control over the culture microenvironment. Herein, we present the design and development of droplet-based microfluidic technology that enables studying of microorganisms under dynamically controlled cultivation conditions.

Droplet on demand generator

The first type of tool developed in the PhD project is a droplet-based nanobioreactor that facilitated nutrient-controlled cultivation in fed-batch mode. Since its operation needed a reliable method for supplying nutrient droplets to cell-containing droplets, a strategy for nutrient droplet generation was initially designed. As a first goal, a scalable microfluidic droplet on-demand (DoD) generator was developed for producing monodisperse water in oil microdroplets, where the droplet volume was primarily dictated by the generator geometry and was independent of operating conditions (Figure 1) (Totlani et al. 2020). The DoD generator was characterized for a range of operating conditions and flow parameters while generating droplets with a high monodispersity. By decoupling droplet formation from its transport, a reliable scale-out was achieved for the sequential generation of droplets on-demand at multiple DoD junctions in the chip (Totlani et al. 2020).

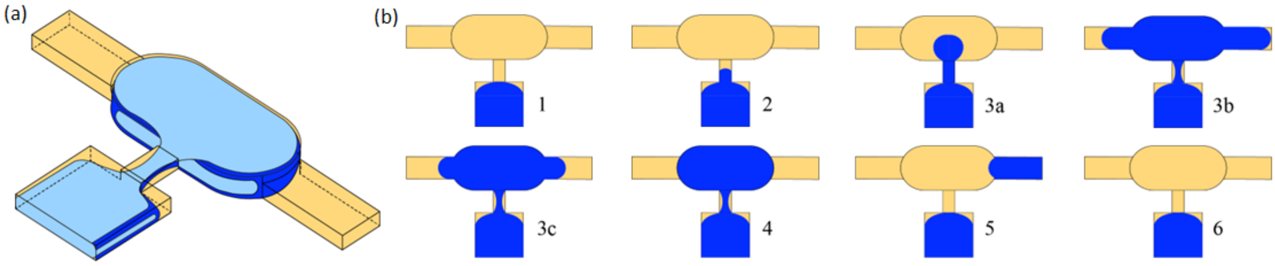

Figure 1: (a) Three-dimensional schematic and (b) working principle of microfluidic droplet on demand (DoD) generator, showing the dispersed phase steadily pressed against the nozzle (1), the dispersed phase filling the chamber (2-3c), the interfaces of the dispersed phase steadily pressed against the entrance of the main channel (4), the release of a droplet with a volume similar to the volume of the chamber into the main channel (5), after which the new interface is steadily pressed against the nozzle (6) ready for a new DoD cycle (Totlani et al. 2020, 2021b). Yellow depicts continuous oil phase and blue depicts dispersed aqueous phase.

Fed-batch droplet nanobioreactor

This DoD methodology was used to develop a microfluidic tool that enabled studying microorganisms under nutrient-controlled fed-batch conditions. The droplet-based fed-batch nanobioreactor comprised of two separate DoD generators, where the first one was used for creating droplets encapsulated with microorganisms and the second one for making nutrient droplets at the desired frequency throughout the cultivation. The nutrient droplets were chemically coalesced to the cell-containing droplet, immobilized inside a trap (Figure 2) (Totlani et al. 2020, 2021b), by temporarily de-stabilizing the droplet-droplet interface through the flow of a poor solvent around it, thereby establishing a fed-batch process. The yeast Cyberlindnera (Pichia) Jadinii was used as the model organism. Nutrient-controlled cell growth experiments as illustrated in Figure 3a were performed by varying the glucose concentration inside the nutrient droplets and by varying the frequency of droplet generation.

Nutrient controlled growth inside the droplets was established by demonstrating different cell growth rates with different glucose concentrations inside nutrient droplets. The growth behavior of the microorganisms for a different set of glucose concentrations agreed well with a simple kinetic growth model (Figure 3b) (Totlani 2021, Totlani et al. 2021b).

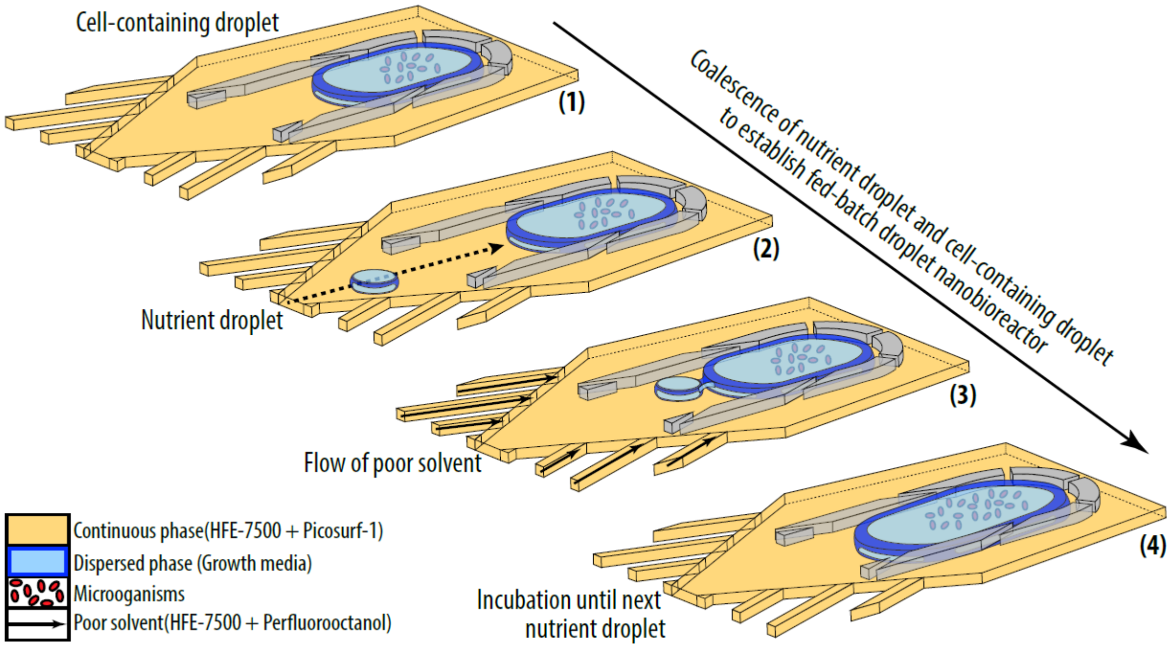

Figure 2: Microdroplet based fed-batch process-on-a-chip illustrating the controlled supply of nutrients to a cell-containing droplet. Cell-containing droplet immobilized inside a cup-shaped trap (1). On-demand supply of a nutrient-containing droplet (2). Coalescence of the surfactant-stabilized interfaces induced by temporarily injecting a solvent in which the surfactant is less soluble through the fork-like structures (3). Incubation until the next nutrient supply (4) (Totlani et al. 2020, Totlani 2021).

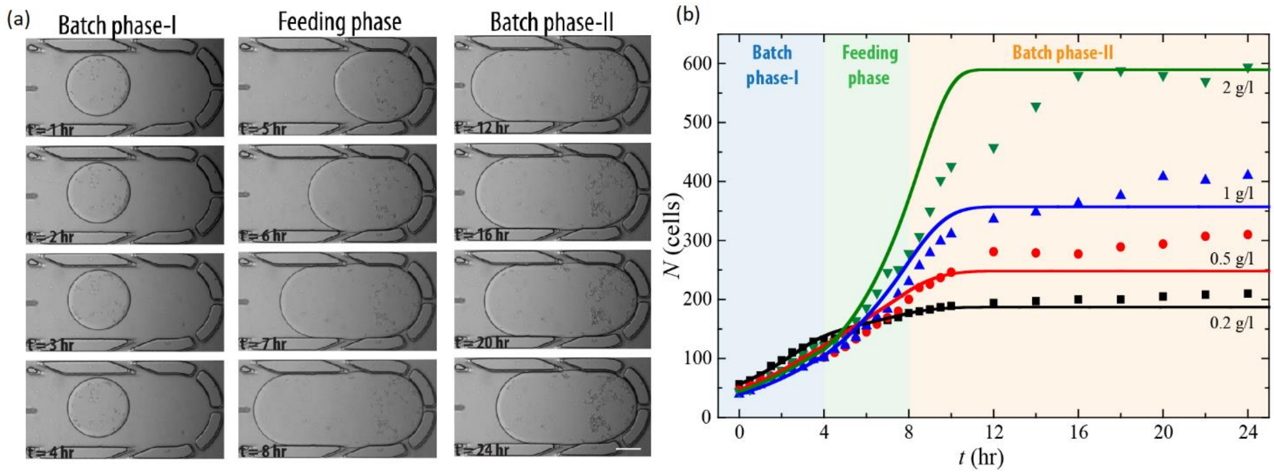

Figure 3: (a) Time lapse of grey scale images depicting nutrient controlled fed-batch growth of Cyberlindnera (Pichia) jadinii inside a fed-batch droplet nanobioreactor. (b) Growth curves for nutrient-controlled growth in the fed-batch droplet nanobioreactor fir different concentrations of glucose concentration in nutrient droplets. The effect of controlled nutrient supply is seen from the difference in the growth rates in the feeding phase (Totlani 2021, Totlani et al. 2021b).

Microdroplet static array for dissolved oxygen

The second type of microfluidic tool developed in this work enabled the cultivation of yeast inside microdroplets with the main supply of oxygen to the cells coming from the fluorinated oil flowing around the droplets (Figure 4a,b) (Totlani 2021, Totlani et al. 2021c). Batch growth of *Cyberlindnera (Pichia) Jadinii* was performed inside droplets under two limiting cases. For the first case, oil saturated with oxygen was flown around the droplets containing microorganisms, which showed exponential cell growth. In contrast, negligible growth was observed in the second case where the oil was saturated with nitrogen and flown around the droplets.

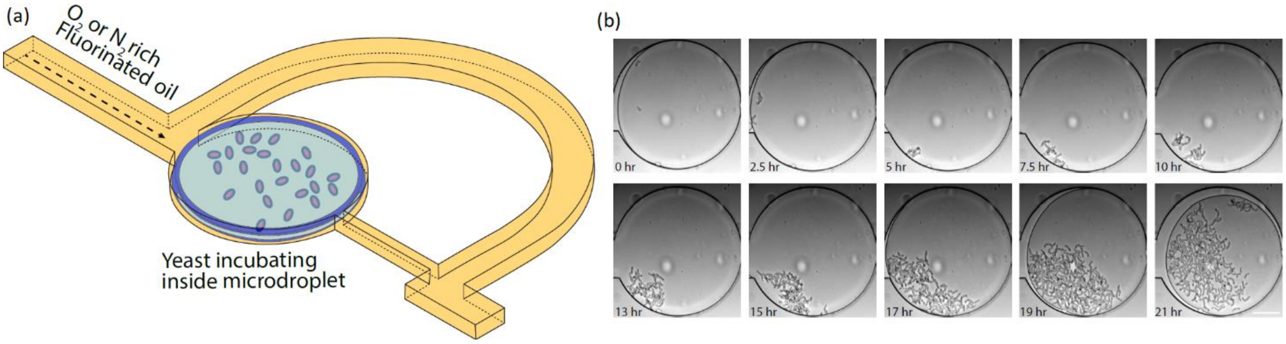

Figure 4: (a) 3D schematic of a single trap with a cell-containing droplet incubated in a growth chamber, while the supply of dissolved oxygen to the cells is controlled through the amount of oxygen dissolved into the oil phase that continuously flows around the droplet through the bypass. (b) Time lapse of grey scale images illustrating the growth of C. Jadinii inside a single microdroplet. Scale bar is 100 µm. (Totlani 2021, Totlani et al. 2021c).

The results from this work form a proof-of-concept of long-term and nutrient-controlled growth of microorganisms inside microdroplets through a controlled supply of nutrients. Diverting away from continuous droplet microfluidics which require sophisticated workflows and integration of multiple devices, a strategy that facilitated simple operation and fabrication of devices from standard procedures was developed. The results from this work form a foundation step towards narrowing the gap between screening and industrial-scale use, with an eye to keeping the technology sufficiently simple to be adopted by the biotechnology and bioengineering community.

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This highlight refers to the PhD Thesis by Evan Milacic (2021)

Liquid injection in fluidized beds

Evan Milacic, Maike Baltussen and Hans Kuipers

Eindhoven University of Technology, Department Chemical Engineering and Chemistry, Multi-scale Modelling of Multi-phase Flows

Fluidized bed reactors are gas-solid contactors which are often used in industry due to their uniform temperature profile throughout the reactor and the high solids mobility. In many industrially operated fluidized bed reactors, liquid is injected to act as reactant, as a carrier for the deposition of materials or as a cooling agent. Although the liquid has an essential role in the operation of this reactor, it also increases the complexity of the reactor drastically. The injected liquid affects the motion of the solids and thereby the bed uniformity. In addition, the liquid also increases the adhesion of the solids leading to the formation of clusters of particles and liquid, which are called wet agglomerates. The effect of the liquid injection on the temperature distribution and the hydrodynamics inside a fluidized bed were studied.

The effect of liquid injection on the bulk behaviour of the fluidized bed was studied using a combination of Particle Image Velocimetry (PIV) and Infra-Red Thermography (IRT) on a pseudo-2D bed. PIV was used to study the solids motion in the bed, while the temperature field was obtained using IRT. The pictures are taken simultaneously to enable calculation of the local solids heat flux. Figure 1 shows the local solids fraction (left) and the temperature profile (right). The probability density function of the particle temperature was determined to study the effect of the liquid injection in the bed. The experiments showed that the temperature was less uniform when small droplets were injected compared to the injection of large particles (Milacic et al., 2022a,b).

