Master Thesis Project Proposals
Q4 2024-2025

Energy Technology & Fluid Dynamics
Department of Mechanical Engineering
Eindhoven University of Technology

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Preface

This is an overview of all the Master Graduation project proposals available in Energy Technology & Flow Dynamics.

Please select 2-3 choices of different projects in order of preference and write a **short motivation** for your first choice to Azahara Luna-Triguero (a.luna.triguero@tue.nl).

Example:

- My first preference is project... because I am very motivated to work on...
- Second preference is... (no motivation needed)
- Third preference is.. (no motivation needed)

If you need more information on a proposal you can contact directly one of the supervisors (the emails are in each project proposal).

Supervisor	Angele Reinders
2nd supervisor	Michael Debije
Starting date	Flexible
Exp./Num./Design	Experimental/Num./Design

EINDHOVEN UNIVERSITY OF TECHNOLOGY


3D Luminescent Solar Concentrator Photovoltaics

Angele Reinders* and Michael Debije
a.h.m.e.reinders@tue.nl,

INTRODUCTION

A Luminescent Solar Concentrator Photovoltaic (LSC PV) device is a technology for harvesting solar energy that consist of PV cells attached to a transparent, thin, shaped plate acting as a concentrating lightguide. This luminescent solar concentrator (LSC) contains luminescent pigments, usually called ‘dyes’, that cause, among others, a red shift (up-conversion) of the incoming irradiance spectrum which better matches the wavelength-dependent efficiency of silicon solar cells or other PV technologies, that are attached to the edges or back of the LSC.

GOALS

The goal of this project is to optimize LSC PV technology for built-environment conditions, regarding its 3D geometrical design, optical properties, coloring, temperatures, durability and system integration.

BENEFITS

The typical material properties of LSC PVs—low cost, colorful, bendable, and transparency—offer a lot of design freedom as compared to other PV technologies. And it is shown that the efficiency of an LSC PV device can exceed the assumed maximum efficiency of 10%, namely close to 20%, which seems a competitive value as compared to other PV technologies in the present market. Therefore, it makes sense to further develop this exciting technology.

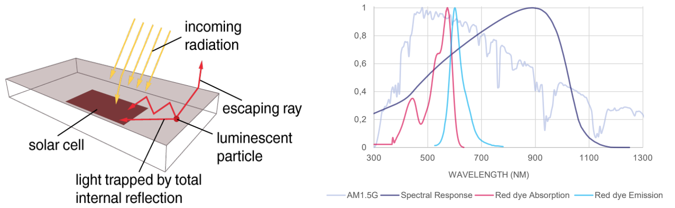

Figure 1: Left, Functional scheme of an LSC PV device, Right, Incoming irradiance spectrum, absorption and emission curves of a luminescent dye and spectral response of PV cell

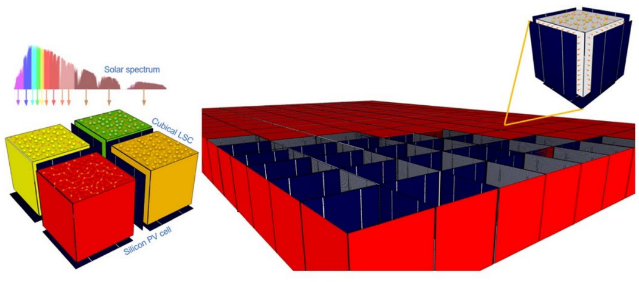

Figure 2. An example of a 3D LSC PV device

PROFILE

The project requires a student with an interest in simulations, prototyping and experimental work. Programming experience is an advantage.

REFERENCES

[1] Aghaei, M., Pelosi, R., Schmidt, T., Debije M.G., Reinders, A.H.M.E., Measured power conversion efficiencies of bifacial luminescent solar concentrator photovoltaic devices of the mosaic series, Progress in Photovoltaics: Research and Applications. 2022

[2] Reinders, A.H.M.E., Kishore, R., Slooff, L., Eggink, W., Luminescent solar concentrator PV designs, Japanese Journal of Applied Physics, Vol. 57, 2018.

[3] P. Bonomo, F. Frontini, R. Loonen, A.H.M.E. Reinders, Comprehensive review and state of play in the use of photovoltaics in buildings, Energy and Buildings, Vol. 323, 2024

Supervisor	**Dr. Maja Rücker, Dr. Thijs de Groot**
Mentor	**Maja Rücker**
Company	**MPIP (Physics of Interfaces, Prof. Hans Jürgen Butt)**
Internal / External	**External (Mainz Germany) or internal**
Starting date	**Any time**
Exp./Num./Design	**Experimental design**

Available for ME- SET

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number:

The impact of flow dynamics on electrification and alteration of porous electrodes

Maja Rücker*, Thijs de Groot, Hans Jürgen Butt

***E-mail: m.rucker@tue.nl**

Porous Electrodes for Electrolysis

Compared to conventional electrodes, porous electrodes show high specific surface areas enhancing the generation of gas bubbles due to water electrolysis. Following the generation, those bubbles travel through the electrode in complex patterns known to hinder reactant transport or induce surface alteration, reducing electrode performance of electrodes. An in-depth understanding of the behaviour of bubbles in porous electrodes is hence, of great importance. [1]

Slide electrification

Previous observation of water drops sliding over an insulated hydrophobic surface, like a raincoat or Teflon pan, have shown that moving fluid-fluid interfaces can cause charge separation. When placing an electrode through the drop in contact with the surface, we can measure a small current [2]. This raises the question about the contribution of slide electrification due to fluid dynamics in the porous electrode to the processes observed during electrolysis: How does it contribute to surface alteration? How does it influence the motion of the fluid? How does it impact the efficiency?

The idea

In this study, we investigate the relevance of fluid dynamics [3] and associated slide electrification on the electrode performance. By developing a new experimental set-up in which we control the ratio and velocity of the flow of two fluids through a porous electrode with and without grounding, we can explore the variation different settings have on slide electrification and hence provide insight into its significance for electrode performance.

Tasks

In this project, you will be expected to complete the following tasks:

- Reviewing the relevant literature on multiphase flow in porous media, slide electrification and alteration of porous electrodes
- Developing an experimental set-up allowing to assess slide electrification in a porous substrate at controlled flow conditions
- Conduct experiments, compare results and develop recommendations to improve porous electrodes for electrolysis

Benefits

In this project, you will benefit from:

- Improving your laboratory skills and learning how to design and carry out experiments.
- Gaining knowledge on fluid dynamics in porous substrates, slide electrification effects and its impact on energy applications such as electrolysis.

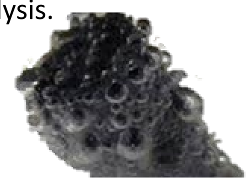

Figure 1: Bubbling H2 from an electrode

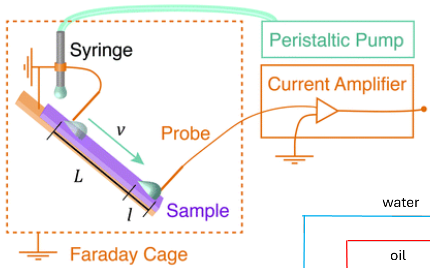

Figure 2: Experimental set-up for slide electrification in a drop [2]

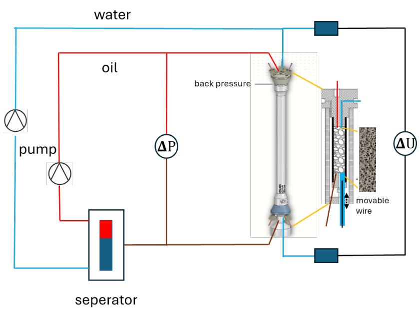

Figure 3: Proposal for an experimental set-up for slide electrification in a porous substrate

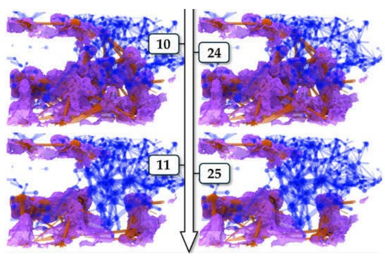

Figure 3: Fluid dynamics In a porous substrate [3]