Although there is a clear correlation between the two images in Figure 1, the right image shows some low temperature spots throughout the reactor, which are the created agglomerates. The agglomeration behaviour is more pronounced when the droplets used for injecting the liquid are larger. In addition, a decrease in the solids motion, e.g., a decrease in the gas velocity, will also promote the formation of agglomerates. Although the agglomerates are very clearly visible in the IRT images, their formation is not visible in the probability density function of the particle temperature (Milacic et al., 2022a,b).

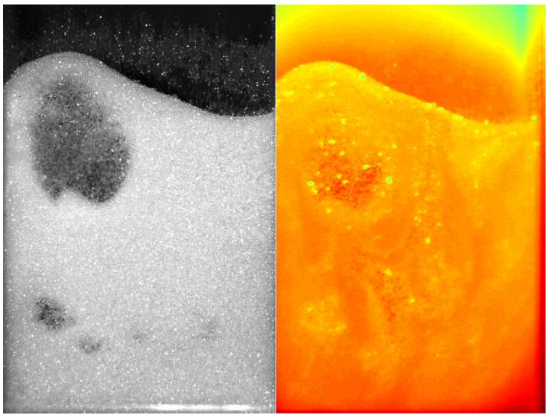

Figure 1: Fluidized bed with liquid injection from a nozzle located at the centre of the inlet plane. The left image is taken by the visual camera and the right image by the infra-red camera. The right image clearly shows the agglomerates in the bed as cold spots, which are not visible in the other image. The particles are glass Geldart B particles.

In the previous experiments, glass particles have been used to study the effect of liquid injection. However, the particles in most industrial applications are porous. Therefore, we have studied the effect of the porosity and the specific surface area of the particle on the particle temperature distribution. The results showed that the distribution of the particle temperature is mainly influenced by the specific surface area (Milacic et al., 2022c).

Besides the effect on the temperature distribution, the introduction of liquid in a fluidized bed of porous particles will also lead to the imbibition of liquid in the particles. Therefore, density driven segregation is more pronounced in the case of porous particles. The main factors that increase the density driven segregation of the particles are the porosity of the particles and a decreased solid agitation. The density segregation leads to the formation of large clusters at the bottom of the bed, which lead to defluidization of (a part of) the bed (Milacic et al., 2022c).

To obtain a better understanding on the formation of the phenomena found in the larger scale experiments, Direct Numerical Simulations are used to determine the lifetime of these agglomerates based on the evaporation of the liquid. For this specific study, the Volume of Fluid method was used to represent the gas-liquid interface, which was coupled to a second-order implicit Immersed Boundary Method of Deen et al. (2012) to represent the gas-solid interface using a static contact angle boundary conditions at the gas-liquid-solid contact line (Milacic et al., 2019).

After validation, the combined Volume of Fluid / Immersed Boundary Method was first used to study the spreading of a viscous droplet on a single particle. Compared to spreading on a flat plate, the droplet spreads less on a curved surface. The main factor determining the coverage of the solid surface by the liquid is the volume ratio of the droplet and the particle. In addition, a dimensionless droplet spreading time was determined that allows for comparison to other relevant time scales in a fluidized bed. For example, the dimensionless spreading time is generally larger than the time between collisions of particles, i.e. particles collide before the liquid of a droplet is completely spread over a surface (Milacic et al., 2019).

This study on single particles was extended to a cluster of particles to better predict the agglomerate lifetime. This lifetime is partly governed by the evaporation rate from the available gas-liquid interface in an agglomerate. Therefore, the available gas-liquid interface was studied as shown in Figure 2. In the study, it was determined that the available area largely depends on the ratio of the liquid and particle volume and the static contact angle near the interface (Milacic et al., 2020).

Figure 2 shows two identical cases from this study. Although the main physical properties are the same in these simulations, the available gas-liquid area for evaporation is much larger for the agglomerate in the left graph compared to the right graph. This difference is caused by the different random positions of the particles. Due to the effect of the particle configurations, several realization of comparable agglomerates should be investigated to enable the development of a predictive correlation of the available gas-liquid interface area in an agglomerate (Milacic et al., 2020).

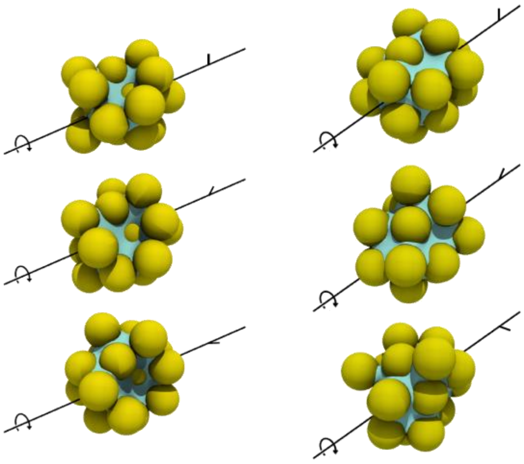

Figure 2: The distribution of the liquid droplet in an agglomerate of 19 particles, with a solids volume fraction of 55% and a static liquid contact angle of 30o (Milacic et al., 2020).

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This highlight refers to the PhD Thesis by Jie Wang (2021)

Design for high efficiency of low-pressure axial fans: use of blade sweep and vortex distribution

Jie Wang, Kees Venner, Niels Kruyt

University of Twente, Faculty of Engineering Technology, Engineering Fluid Dynamics

Fans to drive air flow are a crucial element in many processes in industry, in the built environment, and in domestic applications, on a wide range of scales. Many applications are related to heating/cooling, e.g. in processing equipment, energy conversion plants, in (computer) data-centres, in individual computers, and in air conditioning systems. Fans are part of the "family" of rotating flow equipment. The flow is generated by a set of rotating elements, referred to as blades, of particular shape, and cross section. Fans are classified (see Figure 1) according to the direction of the generated flow relative to the axis of rotation of the blades (centrifugal versus axial), the pressure difference over the fan (low versus high), the structural integration, (free or ducted), and the blade characteristics such as length of the blades relative to the central hub, the orientation of the blades relative to the straight radius from hub to top, and the shape of the blades (sweep, dihedral).

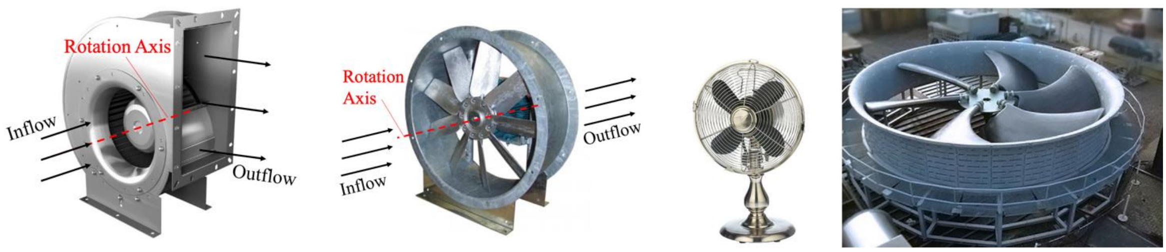


Figure 1: Examples of fans. From left to right: centrifugal fan, axial fan, free fan, ducted fan.

Increasingly strict requirements on energy losses in all processes are a strong driver for the continuous further optimization of fans, where at the same time minimizing the generated noise (environmental impact) is of increasing importance. Fan design is continuously progressing and for many cases quite adequate design criteria/rules exist using the main understanding of the various aspects of the rotating flow. However, nowadays an efficiency increase of only a few percent is already relevant, which may only be achieved by a better detailed understanding and control of the flow field locally in various regions, i.e. near the hub, or near the edges of the blade, like avoiding local backflow or flow separation, in relation to the (blade shape) design parameters.

In this research emphasis has been on the optimization of low pressure, low hub-to-tip ratio (HTR) cooling fans using Computational Fluid Dynamics (CFD) simulations by investigating the effects of sweep, dihedral and skew of the blades on the aerodynamic performance, and subsequently, to develop an optimal vortex distribution design method for high efficiency of such fans.

First the computational method was developed and its predictions were validated with results of experiments for a reference configuration of an axial fan with small HTR, see Figure 2. Secondly, extensive computations on configurations with varying blade orientation and shape were performed. Some characteristic results are shown in Figure 3.

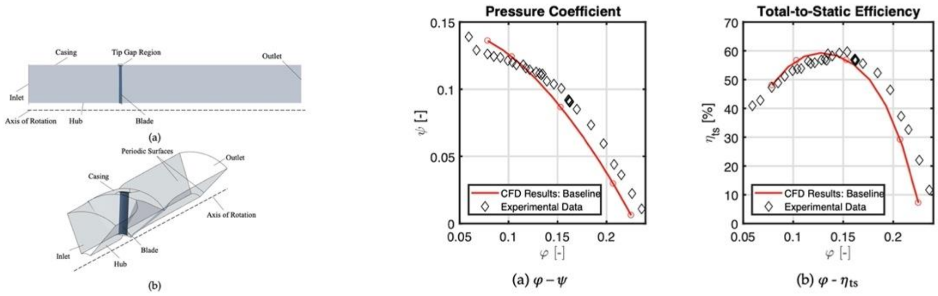


Figure 2: Computational domain in CFD (left) around fan blade, and validation result, of pressure coefficient (centre), and total to static efficiency (right), as a function of dimensionless parameter representative of volume flow.

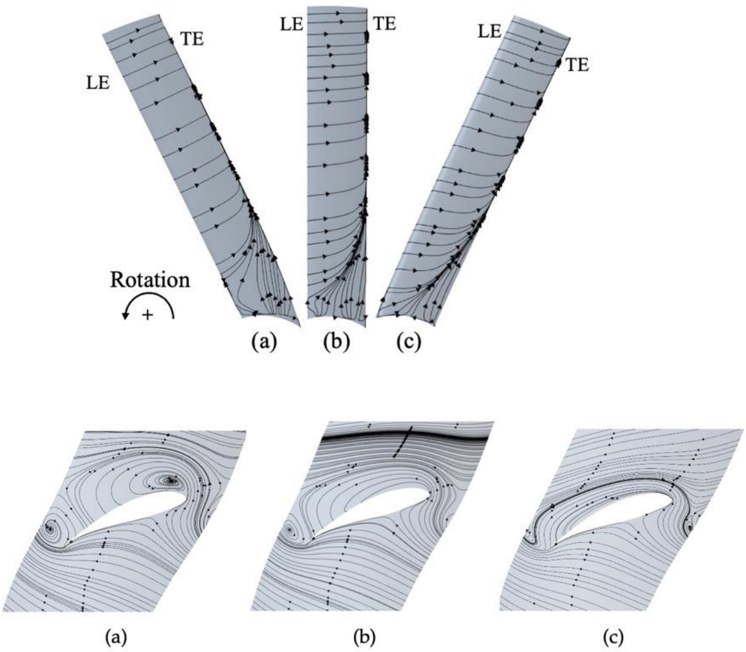


Figure 3: Top: Boundary Layer streamlines near the blade suction side surface. Bottom: velocity streamlines based on the relative velocity in the Blade-to-Blade plane at 2.5% spanwise (a) 25°Forward Sweep, (b) Baseline, and (c) 25°Backward Sweep. All for flow coefficient at Best Efficiency Point BEP. "LE" stands for Leading Edge, "TE" stands for Trailing Edge.

The CFD results have shown that forward sweep of blades can give improved aerodynamic performance, especially for the total-to-total efficiency. Effects of sweep, dihedral and skew in axial and circumferential directions (in forward and backward direction) on the aerodynamic performance of small HTR fans were also investigated, with a linear stacking line. The CFD results show that forward sweep and circumferential skew are beneficial for higher total-to-total efficiency and that higher total-to-static efficiency can be obtained by forward dihedral and axial skew. The backward shape variety generally gives detrimental aerodynamic effects. Forward sweep and circumferential skew shorten the radial migration path, but more flow separation is present near the hub. With forward dihedral and axial skew, the backflow region is reduced in radial size and axial extent, but a more significant hub corner stall region is found. The pressure reduction due to sweep and dihedral is more limited than what could be expected from wing aerodynamics.

Finally, the vortex distribution (polynomial in spanwise coordinate) and the HTR have been determined by maximizing the total-to-static efficiency of a baseline axial fan with small HTR. For free vortex designs, analytical expressions for the maximum total-to-static efficiency and the optimal HTR have been formulated. By combining the vortex distribution with a suitable choice for the spanwise lift coefficient distribution, fan blade designs have been established. The CFD results for these designs show that the free and the polynomial vortex distribution designs satisfy the desired pressure rise, with significantly improved total-to-static and total-to-total efficiency (maximum improvement by 3.9% and 4.6%, respectively). Flow field analyses show that no flow separation is present in the blade-to-blade plane, except near the hub region. For designs with small HTR, some backflow is present downstream of the rotor which affects the flow separation near the hub blade section.

Overall, the results presented in the PhD thesis contribute to better understanding of small HTR axial fan aerodynamics. The results can be applied to the design of low-pressure axial fans with higher efficiency.

Reference

Wang, J. (2021) Design for High Efficiency of Low-Pressure Axial Fans: Use of Blade Sweep and Vortex Distribution, PhD Thesis, University of Twente, Enschede, the Netherlands, ISBN 978-90-365-5299-8, DOI 10.3990/1.9789036552998

This highlight refers to the PhD Thesis by Willian Hoogendoorn (2021, Cum Laude)

Unveiling laminar-turbulent transition dynamics in particle-laden pipe flows using advanced measurement modalities

Willian Hogendoorn and Christian Poelma

Delft University of Technology, 3mE – Process & Energy, Multiphase Systems

Suspension flows are abundantly present in nature and industry. Typical examples include volcanic ash clouds, sediment transport in rivers, blood flow through human capillaries and the dredging industries. Accurate models of suspension flows are of key importance for prediction, optimization and control of particle-laden flows, especially in industrial applications. However, accurate experimental reference data is hardly available for the development and validation of these models. The opaque nature of suspension flows precludes the acquisition of quantitative flow information by means of established optical measurement techniques. Therefore, we study particle-laden flows using state-of-the-art measurement techniques, including ultrasound, magnetic resonance and optical imaging. In particular, the effect of particles (i.e., size and volume fraction) on laminar-turbulent transition in pipe flow is studied, as suspension flows exhibit a distinctly different transition scenario compared to classical, single-phase transition. The measurement modalities are used to study specific cases in this three-dimensional parameter space (i.e., particle-to-pipe diameter ratio, d/D, bulk solid volume fraction, ϕ_b, and suspension viscosity based Reynolds number, Re_s). Each case exhibits characteristic dynamics which underly particle-induced transition (Hogendoorn 2021, Hogendoorn and Poelma 2018, Hogendoorn et al. 2021, 2022). Below, a concise overview is given of the results obtained for various cases.

Velocity statistics in dilute cases using particle image velocimetry

Typical instantaneous flow fields for a particle-induced transition scenario obtained using planar particle image velocimetry (PIV) are shown in Figure 1. Note that u_x' represents the mean-subtracted streamwise velocity component and the mean flow is from left to right. For these experiments a laser light sheet is used in combination with LED back-illumination. In this configuration we are able to simultaneously measure the flow fields at a plane in pipe centre (in the stream-wise direction) and obtain the dispersed phase particles across the complete pipe. From the latter the solid volume fraction is determined. In each image three dispersed phase particles can be observed, where the particles being present in the laser plane show up as bright particles due to overexposure and the particles located outside this laser plane appear as black particles. In particular for the first case, with a suspension Reynolds number, Re_s = 1010, it can be observed that the relatively large particles cause local flow perturbations. The blue-colored vectors show that the particles cause a flow with a locally lower velocity (with respect to the mean flow velocity). This velocity deficit is compensated for at other locations, leading to strong velocity variations in a low Reynolds number pipe flow. In the transition region, Re_s = 2005, elongated flow structures can be observed, which decrease in size when turbulence prevails for higher Reynolds numbers (Hogendoorn et al., 2021).

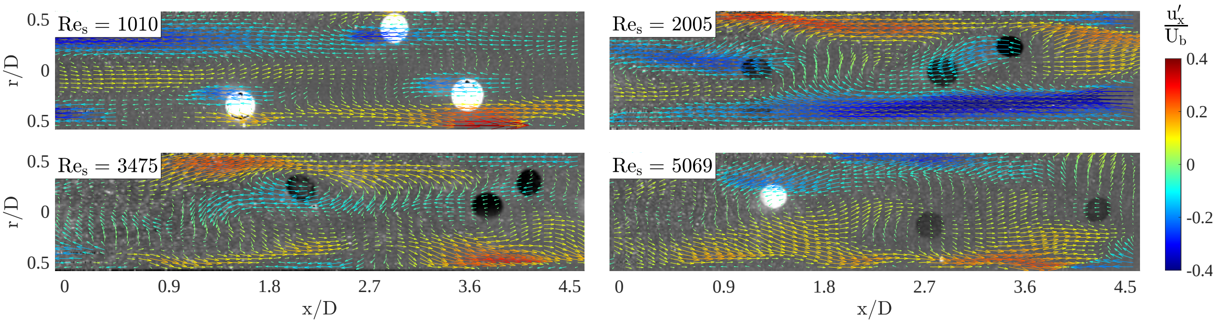


Figure 1: Instantaneous flow fields (obtained using planar particle image velocimetry) are superimposed on the corresponding camera images for a particle-induced transition scenario (d/D = 0.18, ϕ_b *= 0.0025). The vector color represents the bulk velocity normalized streamwise velocity fluctuations (*u'_x/U_b*). For low Reynolds numbers elongated flow structures can be observed, which decrease in size when turbulence prevails for higher Reynolds numbers.*

Scan the following QR codes to see movies similar to the vector fields from Figure 1:

S1 - Re = 1010

S2 - Re = 2005

S3 - Re = 4050

Flow visualizations at intermediate volume fractions using ultrasound image velocimetry

Ultrasound image velocimetry (UIV) is used to study the nature of particle-induced transition for higher volume fractions and smaller *d/D*. These results can be seen in Figure 2, where the time traces of the radial velocity component are shown for increasing Reynolds number. From the radial velocity component, the local flow perturbations can be visualized. For this specific case, ϕ_b = 0.14, it can be seen that the particles introduce flow perturbations, which gradually increase for increasing Reynolds number. Moreover, these perturbations are continuously present along the pipe, even in the transition region. This is in contrast with classical transition, where turbulent patches co-exist with a laminar flow. This UIV result reveals a gradual, particle-induced transition scenario for these conditions (Hogendoorn and Poelma, 2018).

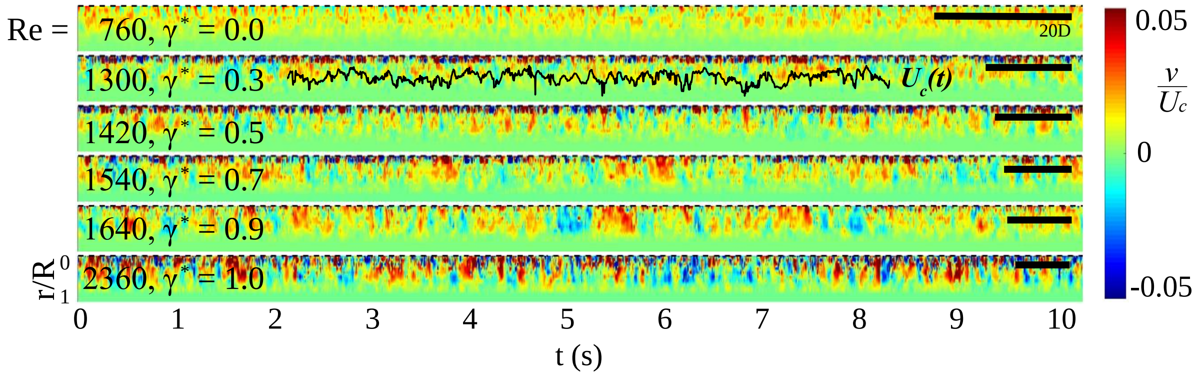


Figure 2: Typical wall-normal velocity time series for different suspension Reynolds numbers for a particle-induced transition case measured with UIV. The (radial) velocity fluctuations gradually increase for increasing Reynolds number and are continuously present along the pipe. For this case the experimental conditions are: ϕ_b = 0.14, and d/D = 0.053.

Unveiling the velocity and volume fraction distributions in dense suspensions using MRI

Magnetic resonance imaging (MRI) is used in order to shed light on the dynamics of dense suspensions. Figure 3 shows the used MRI system with the experimental facility, a typical suspension flow at a bulk solid volume fraction around, $\phi_b \approx 0.5$, captured with optical imaging and typical results in a 'frozen' experiment of particle distributions in a cross-sectional view. Simultaneous measurements of the time-averaged liquid phase velocity and the time-averaged void or solid volume fraction are obtained. Typical results for an approximate constant Reynolds number, Re_s = 2000, and increasing bulk solid volume fraction are presented in Figure 4. It can be seen that the velocity profile flattens for increasing solid volume fraction. This is explained by the particle accumulation at the pipe centre (from the bottom panel). This phenomenon is known as shear-induced particle migration. For higher volume fractions, particle rings can be observed in the vicinity of the pipe wall. Here the pipe wall acts as a restriction, which is likely responsible for this ordering. Note that the velocity profile for second case, ϕ_b = 0.08, deviates from the other cases (ϕ_b= 0, and 0.17). This explained by the corresponding solid volume fraction profile, which shows that the particles are homogeneously distributed across the pipe (not very well visible due to the current color scaling). This is in contrast with the other cases, where shear-induced migration is observed (Hogendoorn, 2021).

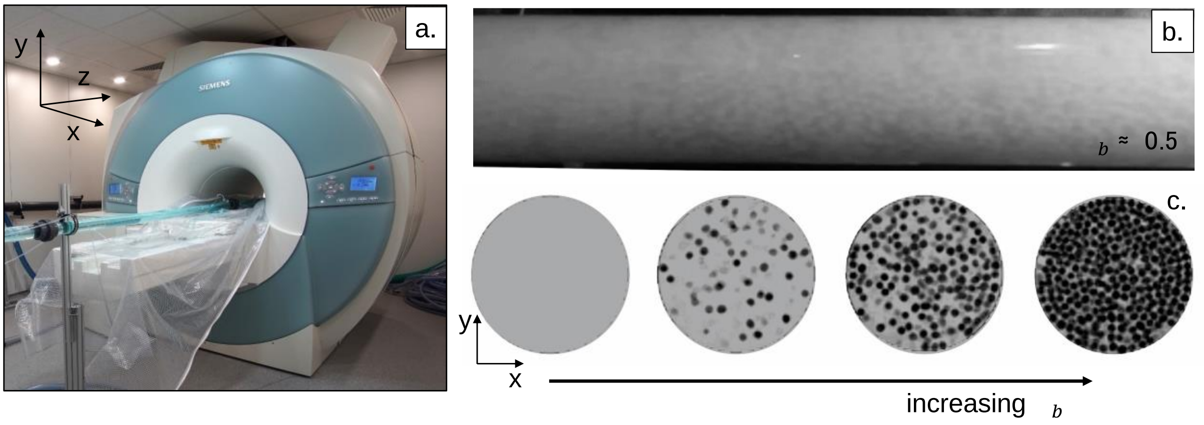


Figure 3: A 3T medical MRI scanner with the experimental facility (a), and an instantaneous camera image from the suspension flow for a dense case with a bulk solid volume fraction, $\phi_b \approx$ 0.5 and d/D = 0.058 (b). Particle distributions in the x-y plane obtained using MRI in a 'frozen' experiment for increasing solid volume fraction, up to $\phi_b \approx$ 0.5 (c).

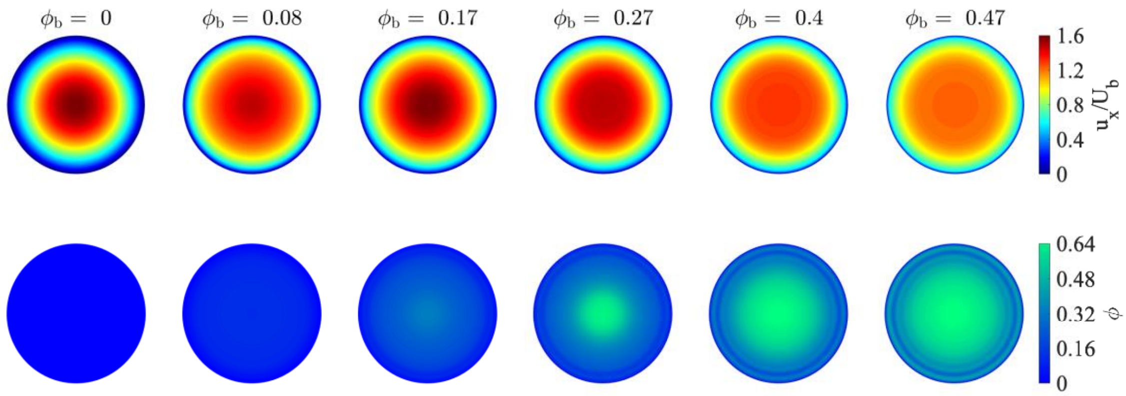


Figure 4: Normalized time-averaged streamwise velocity distributions (top panel) and corresponding time-averaged solid volume fraction distributions (bottom panel) for a constant suspension Reynolds number, $Re_s \approx$ 2000, and increasing bulk solid volume fraction obtained using MRI. The velocity profiles are found to flatten for increasing bulk solid volume fraction. For higher volume fractions, particle rings can be observed in the vicinity of the pipe wall.

Conclusion and outlook

Different measurement modalities shed light on different aspects of laminar-turbulent transition in particle-laden pipe flows. For low solid volume fractions and sufficiently large particle-to-pipe diameter ratios velocity statistics are obtained using particle image velocimetry. The particle-induced transition at higher volume fractions and smaller particle-to-pipe diameter ratios is studied using ultrasound image velocimetry. For dense suspensions, MRI measurements were performed in order to obtain average velocity and solid volume fraction profiles. This sheds light on the spatial particle distributions and the corresponding dynamics. For future work advanced MRI sequences will be used to obtain Reynolds stress tensor measurements in suspension flows.