References

[1] Wu, R., Hu, Z., Zhang, H., Wang, J., Qin, C., & Zhou, Y. (2023). Bubbles in Porous Electrodes for Alkaline Water Electrolysis. *Langmuir*, *40*(1), 721-733.
[2] Stetten, A. Z., Golovko, D. S., Weber, S. A., & Butt, H. J. (2019). Slide electrification: charging of surfaces by moving water drops. Soft matter, 15(43), 8667-8679.
[3] Heijkoop, S., Rieder, D., Moura, M., Rücker, M., & Spurin, C. (2024). A Statistical Analysis of Fluid Interface Fluctuations: Exploring the Role of Viscosity Ratio. Entropy, 26(9), 774.

Supervisor	Prof. David Smeulders
2nd supervisor	Dr. Yukai Liu
Daily supervisor	Dr. Yukai Liu
Company	N.A
Starting date	Any time
Exp./Num./Design	Primarily experimental

ETFD

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Experimental study of borehole Stoneley waves in multi-fractured formation

David Smeulders and Yukai Liu
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y.liu3@tue.nl

INTRODUCTION

The subsurface of the Earth can be used for hydrogen and CO2 storage, but the presence of fractured zones can significantly impact storage integrity by altering permeability and creating potential leakage pathways. Stoneley waves, acoustic waves propagating along boreholes, are highly sensitive to these fractured zones. While their application in reservoir characterization is well-established, research has primarily focused on single-fracture or homogeneous formations. This project aims to experimentally investigate Stoneley wave propagation within fractured zones containing multiple fractures, providing crucial data for their identification and characterization.

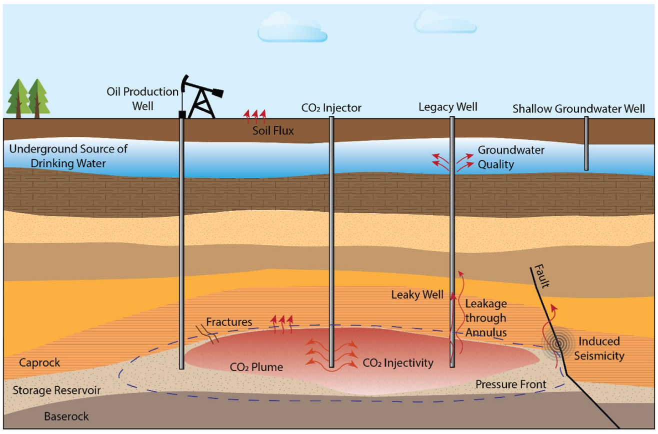

Fig. 1. Geological storage of CO_2 and Its potential leakage pathways (Xiao. T. et al.,2024)

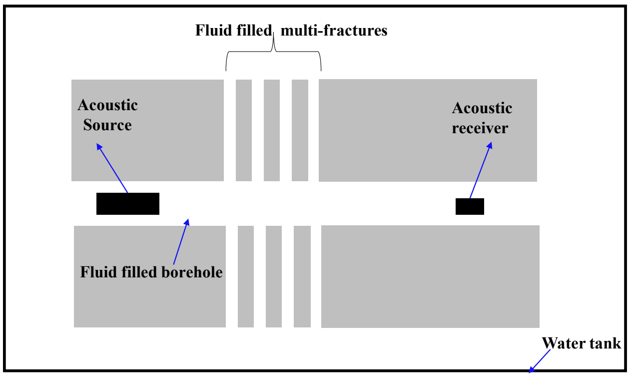

Fig. 2. Schematic diagram of Stoneley wave measurement in a multi-fractured formation.

RESEARCH GOALS

1) Characterize Stoneley wave propagation in fractured zones, focusing on transmission, reflection, and attenuation.
2) Determine the influence of fracture geometry (spacing, aperture, number) on Stoneley wave responses.
3) Understand the underlying physical mechanisms of Stoneley wave-fracture interaction.