References

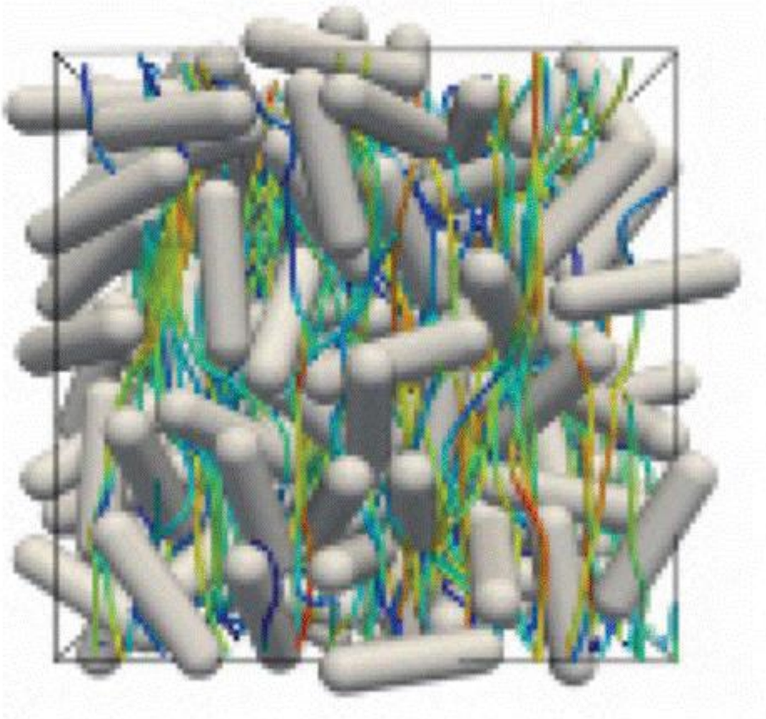
Hogendoorn, W., & Poelma, C. (2018). Particle-laden pipe flows at high volume fractions show transition without puffs. Physical Review Letters, 121, 194501. https://doi.org/10.1103/PhysRevLett.121.194501

Hogendoorn, W. J. (2021). Suspension dynamics in transitional pipe flow. PhD Thesis, Delft University of Technology. https://doi.org/10.4233/uuid:e3f9d78b-8ff0-49a7-8018-142b351ea4de

Hogendoorn, W., Chandra, B., & Poelma, C. (2021). Suspension dynamics in transitional pipe flow. Physical Review Fluids, 6, 064301. https://doi.org/10.1103/PhysRevFluids.6.064301

Hogendoorn, W., Chandra, B., & Poelma, C. (2022). Onset of turbulence in particle-laden pipe flows. Physical Review Fluids, 7, L042301. https://doi.org/10.1103/PhysRevFluids.7.L042301

PHD THESES



2021 PhD Theses

In 2021 a total of 79 PhD theses were delivered within the Burgerscentrum; Delft University of Technology (32), Eindhoven University of Technology (23), University of Twente (20), University of Groningen (1), WUR (2), Utrecht University (1). There were four “Cum Laude” PhD predicates.

The thesis defenses in chronological order in 2021 are listed below.

7 January 2021 – Said Alhaddad – *Breaching Flow Slides and the Associated Turbidity Currents*, PhD Thesis, Delft University of Technology, (Uijttewaal & Labeur).

15 January 2021 – Myrthe Bruning – *Confined and colloidal droplets*, PhD Thesis, Twente University, (Lohse & Marin).

15 January 2021 – Pieter Berghout – *Bubble formation and concentration fields in water electrolysis*, PhD Thesis, Twente University, (Lohse).

18 January 2021 – Júlia Boschán– *Transient mechanics of foams and emulsions*, PhD Thesis, Delft University of Technology, (Vlugt & Tighe).

22 January 2021 – Gonzalo Duró – *Bank erosion in regulated navigable rivers*, PhD Thesis , Delft University of Technology, (Uijttewaal & Crosato).

22 January 2021 – Pim Willemsen – *Biogeomorphology of salt marshes - Understanding the decadal salt marsh dynamics for flood defence*, PhD thesis, Twente University, (Hulscher & Bouma)

27 January 2021 – Cong Xiao – *Surrogate-assisted reservoir history matching*, PhD Thesis, Delft University of Technology, (Heemink, Lin).

3 February 2021 – Boy Van Minderhout – *Microparticle charging in spatial plasma afterglows*, PhD Thesis, Eindhoven University of Technology, (Beckers & Kroessen).

18 February 2021 – Delphine De Tavernier – *Aerodynamic advances in vertical-axis wind turbines*, PhD Thesis, Delft University of Technology, (Ferreira & Van Bussel).

12 February 2021 – Tjebbe Hepkema – *Nonlinear dynamics of tides and sandbars in tidal channels*, Utrecht University, (de Swart, Schuttelaars).

22 February 2021 – Sina Tajfirooz – *Numerical methods for dynamics of particles in magnetized liquids*, PhD Thesis, Eindhoven University of Technology, (Kuerten & Zeegers).

24 February 2021 – Gustavo Otero Rodrigues – *Computational fluid dynamics for non-conventional power cycles*, PhD Thesis, Delft University of Technology, (Pecnik & Klein).

26 February 2021 – Nakul Pande – Bubble formation and concentration fields in water electrolysis, PhD Thesis, Twente University (Lohse, Mul, Mei, Krug).

5 March 2021 – Andres J. Aguirre Guzman – *Numerical study of rapidly rotating turbulent convection*, PhD Thesis, Eindhoven University of Technology, (Clercx & Kunnen).

18 March 2021 – Carine van der Boog – *Dynamics of the Caribbean: Ocean Eddies and Thermohaline Staircases*, PhD Thesis, Delft University of Technology, (Katsman & Pietrzak).

19 March 2021 – Ignaas Jimidar – *Microsphere handling at the microscale: New tools and new effects*, PhD Thesis, University of Twente / Free University Brussel (double degree; Desmet & Gardeniers).

24 March 2021 – Sotiria Georgiou – *Boundary-interior exchanges controlling the labrador sea dynamics*, PhD Thesis, Delft University of Technology, (Katsman & Pietrzak).

26 March 2021 – Zeno Belligoli – *Numerical optimization techniques for practical problems in aerodynamics*, PhD Thesis, Delft University of Technology, (Dwight & Eitelberg).

1 April 2021 – Xiuhan Chen – *Numerical Modelling for Underwater Excavation Process: A Method Based on DEM and FVM*, PhD Thesis, Delft University of Technology, (Van Rhee & Miedema).

1 April 2021 – Emma Hinderink – *Food emulsions stabilised by blends of plant and dairy proteins*, PhD Thesis, Wageningen University & Research, (Schroën, *Berton*-Carabi, Sagis).

15 April 2021 – On Yu Dung - Scalars in bubbly turbulence, PhD Thesis, Twente University, (Lohse, Sun, Huisman).

15 April 2021 – Stephanie Veselá – Advancing *human thermo-physiological modelling: Challenges of predicting local skin temperatures during moderate activities*, PhD Thesis, Eindhoven University of Technology, (Smeulders & Frijns).

26 April 2021 – Riccardo Zamponi – *Investigation of turbulence-surface interaction noise mechanisms and their reduction using porous materials*, PhD Thesis, Delft University of Technology, (Scarano, Schram, Ragni).

10 May 2021 – David Engler Faleiros – *Soap bubbles for large-scale PIV: Generation, control and tracing accuracy*, PhD Thesis, Delft University of Technology, (Scarano & Sciacchitano).

10 May 2021 – Eriola-Sophia Shanko – *Magnetic micromixing: for point of care diagnostics*, PhD Thesis, Eindhoven University of Technology, (Toonder, Anderson, van de Burgt).

19 May 2021 – Srinidhi Nagarada Gadde – *Large eddy simulations of stratified atmospheric boundary layers and wind farms*, PhD Thesis, Twente University, (Lohse & Stevens).

21 May 2021 – Hai Jing Li – *Reactive electro-kinetic flow in complex geometries: towards a numerical approach*, PhD Thesis, Eindhoven University of Technology, (Toschi & Clercx).

1 June 2021 – Ulrich Miessner – *The flow in viscous Taylor droplets*, PhD Thesis, Delft University of Technology, (Westerweel).

14 June 2021 – Simone Silvestri – (Cum Laude) *High temperature turbulence: Coupling of radiative and convective heat transfer in turbulent flows*, PhD Thesis, Delft University of Technology, (Roekaerts & Pecnic).

17 June 2021 – Camille le Coz – *Setting Africa's rainfall straight: A warping approach to position and timing errors in rainfall estimates*, PhD Thesis, Delft University of Technology, (Van de Giesen, Heemink, A.W).

18 June 2021 – Damiano La Zara – *Atomic and molecular layer deposition for controlled drug delivery*, PhD Thesis, Delft University of Technology, (Van Ommen).

21 June 2021 – Abeethi Goyal – *Modelling demixing and structural evolution in thin films*, PhD Thesis, Eindhoven University of Technology, (Toschi & Van der Schoot).

24 June 2021 – Mike Van Meerkerk – *Variability in wave impacts: An experimental investigation*, PhD Thesis, Delft University of Technology, (Poelma & Westerweel).

1 July 2021 – Jelle Will – *Wake-induced dynamics of buoyancy-driven and anisotropic particles*, PhD Thesis, Twente University, (Lohse, Sun, Krug).

5 July 2021 – Anne Markensteijn – *Mathematical models for simulation and optimization of multi-carrier energy systems*, PhD Thesis, Delft University of Technology, (Vuik).

8 July 2021 – Ivan Girotto – *Physics of dense emulsions via high-performance fully resolved simulations*, PhD Thesis, Eindhoven University of Technology, (Toschi, Pareschi, Schifano).

13 July 2021 – Peng Wei – *Characterisation of sludge rheology and sludge mixing in gas-mixed anaerobic digesters*, PhD Thesis, Delft University of Technology, (Uijttewaal, van Lier & de Kreuk).

14 July 2021 – Alejandro Rubio Carpio – *Innovative permeable materials for broadband trailing-edge noise mitigation*, PhD Thesis, Delft University of Technology, (Snellen, Ragni, Avallone).

2 September 2021 – Cristian Carcamo Sanchez – *Numerical analysis of forward and inverse fluid mechanics problems*, PhD Thesis, University of Groningen, (Verstappen, Araya, Bertoglio).

3 September 2021 – Abimbola Ashaju – *Electrocatalytic reaction driven flows*, PhD Thesis, Twente University, (Lammertink & Wood).

9 September 2021 – Santiago Lopez Restrepo – *Ensemble-based data assimilation for high-uncertainty systems: a case of study with particulate matter in the Aburra Valley*, PhD Thesis, Delft University of Technology, (Heemink, Quintero Montoya).

10 September 2021 – Onno Kramer – *Hydraulic modelling of liquid-solid fluidisation in drinking water treatment processes*, PhD Thesis, Delft University of Technology, (Van der Hoek & Padding).

13 September 2021 – Jing Dong – *A free wake vortex model for floating wind turbine aerodynamics*, PhD Thesis, Delft University of Technology, (Watson & Viré).

15 September 2021 – Marijn Blommaert – *Ion transport mechanisms in bipolar membranes for electrochemical applications*, PhD Thesis, Delft University of Technology, (Smith & Vermaas).

15 September 2021 – Hayri Yigit Akargün – *Large Eddy Simulation of diesel spray combustion with Flamelet Generated Manifolds*, PhD Thesis, Eindhoven University of Technology, (Somers & Deen).

24 September 2021 – Xing Zheng – *Computational analysis of the impact of façade geometrical details on wind flow and pollutant dispersion*, PhD Thesis, Eindhoven University of Technology, (Blocken & Montazeri).

24 September 2021 – Binglin Zeng – *Nucleation and dynamics of bubbles/droplets in multicomponent liquids*, PhD Thesis, Twente University, (Lohse, Zandvliet, Wang).

24 September 2021 – Xiaolai Li – *Bubble nucleation and dynamics: surface micro/nanobubbles and plasmonic microbubbles*, PhD Thesis, Twente University, (Lohse, Zandvliet, Wang).

27 September 2021 – Mauro Michele Campagna – *Experimental study of carrier gas and pressure effects on homogeneous water nucleation*, PhD Thesis, Eindhoven University of Technology, (Smeulders, Van Dongen, Hrubý).

29 September 2021 – Annekatrien Daalmans – *Towards an NMR multiphase flowmeter: Method development and performance evaluation for two-phase flow measurements*, PhD Thesis, Delft University of Technology, (Mudde & Portela).

6 October 2021 – Akshay Koodly Ravishankara – *Development of a pressure based incompressible flow solver for wind turbine applications*, PhD Thesis, University of Twente (Venner, v.d. Weide, Özdemir).

8 October 2021 – Yu-Hsuan Juan – *Analysis of urban wind energy potential around high-rise buildings in close proximity using computational fluid dynamics*, PhD Thesis, Eindhoven University of Technology & Taipei Tech, (Blocken & Montazeri).

8 October 2021 – Qiyao Peng – *Mathematical aspects of cell-based and agent-based modelling for skin contraction after deep tissue injury*, PhD Thesis, Delft University of Technology, (Vermolen & Vuik).

11 October 2021 – Antoine Cribellier – (Cum Laude) *Biomechanics of flying mosquitoes during capture and escape*, PhD Thesis, Wageningen University & Research, (Van Leeuwen, Muijres, Spitzen).

21 October 2021 – Roel Tielen – *P-multigrid methods for Isogeometric analysis*, PhD Thesis, Delft University of Technology, (Vuik & Möller).

21 October 2021 – Kartik Totlani – *Droplet microfluidics for bioprocess engineering*, PhD Thesis, Delft University of Technology, (Kreutzer, Gulik, Van Steijn).

29 October 2021 – Michiel Hack – *Wetting and coalescence: beyond single-phase flows*, PhD Thesis, Twente University, (Snoeijer & Segers).

3 November 2021 – Maarten Klapwijk – *Towards predicting cavitation noise using scale-resolving simulations: The importance of inflow turbulence*, PhD Thesis, Delft University of Technology, (Van Terwisga and Westerweel).

4 November 2021 – Alessandro Batistella – *Hydrodynamics, Mass Transfer and Phase Transition in Bubbly Flows*, PhD Thesis, Eindhoven University of Technology, (Van Sint Annaland & Roghair).

8 November 2021 - Tim Nijssen – *Dynamic behaviour of liquid-solid systems: Modelling and experiments applied to the blast furnace hearth*, PhD Thesis, Eindhoven University of Technology, (Kuipers & Buist).

11 November 2021 – Steven Kaptein – *Reproducing estuarine processes with direct numerical simulations in horizontally periodic domains*, PhD Thesis, Eindhoven University of Technology, (Clercx, Armenio, Duran Matute).

19 November 2021 – Venditti, Gianmarco – *The impact of surfactants on ink imbibition in inkjet printing*, PhD Thesis, Eindhoven University of Technology, (Darhuber & Harting).