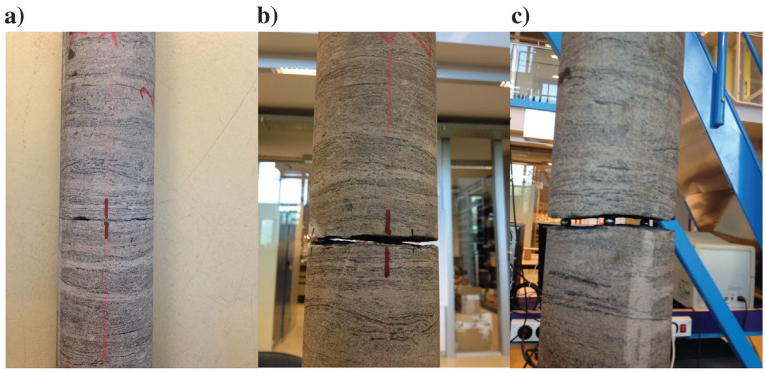

Fig. 3. Photo of three rock samples with varying fracture apertures. (a) Closed fracture, (b) 4 mm fracture, and (c) 6 mm fracture

TASKS

Task1: Build borehole models with different types of fractures (varying size, length, and spacing).

Task2: Perform borehole Stoneley wave measurements using the new borehole models, analyzing reflection, transmission, and attenuation coefficients.

STUDENT PROFILE

- Interested in experimental studies.
- Pro-active attitude.

Supervisor	**Dr. Clemens Verhoosel**
2nd supervisor	**N.A.**
Mentor	**N.A.**
Company	**N.A.**
Internal / External	**Internal**
Starting date	**Any time**
Exp./Num./Design	**Numerical**

Available for ME

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Computational methods in Thermal Fluids Engineering

Clemens Verhoosel, Harald van Brummelen, Michael Abdelmalik or Stein Stoter

Keywords: *Computational Mechanics*

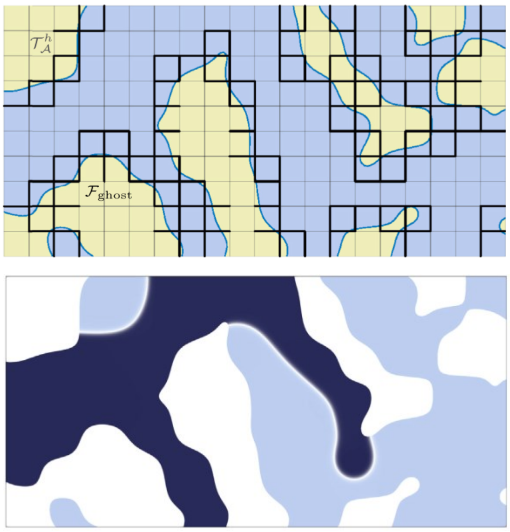

Fig 1: Multi-phase flow through porous material

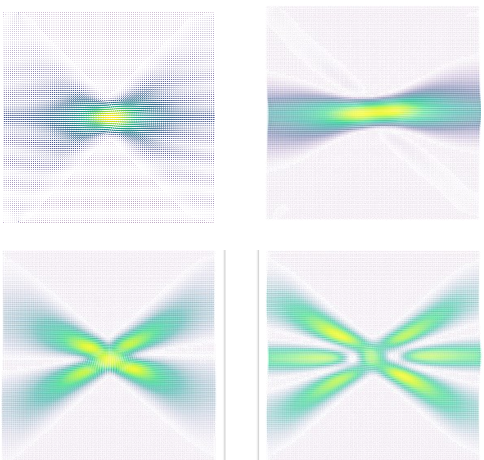

Fig 2: Model order reduction

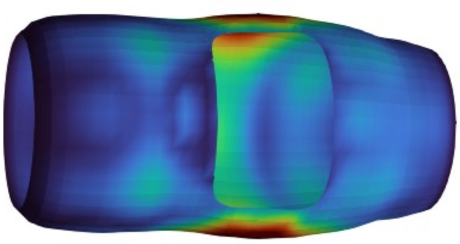

Fig 3: Explicit analysis of a shell-structure

INTRODUCTION

Computational method development plays a crucial role in advancing scientific research and engineering applications. As the complexity of real-world problems continues to grow, there is an increasing demand for efficient, accurate, and robust numerical methods to simulate, analyze, and predict complex systems.
Within this Computational Methods in Thermal Fluids Engineering consortium, we offer a broad scope of master thesis projects on solving complex problems across various scientific and engineering domains.

Project focus

The specific direction of the project can be tailored to your interests, allowing you to work on topics ranging from fluid dynamics and structural mechanics to machine learning and high-performance computing. If you're motivated to tackle challenging problems and eager to make a meaningful impact through computational innovation, we encourage you to reach out to one of the supervisors below to discuss ideas and potential project paths.

STUDENT PROFILE

We are looking for a MSc student who has:

- Affinity towards (advanced) numerical solution methods,
- Interest in programming and eager to improve upon their existing programming skills (e.g., Python).

Contact

From left to right:

- Harald van Brummelen E.H.v.Brummelen@tue.nl
- Clemens Verhoosel CVerhoose@tue.nl
- Michael Abdelmalik M.Abdel.malik@tue.nl
- Stein Stoter K.F.S.Stoter@tue.nl

Supervisor	Maja Rücker
Partners TU Delft	Hanieh Bazyar, Georgia Kontaxi
Daily supervisor	Gijs Wensink
Company	Collaboration with TU Delft
Starting date	Any time
Exp./Num./Design	Experimental

ETFD

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Dynamic response of responsive microgel-coated membranes for CO2 detection in seawater

Gijs Wensink*, Maja Rücker**, Hanieh Bazyar, Georgia Kontaxi
*g.j.wensink@tue.nl,**m.rucker@tue.nl

INTRODUCTION

Indirect ocean capture (IOC) is a negative emission technology which uses the capacities of the oceans to capture atmospheric CO_2. Using electrodialysis [1], the pH of oceanwater can be altered to allow increase dissolution of CO_2. These membranes can be functionalized with a CO_2 sensing layer to allow measuring dissolved CO_2 in-situ. The goal of this project is to experimentally study the applicability of CO_2-responsive etalon membranes for this purpose.

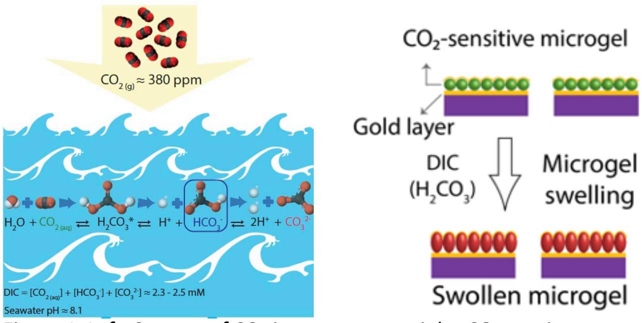

Figure 1. Left: Storage of CO_2 in oceanwater, right: CO_2 sensing concept

TASKS

Tasks during the project:

- Prepare and experimental plan for studying dynamics of CO2-responsive microgels coated on membranes in flow conditions.
- Testing the experimental setup, consisting of an atomic force microscope equipped with a sample holder designed for in-flow measurements.
- Carrying out the experiments under varying conditions.
- Analysing the results with image processing software and statistical analysis.
- Comparing the data with interferometry measurements carried out by partners at TU Delft.

GOALS

The main goal of this project is to understand the dynamic behavior of microgel beads coated on a ceramic membrane under flow conditions. We are interested in:

- The swelling/response time after exposure to CO2 enriched water.
- The swelling rate/volume under different pH conditions
- Microgel layer thickness compared with interferometry measurements.

STUDENT PROFILE

We are looking for a student with interest in a project with experimental focus. The student will learn to use Atomic Force Microscopy (AFM), design and carry out experiments and analyse the results.

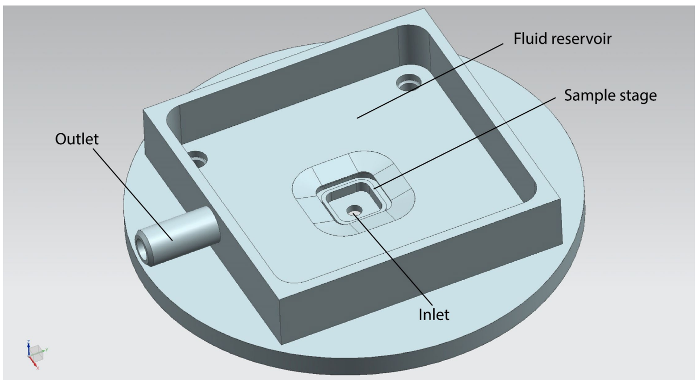

Figure 2: Schematic of AFM in-situ flow sample holder.