23 November 2021 – Vignesh Murali – The physics of ink-jet printing onto thin porous substrates, PhD Thesis, Eindhoven University of Technology, (Darhuber & Zeegers).

25 November 2021 – Luca Vialetto – (Cum Laude) Modelling of plasmas for CO2 conversion: electron kinetics, chemistry and transport, PhD Thesis, Eindhoven University of Technology, (Van Dijk & Van de Sande).

26 November 2021 – Rik Dellaert – *Turbulence and particle behavior in a magnetic density separation application: Studied with LDV, PIV & PTV*, PhD Thesis, Eindhoven University of Technology, (Darhuber, Kuerten, Zeegers).

30 November 2021 – Aromal Vasavan – *Numerical modeling of igniting non-premixed combustion systems using FGM*, PhD Thesis, Eindhoven University of Technology, (Van Oijen & De Goey).

2 December 2021 – Jessica Strickland – *Modelling wakes and blockage in large scale wind farms*, PhD Thesis, Twente University, (Lohse & Stevens).

2 December 2021 – Ricardo Arturo Lopez de La Cruz – *Physicochemical hydrodynamics of binary and ternary liquids*, PhD Thesis, Twente University, (Lohse & Zhang).

2 December 2021 – Matthijs Gensen – *Discharge and water level uncertainty in bifurcating rivers*, PhD Thesis, Twente University, (Hulscher).

9 December 2021 – SeyyedMousa HosseiniMehr – *Scalable simulation models for fractured porous media with complex geometries*, PhD Thesis, Delft University of Technology, (Vuik, Hajibeygi).

9 December 2021 – Aad Vijn – *Development of a closed-loop degaussing system: Towards magnetic unobservable vessels*, PhD Thesis, Delft University of Technology, (Heemink, Van Gijzen, Dubbeldam).

9 December 2021 – Beybin Ilhan – *Role of Surface Roughness in Colloidal Dynamics of Dense Suspensions*, PhD Thesis, Twente University, (Mugele, Duits, Luding).

13 December 2021 – Evan Milacic – *Studying liquid injection in fluidised beds through simulations and experiments*, PhD Thesis, Eindhoven University of Technology, (Kuipers & Baltussen).

15 December 2021 – Willian Hogendoorn – (Cum Laude) *Suspension dynamics in transitional pipe flow*, PhD Thesis, Delft University of Technology, (Poelma & Breugem).

15 December 2021 – Jie Wang – Design *for high efficiency of low-pressure axial fans: use of blade sweep and vortex distribution*, PhD Thesis, Twente University, (Venner & Kruyt).

16 December 2021 – Weiqiu Chen – *The influence of berms, roughness and oblique waves on wave overtopping at dikes*, PhD Thesis, Twente University, (Hulscher).

16 December 2021 – Sachin Nair – *Fast and non-invasive Raman imaging of material distributions at interfaces*, PhD Thesis, Twente University, 16 December 2021 (Mugele).

17 December 2021 – Koen Heijmans – *Thermochemical storage materials: advances in molecular modeling and applications*, PhD Thesis, Eindhoven University of Technology (Smeulders & Gaastra-Nedea).

23 December 2021 – Andrei Kozhevnikov – *Towards sensing and controlling of the liquid surface topography in stereolitography*, PhD Thesis, Eindhoven University of Technology, (Clercx & Kunnen).

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

Delft University of Technology

Faculty Mechanical Maritime and Material Engineering (3mE)

Department Process & Energy

Energy Technology (TUD-3mE-ET)

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

Group's research areas

- Turbulent heat and mass transfer
- Non-ideal fluid dynamics (supercritical fluids)
- Turbomachinery and rotating equipment
- Large scale numerical simulations (GPGPU)

Grant obtained in 2021

- RVO/NWO

Project started in 2021

- RVO kickstart

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

Other 2021 highlights

- Asif Hasan won Tata Steel prize from the Royal Dutch Society of Sciences for the best MSc thesis
- Dr. Simone Silvestri graduated cum laude, among the top 5 finalists of the Da Vinci best fluid mech ERCOFTAC award.

PhD theses delivered in 2021

- 24 February 2021 – Gustavo Otero Rodrigues – *Computational fluid dynamics for non-conventional power cycles*, PhD Thesis, Delft University of Technology, (Pecnik & Klein).
- 14 June 2021 – Simone Silvestri – (Cum Laude) *High temperature turbulence: Coupling of radiative and convective heat transfer in turbulent flows*, PhD Thesis, Delft University of Technology, (Roekaerts & Pecnic).

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	Assistant 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

Projects started in 2021

- Covid-PIVOT (NWO Take-Off Phase 1 / 18866): Greidanus, Oldenziel, Westerweel
- HyProRow - Hydrodynamics & Propulsion in Rowing (ZonMW): Greidanus, Westerweel
- FlexFloat (NWO-TTW OTP 19002): Schreier (MTT/3mE/TUD) et al.

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)

PhD theses delivered in 2021

- 1 June 2021 – Ulrich Miessner – *The flow in viscous Taylor droplets*, PhD Thesis, Delft University of Technology, (Westerweel).
- 24 June 2021 – Mike Van Meerkerk – *Variability in wave impacts: An experimental investigation*, PhD Thesis, Delft University of Technology, (Poelma & Westerweel).
- 3 November 2021 – Maarten Klapwijk – *Towards predicting cavitation noise using scale-resolving simulations: The importance of inflow turbulence*, PhD Thesis, Delft University of Technology, (Van Terwisga and 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. Angeliki Laskari	Assistant prof.
Dr. B.P. Tighe	Assistant prof.

Group's research areas

- Flow of dense suspensions
- Flow measurement techniques for multiphase systems
- Rheology
- (Transition to) Turbulence in multiphase systems

Project started in 2021

- Floating particle transport in turbulent flows

Collaboration with other groups (inside or outside Burgerscentrum)

- Flow measurements using Magnetic Resonance Imaging (with University of Rostock)
- Urban Flow and Climate – large scale simulations for climate modeling (with CITG, TU Delft)

Other 2021 highlight

- "Suspension dynamics in transitional pipe flow" Hoogendoorn et al. (2021) – Editors' Suggestion in Physical Review Fluids

PhD theses delivered in 2021

- 18 January 2021 – Júlia Boschán– *Transient mechanics of foams and emulsions*, PhD Thesis, Delft University of Technology, (Vlugt & Tighe).
- 24 June 2021 – Mike Van Meerkerk – *Variability in wave impacts: An experimental investigation*, PhD Thesis, Delft University of Technology, (Poelma & Westerweel).
- 15 December 2021 – Willian Hogendoorn – (Cum Laude) *Suspension dynamics in transitional pipe flow*, 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 polydispersed suspensions
- Spray drying of 2D materials and rheology of complex fluid interfaces

Grant obtained in 2021

- RVO Mobility grant "SH2IPDRIVE"

Projects started in 2021

- Multi-channel Capacitive Deionization for the targeted removal of ionic contaminants
- Hydrodynamic drag, lift and torque correlations for ellipsoidal particles
- E-sponge: Electrocapillary based separation of emulsions
- Continuous electrochemical separation of formate ions from CO2 electrolysis with electrochemical swing adsorbtion
- Battery recycling with eutectic freeze crystallization
- Battery recycling by crushing and slurry fractionation
- Spray drying of 2D materials for surface area enhancement in catalysis
- Smart fractionation of poly-dispersed particulate suspensions

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)
- Viscoelastic Droplet Collisions, 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, 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 2021

- 10 September 2021 – Onno Kramer – *Hydraulic modelling of liquid-solid fluidisation in drinking water treatment processes*, PhD Thesis, Delft University of Technology, (Van der Hoek & Padding).

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. 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.

Group's research areas

- Ship hydromechanics
- Cavitation, phase transition
- Multiphase flow

Projects started in 2021

- NWO: Flexfloat- Efficient hydroelastic loading and response modelling of Very Flexible Floating Structure, dr.-ing. S. Schreier
- NWO: Lift Control for hydrofoil craft, dr.ir. I. Akkerman
- NWO: Fusie: Slimme detective voor intelligent onderhoud & Geoptimaliseerd ontwerp van marineschepen
- CISCON-Cavitation inception Speed Control, Prof.dr.ir. T.J.C. Van Terwisga

Collaboration with other groups inside and outside the Burgerscentrum

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

PhD thesis delivered in 2021

- 3 November 2021 – Maarten Klapwijk – *Towards predicting cavitation noise using scale-resolving simulations: The importance of inflow turbulence*, PhD Thesis, Delft University of Technology, (Van Terwisga and Westerweel).

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

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

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 2021

- 1 April 2021 – Xiuhan Chen – *Numerical Modelling for Underwater Excavation Process: A Method Based on DEM and FVM*, PhD Thesis, Delft University of Technology, (Van Rhee & Miedema).

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

Projects started in 2021

- Electrically switchable Reverse Osmosis (RO) membrane (PhD candidate Qi An)
- Heat transfer in electrolysis (PhD candidate Jan-Willem Hurkmans)

Collaboration with other groups (inside or outside Burgerscentrum)

- 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 Mecanique des Fluides de Toulouse (IMFT), France.
- Computation for Rational Design of Bioreactors: collaboration with Department of Biotechnology, Delft University of Technology (TUDelft).
- 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 Embriology; 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 2021 highlights

- Harrie van den Akker was the William R. Kenan Jr. Visiting Professor for Distinguished Teaching at Princeton University
- Valeria Garbin was appointed Associate Editor for the International Journal of Multiphase Flow.

PhD theses delivered in 2021

- 15 September 2021 – Marijn Blommaert – *Ion transport mechanisms in bipolar membranes for electrochemical applications*, PhD Thesis, Delft University of Technology, (Smith & Vermaas).
- 29 September 2021 – Annekatrien Daalmans – *Towards an NMR multiphase flowmeter: Method development and performance evaluation for two-phase flow measurements*, PhD Thesis, Delft University of Technology, (Mudde & Portela).

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	Assistant 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 2021

- Rapid diagnosis of stroke using hydrogel-based detection of circulating RNAs – towards a diagnostic point-of-care tool for in-ambulance use. Funded by Delft Health Initiative.

Projects started in 2021

- Rapid diagnosis of stroke using hydrogel-based detection of circulating RNAs – towards a diagnostic point-of-care tool for inambulance use. P. Quax / J. van Esch / Y. Nossent / N. Kruyt / V. van Steijn
- Isolation of circulating tumor cells from patient samples on a chip (P. Boukany, funded by ZonMW project via collaboration with LUMC)

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 2021

- 18 June 2021 – Damiano La Zara – *Atomic and molecular layer deposition for controlled drug delivery*, PhD Thesis, Delft University of Technology, (Van Ommen).
- 21 October 2021 – Kartik Totlani – *Droplet microfluidics for bioprocess engineering*, PhD Thesis, Delft University of Technology, (Kreutzer, Gulik, Van Steijn).

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. Deepesh Toshniwal	Assistant prof.
Dr. ir. Matthias Möller	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

Grant obtained in 2021

- NWO Veni Grant Deepesh Toshniwal

Other 2021 highlight

- Start of the DelftBlue supercomputer: https://www.tudelft.nl/dhpc/

PhD theses delivered in 2021

- 5 July 2021 – Anne Markensteijn – *Mathematical models for simulation and optimization of multi-carrier energy systems*, PhD Thesis, Delft University of Technology, (Vuik).
- 8 October 2021 – Qiyao Peng – *Mathematical aspects of cell-based and agent-based modelling for skin contraction after deep tissue injury*, PhD Thesis, Delft University of Technology, (Vermolen & Vuik).
- 21 October 2021 – Roel Tielen – *P-multigrid methods for Isogeometric analysis*, PhD Thesis, Delft University of Technology, (Vuik & Möller).
- 9 December 2021 – SeyyedMousa HosseiniMehr – *Scalable simulation models for fractured porous media with complex geometries*, PhD Thesis, Delft University of Technology, (Vuik, Hajibeygi).

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. Arnold Heemink	Full prof.
Prof. dr. ir. Henk Schuttelaars	Full prof.
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

Project started in 2021

- Project started on Evolutionary Game Theory on networks

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)

PhD theses delivered in 2021

- 27 January 2021 – Cong Xiao – *Surrogate-assisted reservoir history matching*, PhD Thesis, Delft University of Technology, (Heemink, Lin).
- 12 February 2021 – Tjebbe Hepkema – *Nonlinear dynamics of tides and sandbars in tidal channels*, Utrecht University, (de Swart, Schuttelaars).
- 17 June 2021 – Camille le Coz – *Setting Africa's rainfall straight: A warping approach to position and timing errors in rainfall estimates*, PhD Thesis, Delft University of Technology, (Van de Giesen, Heemink, A.W).
- 9 September 2021 – Santiago Lopez Restrepo – *Ensemble-based data assimilation for high-uncertainty systems: a case of study with particulate matter in the Aburra Valley*, PhD Thesis, Delft University of Technology, (Heemink, Quintero Montoya).
- 9 December 2021 – Aad Vijn – *Development of a closed-loop degaussing system: Towards magnetic unobservable vessels*, PhD Thesis, Delft University of Technology, (Heemink, Van Gijzen, Dubbeldam).