REFERENCES

[1] Eisaman, M. D., Parajuly, K., Tuganov, A., Eldershaw, C., Chang, N., & Littau, K. A. (2012). CO2 extraction from seawater using bipolar membrane electrodialysis. Energy & Environmental Science, 5(6), 7346–7352. https://doi.org/10.1039/C2EE03393C

[2] Kontaxi, G., Wensink, G., Sberna, P. M., Rücker, M., Garbin, V., Serpe, M. J., & Bazyar, H. (2024). Microgel-based etalon membranes: Characterization and properties. APL Materials, 12(9). https://doi.org/10.1063/5.0227483/3312338

Supervisor	Paul Grassia
2nd/3rd supervisor	Maja Rucker/David Rieder
Starting date	Flexible
Exp./Num./Design	Modelling/Numerical

ETFD

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Foamed Gas Flow in Porous Media for Energy Storage

Paul Grassia, Maja Rucker, David Rieder
p.s.grassia@tue.nl, m.rucker@tue.nl, d.r.rieder@tue.nl

INTRODUCTION

There are many scenarios which involve gas displacing other fluids in porous media (e.g. soil/aquifer remediation, CO2 capture/storage, seasonal storage of green hydrogen). However the high mobility of gas in porous media leads to flow control issues (gas override, fingering and channelling phenomena). These can be overcome by foaming the gas, which reduces its mobility by orders of magnitude. Looking inside porous media to see how foamed gas distributes remains however challenging. Hence it is useful to have models describing both foamed gas mobility and how foamed gas flows. One additional challenge in the case of seasonal hydrogen storage is that stored gas eventually needs to recovered by flowing gas out of the medium again. Models suggest however that foamed gas flowing back out of a medium has an even lower mobility than foamed gas flowing in [1]. This impact of this upon how readily hydrogen can be recovered from porous media is not yet understood.

GOALS

The goal is to develop a computer simulation for foamed gas moving in porous media. The model will be used to design geological gas storage processes with a balance being sought between the amount of gas stored and the subsequent ease/rapidity of extracting it.

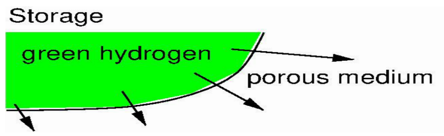

Figure 1: Seasonal storage of green hydrogen

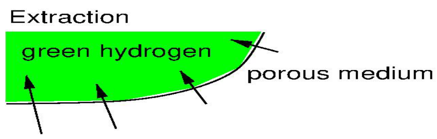

Figure 2. Seasonal extraction of green hydrogen

BENEFITS

The project will contribute to the goals of energy transition. Technology already exists to generate green hydrogen from renewable sources (solar, wind), but challenges remain in storing it safely and in large quantities.

PROFILE

The project requires a student interested in porous media and multiphase flows. Experience with numerical methods for partial differential equations and with computer programming will also be an advantage.

REFERENCES

[1] M. Eneotu and P. Grassia. Foam improved oil recovery: Towards a formulation for pressure-driven growth with flow reversal. Proc. Roy. Soc. London Ser. A, 476:20200573, 2020 doi: 10.1098/rspa.2020.0573.

Supervisor	Maja Rucker
2nd/3rd supervisor	Paul Grassia/David Rieder
Starting date	Flexible
Exp./Num./Design	Experimental/Design

ETFD

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Visualising Foamed Gas Flow in Energy Storage

Maja Rucker, Paul Grassia, David Rieder

m.rucker@tue.nl, p.s.grassia@tue.nl, d.r.rieder@tue.nl

INTRODUCTION

Geological porous media are candidates for seasonal storage of green hydrogen. Gas flows in media however face mobility control issues, e.g. fingering and channelling phenomena. Such phenomena are associated with low mobility fluids displacing higher mobility ones. For flowing gas into media at least, such issues can be solved by foaming the gas. At a foam front, a layer of very low mobility foamed gas is known to develop, leading to smooth displacement of any fluids already present in the medium. Applications involving seasonal hydrogen storage are distinct though from other gas in porous media applications (e.g. CO2 capture and storage), in that it is needed to extract the hydrogen again. During extraction, models now predict fluids originally present in the reservoir displacing very low mobility foam, not vice versa [1]. An open scientific question is then whether the aforementioned mobility control issues, avoided during storage, might simply arise during extraction, reducing how efficiently hydrogen can be recovered.