Delft University of Technology

Faculty of Aerospace Engineering

Department Aerodynamics, Wind Energy, Flight Performance and Propulsion

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. 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. Andrea Sciacchitano	Assistant prof.
Dr. ir. Woutijn Baars	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 2021

- TU Delft: AI for Fluid Dynamics Lab (AIFluids)
- NWO: OTP ECoProp (ecological self-monitoring composite propeller)
- PRACE: INSULATE, 1mio Core Hours on Piz Daint

Projects started in 2021

- Real-time control of wall-bounded turbulence for drag reduction

- Passive control of shock-wave / boundary-layer interactions
- Data-driven surrogate modelling of porous media effect for trailing edge noise mitigation
- AI-based flow control for transition delay
- PIV for industrial wind tunnels
- On-site car aerodynamics measurements
- Robotic PIV for automotive aerodynamics

Collaboration with other groups (inside or outside Burgerscentrum)

- Iso-geometric methods: TU Delft / Mathematics
- Sports aerodynamics: TU Delft / 3ME / Fluid Mechanics
- COVID related research: TU Delft / 3mE
- 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

Other 2021 highlights

- On-site aerodynamic measurements performed via the Ring of Fire system both for ice-skating (Thialf ice rink in the Netherlands) and for automotive (Volkswagen proving ground)
- Plenary talk at the 19th International symposium of Flow Visualisation: Quantitative 3D Visualisation of Fluid-Structures Interactions by PIV
- Keynote lecture at the 2nd HiFiLED conference: Wall modelling in Large Eddy Simulations

PhD theses delivered in 2021

- 26 March 2021 – Zeno Belligoli – *Numerical optimization techniques for practical problems in aerodynamics*, PhD Thesis, Delft University of Technology, (Dwight & Eitelberg).

- 26 April 2021 – Riccardo Zamponi – *Investigation of turbulence-surface interaction noise mechanisms and their reduction using porous materials*, PhD Thesis, Delft University of Technology, (Scarano, Schram, Ragni).
- 10 May 2021 – David Engler Faleiros – *Soap bubbles for large-scale PIV: Generation, control and tracing accuracy*, PhD Thesis, Delft University of Technology, (Scarano & Sciacchitano).

Delft University of Technology

Faculty of Aerospace Engineering

Department Aerodynamics, Wind Energy, Flight Performance and Propulsion

Wind Energy (TUD-AE-WE)

Prof. dr. Damiano Casalino	Full prof.
Dr. Daniele Ragni	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 2021

- NWO KIC Holi-Doctor: Holi-DOCTOR: Holistic framework for DiagnOstiCs and moniTORing of wind turbine blades
- NWO Take Off 1-2 for Mutek Company on noise reduction technologies
- COLOSSUS project, H2020 call with leading partner DLR for developing digital aviation technologies for new aviation business models, services, including emergency missions for treatment of wild-fires.

Projects started in 2021

- GARTEUR project, for the benchmarking of airfoil for trailing edge noise and propeller blades in multi-rotor and isolated configuration
- Task39 and Anechoic Wind-Tunnel Benchmarking, for trailing edge noise characterization with NACA63018 cross-comparison in different facilities.

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).

Other 2021 highlights

- Filed 2 new patents, with new single and multi-layered materials for trailing edge noise, mimicking the flow communication with high aerodynamic performance of bird's wings.
- Demonstrated the applicability of porous materials in a permeable flap in an industrial demonstrator at DNW.

PhD theses delivered in 2021

- 18 February 2021 – Delphine De Tavernier – *Aerodynamic advances in vertical-axis wind turbines*, PhD Thesis, Delft University of Technology, (Ferreira & Van Bussel).
- 26 April 2021 – Riccardo Zamponi – *Investigation of turbulence-surface interaction noise mechanisms and their reduction using porous materials*, PhD Thesis, Delft University of Technology, (Scarano, Schram, Ragni).
- 14 July 2021 – Alejandro Rubio Carpio – *Innovative permeable materials for broadband trailing-edge noise mitigation*, PhD Thesis, Delft University of Technology, (Snellen, Ragni, Avallone).
- 13 September 2021 – Jing Dong – *A free wake vortex model for floating wind turbine aerodynamics*, PhD Thesis, Delft University of Technology, (Watson & Viré).

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. Julie Pietrzak	Full prof.
Prof. dr. ir. Ad Reniers	Full prof.
Dr. ir. Claire Chassagne	Associate prof.
Dr. Ton den Bremer	Associate prof.
Dr. Caroline Katsman	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

Grant obtained in 2021

- Can floating plastic pollution be observed by satellites through wave damping?, European Space Agency, TU Delft (Ton van den Bremer)

Project started in 2021

- Delta Transport Processes Laboratory, TU Delft (Ton van den Bremer)

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
- 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 2021

- 7 January 2021 – Said Alhaddad – *Breaching Flow Slides and the Associated Turbidity Currents*, PhD Thesis, Delft University of Technology, (Uijttewaal & Labeur).
- 22 January 2021 – Gonzalo Duró – Bank erosion in regulated navigable rivers, PhD Thesis, Delft University of Technology, (Uijttewaal & Crosato).
- 18 March 2021 – Carine van der Boog – *Dynamics of the Caribbean: Ocean Eddies and Thermohaline Staircases*, PhD Thesis, Delft University of Technology, (Katsman & Pietrzak).
- 24 March 2021 – Sotiria Georgiou – *Boundary-interior exchanges controlling the labrador sea dynamics*, PhD Thesis, Delft University of Technology, (Katsman & Pietrzak).
- 13 July 2021 – Peng Wei – *Characterisation of sludge rheology and sludge mixing in gas-mixed anaerobic digesters*, PhD Thesis, Delft University of Technology, (Uijttewaal, van Lier & de Kreuk)

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. Matias Duran Matute	Assistant prof.
Dr. Alessandro Corbetta	Assistant prof.
Dr. ir. Hanneke Gelderblom	Assistant prof.
Dr. ir. Rudie Kunnen	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 2021

- Fundamental Fluid Dynamics Challenges in Inkjet Printing Phase II (FIP2 grant; Toschi & Darhuber)
- SRCrowd: Individual and collective agency in Socially Responsible nudging of Crowds (Toschi & Corbetta)
- Machine Learning for the complex response of the Wadden Sea (OpenSSI 2021 grant; Duran Matute)

Projects started in 2021

- The physics of inkjet printing – fast multicomponent transport in porous media (Darhuber; PhD: Karimnejad)
- Plasma-induced flow in the liquid phase (Gelderblom & Sobota; PhD: Ryan)
- Understanding mitigation measures for salt intrusion (Duran Matute & Clercx; PhD: Kaveripuram Ramasamy)
- Magnetic particles in turbulence: numerics (Toschi, Clercx & Kunnen; PhD: Abdulrazaq)

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), 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)
- “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

Other 2021 highlights

- IG-Nobel prize in Physics for the study of pedestrian flows (Corbetta & Toschi)
- “How to unloop a self-adherent sheet”, Wilting, Essink, Gelderblom & Snoeijer, EPL 134 (2021)
- "How do people go with the flow?", Corbetta, Universiteit van Nederland - Online public lecture (https://www.youtube.com/watch?v=iEOUgUKFMTs)

PhD theses delivered in 2021

- 5 March 2021 - Andres J. Aguirre Guzman – *Numerical study of rapidly rotating turbulent convection*, PhD Thesis, Eindhoven University of Technology, (Clercx & Kunnen).
- 21 May 2021 – Hai Jing Li – *Reactive electro-kinetic flow in complex geometries: towards a numerical approach*, PhD Thesis, Eindhoven University of Technology, (Toschi & Clercx).

- 21 June 2021 – Abeethi Goyal – *Modelling demixing and structural evolution in thin films*, PhD Thesis, Eindhoven University of Technology, (Toschi & Van der Schoot).
- 8 July 2021 – Ivan Girotto – *Physics of dense emulsions via high-performance fully resolved simulations*, PhD Thesis, Eindhoven University of Technology, (Toschi, Pareschi, Schifano).
- 11 November 2021 – Steven Kaptein – *Reproducing estuarine processes with direct numerical simulations in horizontally periodic domains*, PhD Thesis, Eindhoven University of Technology, (Clercx, Armenio, Duran Matute).
- 19 November 2021 – Venditti, Gianmarco – *The impact of surfactants on ink imbibition in inkjet printing*, PhD Thesis, Eindhoven University of Technology, (Darhuber & Harting).
- 23 November 2021 – Vignesh Murali – The physics of ink-jet printing onto thin porous substrates, PhD Thesis, Eindhoven University of Technology, (Darhuber & Zeegers).
- 26 November 2021 – Rik Dellaert – *Turbulence and particle behavior in a magnetic density separation application: Studied with LDV, PIV & PTV*, PhD Thesis, Eindhoven University of Technology, (Darhuber, Kuerten, Zeegers).
- 23 December 2021 – Andrei Kozhevnikov – *Towards sensing and controlling of the liquid surface topography in stereolitography*, PhD Thesis, Eindhoven University of Technology, (Clercx & Kunnen).

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)

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

Projects started in 2021

- Plasma-induced flow in the liquid phase (Sobota (PI) and Gelderblom; PhD: Ryan)
- Disinfection WASPD: Water, Air, Spray. Purification and Dispersion (Sobota, PhD: Petković)

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 2021

- 3 February 2021 – Boy Van Minderhout – *Microparticle charging in spatial plasma afterglows*, PhD Thesis, Eindhoven University of Technology, (Beckers & Kroessen).
- 25 November 2021 – Luca Vialetto – (Cum Laude) Modelling of plasmas for CO2 conversion: electron kinetics, chemistry and transport, PhD Thesis, Eindhoven University of Technology, (Van Dijk & Van de Sande).

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 Azahara Luna-Triguero	Assistant prof.

Group's research areas

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

Grant obtained in 2021

- Making Digital Material Technologies a practical reality for sustainable utilisation of porous materials, Veni 2021 grant (Recipient: Rücker)

Projects started in 2021

- Sorption Heat & Cold in District Heating Networks- HeCoNet (Camilo Rindt)
- THIO (The Heat Is On) – MOOI 42009 RVO EZ-kaderregeling (David Smeulders)
- Making digital rocks a practical reality for energy storage within subsurface reservoirs – NWO DEEPNL 2019.006 DR4ES (Maja Rücker)
- KickStart Heat Pumps – MOOI 42002 RVO EZ-kaderregeling (Michel Speetjens)
- SIMCOR (In-Silico testing and validation of Cardiovascular Implantable devices) – EU H2020 (Clemens Verhoosel)

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 2021 highlights

- InterPore PoreLab Young Researchers (Recipient: Rücker)
- Smeulders (08.02.21) Warmtewet bij TROS Radar TV
- Smeulders (11.02.21) Biomassa bij 'de Hofbar' TV
- Smeulders (02.06.21)Warmtewet bij 'de Hofbar' TV
- Smeulders (15.12.21) Datacenter Zeewolde bij 'de Hofbar' TV

PhD theses delivered in 2021

- 15 April 2021 – Stephanie Veselá – Advancing *human thermo-physiological modelling: Challenges of predicting local skin temperatures during moderate activities*, PhD Thesis, Eindhoven University of Technology, (Smeulders & Frijns).
- 27 September 2021 – Mauro Michele Campagna – *Experimental study of carrier gas and pressure effects on homogeneous water nucleation*, PhD Thesis, Eindhoven University of Technology, (Smeulders, Van Dongen, Hrubý).
- 17 December 2021 – Koen Heijmans - *Thermochemical storage materials: advances in molecular modeling and applications*, PhD Thesis, Eindhoven University of Technology (Smeulders & Gaastra-Nedea).

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. ir. Bert Vreman	Full prof. (part time)
Prof dr. Michael Golombok	Full prof. (part time)
Prof. dr. ir. Rob Bastiaans	Associate prof.
Dr. Nico Dam	Associate prof.
Dr. Bart van Esch	Associate prof.
Dr. ir. Bart Somers	Associate prof.
Dr. Giulia Finotello	Assistant prof.
Dr. Tess Homan	Assistant prof.
Dr. ir. Noud Maes	Assistant prof.
Dr. Yali Tang	Assistant prof.
Dr. ir. Xander Seykens	Assistant prof.

Group's research areas

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

Projects started in 2021

- Regeneration of metal powder: closing the metal fuel cycle
- METPAM: Production of metal powder for additive manufacturing
- Acoustic-assisted removal of microplastics
- High Hydrogen Gas Turbine Combustor High Pressure Test DEI120081

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)
- Delft University (Klein)
- Thomassen Energy
- Delft University (de Vos)

- Delft University (Roekaerts, Rao)
- Dutch Section of the Combustion Institute (DSCI) en Nederlandse Vereniging voor Vlamonderzoek (NVV)

PhD theses delivered in 2021

- 22 February 2021 – Sina Tajfirooz – *Numerical methods for dynamics of particles in magnetized liquids*, PhD Thesis, Eindhoven University of Technology, (Kuerten & Zeegers).
- 15 September 2021 – Hayri Yigit Akargün – *Large Eddy Simulation of diesel spray combustion with Flamelet Generated Manifolds*, PhD Thesis, Eindhoven University of Technology, 15 September 2021 (Somers & Deen).
- 30 November 2021 – Aromal Vasavan – *Numerical modeling of igniting non-premixed combustion systems using FGM*, PhD Thesis, Eindhoven University of Technology, (Van Oijen & De Goey).

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	Assistant prof.
Dr. Ye Wang	Assistant prof.

Group's research areas

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

Grant obtained in 2021

- NWO-TTW-Perspectief Grant "SMART Organ-on-Chip: Standardized open Modular Approach to Recapitulate Tissues", Grant No. 12126 & 12127

Projects started in 2021

- NWO-TTW-Perspectief Grant "SMART Organ-on-Chip: Standardized open Modular Approach to Recapitulate Tissues", Grant No. 12126 & 12127
- NWO-TTW Take off phase 1 Grant "Purecyte". Grant No. 19293

Collaboration with other groups (inside or outside Burgerscentrum)

- 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.

- Chemelot InSciTe Grant, “Innovative Surgery for Eyes with Advanced glaucoma (ISEA)”, collaboration with DIRM group at TU/e, Biomedical Engineering at TU/e, MUMC+, Santen.
- 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 2021 highlight

- Our work on artificial cilia in the ERC Adv project “Bio-Plan” has resulted in groundbreaking results reported in: Tanveer ul Islam, Bellouard, Y. & Toonder, J.M.J. den (2021). Highly motile nanoscale magnetic artificial cilia. PNAS Vol. 118, No. 35, e2104930118. https://doi.org/10.1073/pnas.2104930118

PhD thesis delivered in 2021

- 10 May 2021 – Eriola-Sophia Shanko – *Magnetic micromixing: for point of care diagnostics*, PhD Thesis, Eindhoven University of Technology, (Toonder, Anderson, van de Burgt).

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

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-ST-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
- Kriebitzsch and Richter, TU Bergakademie Freiberg, Germany
- Particulate Flow Modelling, Pirker, JKU, Austria

PhD theses delivered in 2021

- 8 November 2021 - Tim Nijssen – *Dynamic behaviour of liquid-solid systems: Modelling and experiments applied to the blast furnace hearth*, PhD Thesis, Eindhoven University of Technology, (Kuipers & Buist).
- 13 December 2021 – Evan Milacic – *Studying liquid injection in fluidised beds through simulations and experiments*, PhD Thesis, Eindhoven University of Technology, (Kuipers & Baltussen).

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

Projects started in 2021

- CSC - Mesoscale study on transport characteristics of porous particles in gas-solid two-phase reaction systems
- CSC - Turbulent flow and droplets behavior to optimize coalescence filter separators
- RAAK-PRO - Totally Nuts: Circular biobased thermosets from cashew nut shells
- Electrification and Energy Efficiency – Emissi0n
- RVO - THOR – induction heating of processes

Collaboration with other groups (inside or outside Burgerscentrum)

- THOR: collaboration with TNO, Ambrell, TotalEnergies, Hybrid Catalysis
- DPI HEMPR: collaboration with P&F/ Prof. Deen and SMM / Prof. Kuipers and Dr. Baltussen
- Zeocat: collaboration with VITO, Hybrid Catalysis, a.o.
- Totally nuts: collaboration with Avans
- Emissi0n: collaboration with TNO

PhD thesis delivered in 2021

- 4 November 2021 – Alessandro Batistella – *Hydrodynamics, Mass Transfer and Phase Transition in Bubbly Flows*, PhD Thesis, Eindhoven University of Technology, (Van Sint Annaland & Roghair).

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.
Dr. ir. Martijn Anthonissen	Assistant prof.

Group's research area

- Computational Fluid Dynamics

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 Star Dynamics 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: Flow Assurance and Vibrations Group, Aker Solutions, Oslo (Arnout Klinkenberg)
- Parallel Solution Methods for Large Dense Linear Systems: CFD Group, MARIN, Wageningen (Rik Hoekstra and Auke van der Ploeg)
- Enforcing Physical Behavior 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)
- Advances in Structure-Preserving Reduced Order Models for the Incompressible Navier-Stokes Equations: Scientific Computing Group, CWI, Amsterdam (Henrik Rosenberger and Benjamin Sanderse)
- Performance of Airfoils with Permeable Trailing Edges: DIMPLE Aerospace B.V., Delft (Jordi Leemans and Michiel van Nesselrooij)

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.

Group's research areas

- Building aerodynamics
- Sports aerodynamics
- Indoor/Outdoor ventilation
- Pollutant/aerosol dispersion
- Wind comfort
- Static tests of wind forces
- Automotive aerodynamics
- Maritime aerodynamics
- Urban wind energy
- Solar energy
- Wind effects on PV panels
- Urban microclimate

Grant obtained in 2021

- HORIZON-INFRA-2021-SERV-01

Projects started in 2021

- Aircleaning against COVID-19 aerosol transfer: the 1000 classrooms project
- Time trial aerodynamic optimization for Team Jumbo Visma cyclists Jonas Vingegaard (Yellow Jersey winner in Tour de France), Primoz Roglic, Wout van Aert, Tom Dumoulin, and others
- Time trial aerodynamic optimization for Paralympics Ireland cyclists Katie George-Dunlevy and Even McCrystal
- Attempting the Sub-7 hour Iron-Distance Triathlon by Kristian Blummenfelt
- Towards an Eco-City in Oman

Collaboration with other groups (inside or outside Burgerscentrum)

- Fluids and Flows, Applied Physics, Eindhoven University of Technology
- Civil Engineering, National University of Ireland, Galway, Ireland
- Environmental and Hydraulic Engineering, Sapienza University Rome
- Energy and Refrigerating Airconditioning Engineering, National Taipei University of Technology, Taiwan
- Department of Particulate Flow Modelling, Johannes Kepler University, Linz, Austria

- Department of Architecture, Delft University of Technology
- Department of Civil, Chemical and Environmental Engineering, University of Genoa, Italy

Oher 2021 highlights

- Bert Blocken: Listed as 2021 Highly Cited Researcher by Clarivate Analytics (Web of Science)
- Gold medal with Primoz Roglic (Slovenia) at Tokyo 2021 Olympics (Time trial)
- Silver medal with Tom Dumoulin (Netherlands) at Tokyo 2021 Olympics (Time trial)
- General classification victory of Primoz Roglic (Slovenia) in Vuelta (Tour of Spain)
- Two Gold medals and one Silver medal with Katie George-Dunlevy and Even McCrystal (Ireland) at Tokyo Paralympics – Tandem cycling
- Kristian Blummenfelt (Norway): Iron-Distance Marathon below 7 hours

PhD theses delivered in 2021

- 24 September 2021 – Xing Zheng – *Computational analysis of the impact of façade geometrical details on wind flow and pollutant dispersion*, PhD Thesis, Eindhoven University of Technology, (Blocken & Montazeri).
- 8 October 2021 – Yu-Hsuan Juan – *Analysis of urban wind energy potential around high-rise buildings in close proximity using computational fluid dynamics*, PhD Thesis, Eindhoven University of Technology & Taipei Tech, (Blocken & 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 and particles
- Melting and dissolution
- Microbubble physics
- Ultrasound
- Blood flow characterization
- Microscale heat and mass transfer
- Deep learning
- Fully developed turbulence and in particular thermally driven turbulence
- Micro- and nano fluidics
- Inkjet printing
- Surface nanobubbles and nanodroplets, colloidal science
- Bubble dynamics and cavitation
- Granular matter
- Acoustics

Grants obtained in 2021

- ERC starting grant Sander Huisman - Melting and dissolution in turbulent flows

- NWO M2 open competitie Sander Huisman - Turbulence with tailored fibers
- Fundamental Fluid Dynamics Challenges in Inkjet Printing: Physicochemical Hydrodynamics of Droplets", (2021-2025), Connecting Industries" Grant from Ministry for Economics.
- New Chemistry for a Sustainable Future: Growth of electrolytic bubbles in the electrochemical reduction of CO2: experiments" (2021-2025), ARC CBBC
- “Towards upscaling alkaline electrolysis: Pushing the limits of interfacial transport” NWO-ECCM KICKstart DE-NL

Projects started in 2021

- Fundamental Fluid Dynamics Challenges in Inkjet Printing: Physicochemical Hydrodynamics of Droplets", (2021-2025), Connecting Industries" Grant from Ministry for Economics.
- New Chemistry for a Sustainable Future: Growth of electrolytic bubbles in the electrochemical reduction of CO2: experiments" (2021-2025), ARC CBBC

Collaboration with other groups (inside or outside Burgerscentrum)

- Max Planck Center Twente for Complex Fluid Dynamics: collaboration with MPI-DS in Goettingen 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, UT
- 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 Radboudumc
- NWO Perspective 3D ultrasound in vascular surgery (ultra-X-treme) with Radboudumc, TU/e, Rijnstate Hospital, CZ Eindhoven, Erasmuc 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, Radboudumc, 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 2021 highlights

- Phys. Rev. Fluids selected "L. Liu, R.J.A.M. Stevens, Enhanced wind-farm performance using windbreaks, Phys. Rev. Fluids 6, 074611 (2021)." as editor suggestion. Also highlighted in, for example, Science News, Physics Magazine.
- AIP featured the article "S.N. Gadde, R.J.A.M. Stevens, Effect of low-level jet height
- Selected as editor's suggestion: High-Frequency Acoustic Droplet Vaporization is Initiated by Resonance, Guillaume Lajoinie, Tim Segers, and Michel Versluis, Phys. Rev. Lett. 126, 034501
- Michels, S. E., Kersemans, M., Versluis, M., Lajoinie, G., Smet, P. F., Fast and High-Resolution Ultrasound Pressure Field Mapping Using Luminescent Membranes. Adv. Optical Mater. 2021, 9, 2100085. https://doi.org/10.1002/adom.202100085
- Ultrasound velocimetry in participants with aortoiliac occlusive disease. Stefan Engelhard, Majorie van Helvert, Jason Voorneveld, Johan G. Bosch, Guillaume Lajoinie, Michel Versluis, Erik Groot Jebbink, and Michel M.P.J. Reijnen. Radiology 301(2), 332–338 (2021) https://doi.org/10.1148/radiol.2021210454
- Selected as Editor's suggestion: Dennis Bakhuis, Rodrigo Ezeta, Pim A. Bullee, Alvaro Marin, Detlef Lohse, Chao Sun, and Sander G. Huisman, Catastrophic phase inversion in high-Reynolds number turbulent Taylor Couette flow, Phys. Rev. Lett. 126, 064501 (2021)
- Selected as Editor's suggestions, featured in Physics, etc: Chong Shen Ng, Kai Leong Chong, Rui Yang, Mogeng Li, Roberto Verzicco, and Detlef Lohse, Growth of respiratory droplets in cold and humid air, Phys. Rev. Fluids 6, 054303 (2021).
- Several papers were selected as Cover in Phys. Rev. Lett. and in JFM

PhD theses delivered in 2021

- 15 January 2021 – Myrthe Bruning – *Confined and colloidal droplets*, PhD Thesis, Twente University, (Lohse & Marin).
- 15 January 2021 – Pieter Berghout – *Bubble formation and concentration fields in water electrolysis*, PhD Thesis, Twente University, (Lohse).
- 26 February 2021 – Nakul Pande – Bubble formation and concentration fields in water electrolysis, PhD Thesis, Twente University (Lohse, Mul, Mei, Krug).
- 15 April 2021 – On Yu Dung - Scalars in bubbly turbulence, PhD Thesis, Twente University, (Lohse, Sun, Huisman).
- 19 May 2021 – Srinidhi Nagarada Gadde – *Large eddy simulations of stratified atmospheric boundary layers and wind farms*, PhD Thesis, Twente University, (Lohse & Stevens).
- 1 July 2021 – Jelle Will – *Wake-induced dynamics of buoyancy-driven and anisotropic particles*, PhD Thesis, Twente University, (Lohse, Sun, Krug).
- 24 September 2021 – Binglin Zeng – *Nucleation and dynamics of bubbles/droplets in multicomponent liquids*, PhD Thesis, Twente University, (Lohse, Zandvliet, Wang).
- 24 September 2021 – Xiaolai Li – *Bubble nucleation and dynamics: surface micro/nanobubbles and plasmonic microbubbles*, PhD Thesis, Twente University, (Lohse, Zandvliet, Wang).

- 29 October 2021 – Michiel Hack – *Wetting and coalescence: beyond single-phase flows*, PhD Thesis, Twente University, (Snoeijer & Segers).
- 2 December 2021 – Jessica Strickland – *Modelling wakes and blockage in large scale wind farms*, PhD Thesis, Twente University, (Lohse & Stevens).
- 2 December 2021 – Ricardo Arturo Lopez de La Cruz – *Physicochemical hydrodynamics of binary and ternary liquids*, PhD Thesis, Twente University, (Lohse & Zhang).

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

Project started in 2021

- cCOOL (clay-based CO2 storage; 1 PhD)

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 theses delivered in 2021

- 9 December 2021 – Beybin Ilhan – *Role of Surface Roughness in Colloidal Dynamics of Dense Suspensions*, PhD Thesis, Twente University, (Mugele, Duits, Luding).
- 16 December 2021 – Sachin Nair – *Fast and non-invasive Raman imaging of material distributions at interfaces*, PhD Thesis, Twente University, 16 December 2021 (Mugele).

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 2021

- ECCM Kickstart "Towards upscaling alkaline electrolysis: Pushing the limits of interfacial transport"
- AquaConnect Key technologies for safeguarding regional water provision in fresh water stressed deltas
- ReCoVR: Recovery and Circularity of Valuable Resources

Projects started in 2021

- Combining Cake and Membrane Filtration for Removal of Micropollutants from Concentrate Streams in Reverse Osmosis Treated Drinking Water

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 thesis delivered in 2021

- 3 September 2021 - Ashaju, Abimbola - Electrocatalytic reaction driven flows, PhD Thesis, Twente University, (Lammertink & Wood).

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. 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 2021

- NWO "Stairways to Impact " (Fernandez Rivas)
- KIVI Prins Friso Ingenieurs award (Fernandez Rivas)

Projects started in 2021

- Microflow magnetic resonance - NWO demonstrator project
- Needle-free microjet injector - NWO Take-off grant

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
- Integrated Solid-to-Liquid Acoustic Wave Devices: collaboration with Wiegerink / Lötters (UT)
- 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)

Additional 2021 highlight

- "Straaltje vloeistof doorboort druppel", De Ingenieur 16 Aug. 2021, https://deingenieur.nl/artikel/straaltje-vloeistof-doorboort-druppel; see also "Impact of a microfluidic jet on a pendant droplet" in Soft Matter, doi: 10.1039/D1SM00706H

PhD thesis delivered in 2021

- 19 March 2021 – Ignaas Jimidar – *Microsphere handling at the microscale: New tools and new effects*, PhD Thesis, University of Twente / Free University Brussel (double degree; Desmet & Gardeniers).