GOALS

The goal is to develop a laboratory experiment to visualise how foamed gas distributes during both gas storage and gas extraction processes. Mobility of foamed gas during storage and extraction will also be measured.

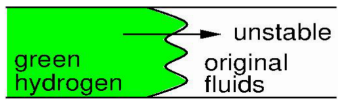


Figure 1: Unstable flow (fingering) of unfoamed gas

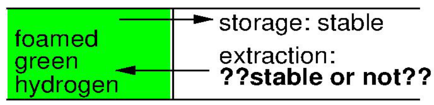


Figure 2. Foamed gas stable flow during storage; behaviour during extraction unknown

BENEFITS

The project will contribute to the goals of energy transition. Technology already exists to generate green hydrogen from renewable sources (solar, wind), but challenges remain in storing it safely and in large quantities within geological porous media.

PROFILE

The project requires a student interested in experimental studies on porous media and multiphase flows. Experimental skills and experience in designing and building experimental set ups are essential.

REFERENCES

[1] M. Eneotu and P. Grassia. Foam improved oil recovery: Towards a formulation for pressure-driven growth with flow reversal. Proc. Roy. Soc. London Ser. A, 476:20200573, 2020 doi: 10.1098/rspa.2020.0573.

Supervisor	Prof. Harald van Brummelen
2nd supervisor	Dr. Stein Stoter
Mentor	Tom van Sluijs
Company	N.A.
Internal / External	Internal
Starting date	Anytime
Exp./Num./Design	Numerical

Available for ME

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number:

Analysis of droplet jetting and subsequent Rayleigh break-up in a Navier-Stokes Cahn-Hilliard framework

Tom van Sluijs*, Stein Stoter, Harald van Brummelen

*E-mail: t.b.v.sluijs@tue.nl

INTRODUCTION

The Cahn-Hilliard equations describe phase separation, such as water-air systems. The Navier-Stokes equations describe the motion of viscous fluids. Coupling these models gives the opportunity to describe the dynamics of multiphase flow. This Navier-Stokes-Cahn-Hilliard (NSCH) model is implemented numerically and used to simulate multiphase problems. See the figure below or this video for a typical result.

The main application area for this research is inkjet printing, where many problems—such as droplet dynamics, Rayleigh break-up, and jetting ink from a single nozzle—can be described with axisymmetric models. To achieve accurate and efficient simulations, a mathematically sound and numerically efficient implementation of the NSCH model is needed.
The goal of this project is to develop the mathematical formulation of an axisymmetric NSCH model, implement it numerically, and apply it to study relevant axisymmetric test cases.

TASKS

In this project, you are expected to do:

- Literature review, focused on multiphase flow, capillarity, the NSCH model and axisymmetry.
- Program a numerical implementation in our existing framework.
- Qualitative and quantitative assessment of the numerical results.
- Conclusion and advise on both modelling and the numerical implementation.

STUDENT PROFILE

We are looking for a motivated MSc student who:

- is curious about the mathematical modeling of fluid dynamics, in particular multiphase flow, interface phenomena and boundary conditions.
- is interested in theoretical modelling, numerical methods, and programming.
- is looking to develop his/her personal skillset: physical modelling, numerical methods, literature study, programming, and data analysis.