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. Leandro De Santana	Assistant 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

PhD theses delivered in 2021

- 6 October 2021 – Akshay Koodly Ravishankara – *Development of a pressure based incompressible flow solver for wind turbine applications*, PhD Thesis, University of Twente (Venner, v.d. Weide, Özdemir).
- 15 December 2021 – Jie Wang – *Design for high efficiency of low-pressure axial fans: use of blade sweep and vortex distribution*, PhD Thesis, Twente University, (Venner & Kruyt).

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.

Group's research areas

- Energy efficient processes
- Heat conversion and storage
- Heat pumps and district heating systems
- Hydrogen production and storage
- 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

Grants obtained in 2021

- NWO Open Technology program 750 kEuro
- TKI Nieuw Gas 200 kEuro

Projects started in 2021

- ENGENDER – Compact Energy Efficient Dryer
- DYNAF -- combustion dynamics and acoustic oscillations in large industrial furnaces and boilers, NWO OTP project collaboration TUE, Oxford university, Barcelona Supercomputing Centre, IFTA.

Collaboration with other groups (inside or outside Burgerscentrum)

- Engender: ISPT, UCLouvain, Avebe, Corbion, Givaudan
- RMZD: ISPT, UCLouvain, TNO, FrieslandCampina, Unilever
- RECOWATDIG: WUST, AGH, KTH, HoSt, GAC

- Heat Land: De Kleijn Energy Consulting, FPsim, Ennatuurlijk B.V., Twence holding B.V.
- CRESTCOOL: RBK Group, Graco, IBK, Kors
- DYNAF: TUE, Oxford university, Barcelona Supercomputing Centre, IFTA.

Other 2021 highlights

- Launch of HeatQuiz for teaching Heat Transfer and Thermodynamics

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 (transitions), and Open Source Software Project: https://urldefense.com/v3/__http://www.mercuryDPM.org__;!!PAKc-5URQlI!_44uTp72tkg_oXNfT0CSNt6R8N_s9kmSWwS7LQn7qm5MOBxPvcm7TUeB9MuREWNO9wPpn4H_V1mf28WNbOwbytpe8yI$)
- Molecular Modeling of Complex Fluids Fluids
- Virtual Prototyping of Particulate Processes
- Shaping segregation: Multiscale modelling of segregation in industrial processes
- Mechanical wave propagation applied to gas/oil exploration, production, and processing
- Multiscale modelling of agglomeration: Applications tabletting, powder bed 3D-printing
- Upscaling and Multiscale analysis of particle processes in industry

Project started in 2021

• EU-ITN TUSAIL => www.tusail.eu; Upscaling to large industrial particulate processes and 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 prof. Darhuber TU/e)
- TUSAIL (with: University of Edinburgh, TU Hamburg Harburg, TU Braunschweig, University of Salerno)
- Modeling the dynamics of electrolyte in supercapacitors (with UU)

PhD thesis delivered in 2021

- 9 December 2021 – Beybin Ilhan – *Role of Surface Roughness in Colloidal Dynamics of Dense Suspensions*, PhD Thesis, Twente University, (Mugele, Duits, Luding).

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. 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 2021

- VIDI Bas Borsje LIVING ON THE EDGE: Using soft solutions to buffer coasts against extreme hydro-meteorological events
- KNAW Ecology Fund - Rik Gijsman - Informing ecological mangrove restoration in Lac Bay, Bonaire.
- NWO-TTW MELODY: Modeling LOwer Shoreface Seabed Dynamics for a Climate-Proof Coast

Projects started in 2021

- Project 1: Salt Accumulation at Floodgates and Salt-water intrusion in rivers, Fateme Ebrahimierami (PhD), Funding from NWO

- Project 2: Hydraulic river modelling approaches to link high flow and low flow conditions, Parisa Khorsani Kuhnestani (PhD), Funding from Sectorplan
- Project 3: Seacode: efficient modelling of sand wave field dynamics for engineering purposes, Pauline Overes (PhD), Funding from UT and Deltares
- Project 4: From micro to macro scale: from sand grain behavior to emergent coastal dune properties, Xiuqi Wang (PhD), Funding from Sectorplan
- Project 5: Thomas van Veelen (PD), Modelling sandbank dynamics in sediment-scarce environments, Funding from UT
- Project 6: Johan Damveld (PD), Footprint: effects of offshore wind farms on sediments in the Coastal North Sea, Funding from NWO

Collaboration with other groups (inside or outside Burgerscentrum)

- Project 1: collaboration with WUR.
- Project 2: collaboration with Multidisciplinary Water Management group (UT)
- Project 3: collaboration with Deltares
- Project 4: collaboration with Multiscale Mechanics group (UT)
- Project 5: collaboration with Royal Belgian Institute of Natural Sciences (RBINS) and University of Ghent (Belgium)
- Project 6: collaboration with NIOZ

Other 2021 highlights

- Highlight: The sea level is rising, large parts of the Netherlands are in danger of being flooded in the future. Scientists are looking for a solution and coastal engineer Bas Borsje (Facutly of Engineering Technology, Department of Civil Engineering, Group of Marine and Fluvial Systems) has one: the living dike. He explains in "de Werkplaats" how that should protect us against flooding from the sea (video is in Dutch only).
https://www.youtube.com/watch?v=Ine7P_SzEI8&feature=emb_logo

PhD theses delivered in 2021

- 22 January 2021 – Pim Willemsen – *Biogeomorphology of salt marshes - Understanding the decadal salt marsh dynamics for flood defence*, PhD thesis, Twente University, (Hulscher & Bouma)
- 2 December 2021 – Matthijs Gensen – *Discharge and water level uncertainty in bifurcating rivers*, PhD Thesis, Twente University, (Hulscher).
- 16 December 2021 – Weiqiu Chen – *The influence of berms, roughness and oblique waves on wave overtopping at dikes*, PhD Thesis, Twente University, (Hulscher).

University of Twente

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

System Analysis and Computational Science (SACS)

Multiscale Modelling and Simulation (UT-EEMCS-MMS)

Prof. dr. ir. Bernard Geurts Full prof.

Group's research areas

- Ccomputational 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.)
Dr. ir. Fred Wubs	Associate prof.
Dr. Cristóbal Bertoglio	Assistant prof.
Dr. Julian Koellermeier	Assistant prof.

Group's research areas

- CFD methods for numerical simulation (LES, DNS) of turbulent flows
- Modeling and numerical simulation of the cardiovascular system
- Numerical bifurcation analysis of fluid flows
- Structure-preserving discretization methods for fluid flows
- Numerical simulation methods for multi-phase flows

Projects started in 2021

- Propagation of uncertainties in large eddy simulations, PhD project J. Sun
- Optimal measurement design from MRI in cardiovascular modeling, PhD project M. Locke
- Modelling and experimental studies on internal reforming solid oxide fuel cells (SOFCs) for efficient thermal management, PhD project Y. Li
- Numerical simulation of multi-phase flows, Postdoc project N. Valle
- ComFLOW User Group
- Supraconservative discretization methods for the compressible Euler equations

Collaboration with other groups (inside or outside Burgerscentrum)

- Heat and Mass Technology Center, Universitat Politecnica de Catalunya
- Institute for Aerodynamics and Flow Technology, DLR
- Center for Mathematical Modeling, University of Chili
- Cardiology & Radiology UMCG
- Cardiovascular MRI, Amsterdam AMC
- Computational Biophysics, RUG
- Scientific Computing, CWI
- SLING - Liquid sloshing in LNG tanks: collaboration with MARIN, TUD, TUE, UT, CWI, GTT (France) + over 20 engineering companies
- ComFLOW User Group: collaboration with MARIN, TUD + several shipyards and offshore companies
- University of Naples
- Institute for Marine and Atmospheric Research (IMAU)

PhD thesis delivered in 2021

- 2 September 2021 – Cristian Carcamo Sanchez – *Numerical analysis of forward and inverse fluid mechanics problems*, PhD Thesis, University of Groningen, (Verstappen, Araya, Bertoglio).

Wageningen University & Research (WUR)

Department of Animal Sciences

Experimental Zoology (WUR-ASG-EZO)

Prof. dr. ir. Johan van Leeuwen	Full prof.
Dr. ir. Florian Muijres	Associate prof.
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 2021

- NWO Vidi *Aerodynamics and control of Diptera flight*
- HFSP *Swarming and in-flight mating of malaria mosquitoes*
- Alliance EWUU *Preventing malaria disease spreading by smart turbulence flow fields*
- NWO TTW *Low impact bottom trawling*
- WIAS PhD Talent Program *Escape flights of moths as greenhouse pests*

Projects started in 2021

- NWO Vidi *Aerodynamics and control of Diptera flight*
- HFSP *Swarming and in-flight mating of malaria mosquitoes*
- Alliance EWUU *Preventing malaria disease spreading by smart turbulence flow fields*
- NWO TTW *Low impact bottom trawling*
- WIAS PhD Talent Program *Escape flights of moths as greenhouse pests*

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.
- WIAS PhD Talent Program Escape flights of moths as greenhouse pests: collaboration with TU Delft.

Other 2021 highlights

- 2021 key publications by the group:

- Le Roy C, Amadori D, Charberet S, Windt J, Muijres FT, Llaurens V, Debat V. 2021 Adaptive evolution of flight in Morpho butterflies. *Science* **374**, 1158–1162. (doi:10.1126/science.abh2620)
- Amador GJ, Van Dijk D, Kieffer R, Aubin-Tam ME, Tam D. 2021 Hydrodynamic shear dissipation and transmission in lipid bilayers. *Proceedings of the National Academy of Sciences* **118**, p.e2100156118.
- Göttler C, Amador GJ, van de Kamp T, Zuber M, Böhler L, Siegwart R, Sitti M. 2021 Fluid mechanics and rheology of the jumping spider body fluid. *Soft Matter* **17**, pp.5532-5539.
- Goyal P, Cribellier A, de Croon GCHE, Lankheet MJ, van Leeuwen JL, Pieters RPM, Muijres FT. 2021 Bumblebees land rapidly and robustly using a sophisticated modular flight control strategy. *iScience* **24**, 102407. (doi:10.1016/j.isci.2021.102407)

PhD thesis delivered in 2021

- 11 October 2021 – Antoine Cribellier – (Cum Laude) *Biomechanics of flying mosquitoes during capture and escape*, PhD Thesis, Wageningen University & Research, (Van Leeuwen, Muijres, Spitzen).

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

Grants obtained in 2021

- NWO Perspectief: ReCoVR

Projects started in 2021

- ReCoVR
- EU React: InAirMicrofluidics

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.

PhD thesis delivered in 2021

- 1 April 2021 – Emma Hinderink – *Food emulsions stabilised by blends of plant and dairy proteins*, PhD Thesis, Wageningen University & Research, (Schroën, *Berton*-Carabi, Sagis).

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. Joshua Dijksman	Associate prof.

Group's research areas

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

Projects started in 2021

- Polyelectrolyte complex materials
- Capillary suspensions (ITN Nanopaint)
- Friction in colloidal systems

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)

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

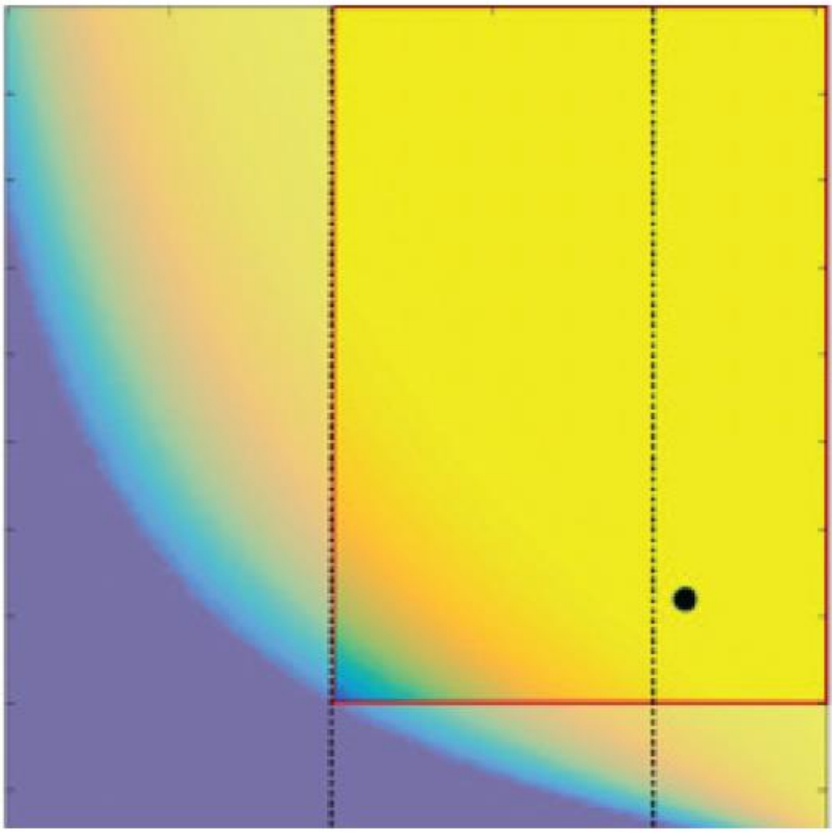
Grants obtained in 2021

- NWO-VICI (Von der Heydt), awarded in 2022 but was the 2021 call
- ERC-Advanced Grant (Dijkstra), awarded in 2022 but was the 2021 call

PhD thesis delivered in 2021

- 12 February 2021 – Tjebbe Hepkema – *Nonlinear dynamics of tides and sandbars in tidal channels*, Utrecht University, (de Swart, Schuttelaars).

ORGANISATION



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Prof. dr. Hans Kuerten	Eindhoven University of Technology
Prof. dr. Detlef Lohse	University of Twente

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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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