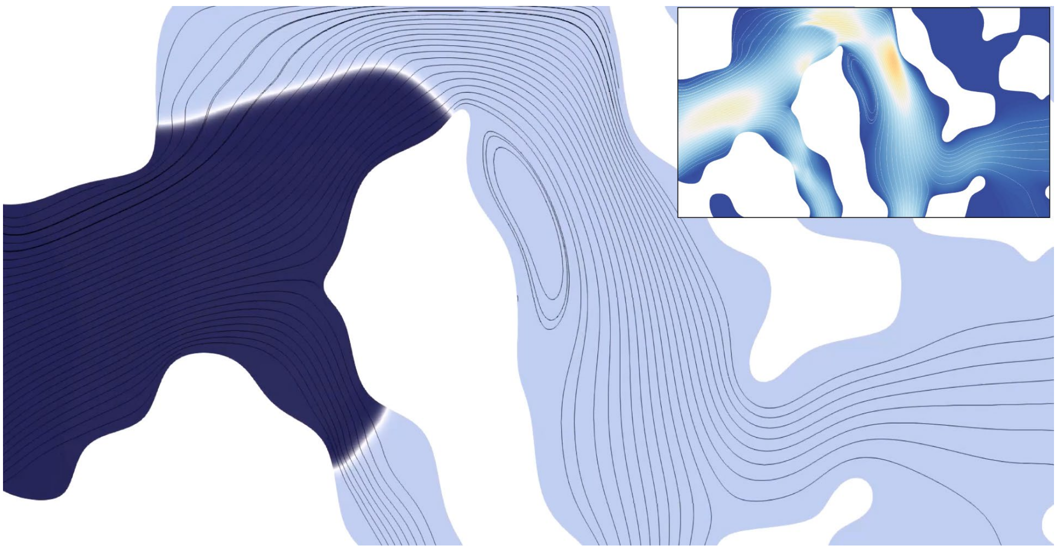


Figure 1: The velocity field (bottom left) and pressure field (top right) of a water-air flow in a porous medium.

REFERENCES

Abels, H., Garcke, H., & Grün, G. (2012). Thermodynamically consistent, frame indifferent diffuse interface models for incompressible two-phase flows with different densities. Mathematical Models and Methods in Applied Sciences, 22(3). doi: 10.1142/S0218202511500138

Van Brummelen, E. H., Demont, T. H., & van Zwieten, G. J. (2020). An adaptive isogeometric analysis approach to elasto-capillary fluid-solid interaction. International Journal for Numerical Methods in Engineering(March), 1–22. doi: 10.1002/nme.6388

Keywords: Physical modelling, *Numerical methods, Finite Elements, Navier-Stokes, Cahn-Hilliard*

Stein K.F. Stoter, Tom B. van Sluijs, Tristan H.B. Demont, E. Harald van Brummelen, Clemens V. Verhoosel (2023) Stabilized immersed isogeometric analysis for the Navier–Stokes–Cahn–Hilliard equations, with applications to binary-fluid flow through porous media, Computer Methods in Applied Mechanics and Engineering, 2023, 116483, ISSN 0045-7825, https://doi.org/10.1016/j.cma.2023.116483.

Daily supervisor	Dr. David Rieder
Supervisor	Dr. Maike Baltussen
Supervisor	Dr. Maja Rücker
Starting date	asap
Exp./Num./Design	Experimental & Numerical

ETFD

Collaborative Hide and Seek with droplets

Imbibition dynamics with 4D µCT imaging and multiphase CFD

D.R. Rieder*, M.W. Baltussen, M. Rücker
*d.r.rieder@tue.nl

INTRODUCTION

Multiphase flows traditionally belong to the most relevant phenomena for the energy-relevant industry, i.e. hydrogen-formation in electrolyzers, brine-displacement during CCS or synthesis of liquid fuels. However, those flows also belong to the least understood phenomena, due to the complex material interaction at the interfaces.

Additionally, gaining insights into those phenomena via multiphase CFD is often limited by unsatisfying overlap with experiments. There, the material and system properties are often not included in the models or simply not known, e.g. wettability and contact angle [1].

In this collaborative project between ME & CEC, we aim to improve our understanding of multiphase flow using simultaneously advanced multiphase CFD in combination with 4D (3D + time) µCT-imaging. Here, the droplet spreading inside a regular, idealized porous media will be studied and the experimental results compared with complementary simulations.

GOALS

You will design an idealized porous structure, conduct µCT experiments, compare those results with high-fidelity multiphase CFD, schematically shown in fig. 1. Finally, you will critically analyze the results and evaluate the quality of the current state of the art of multiphase models.

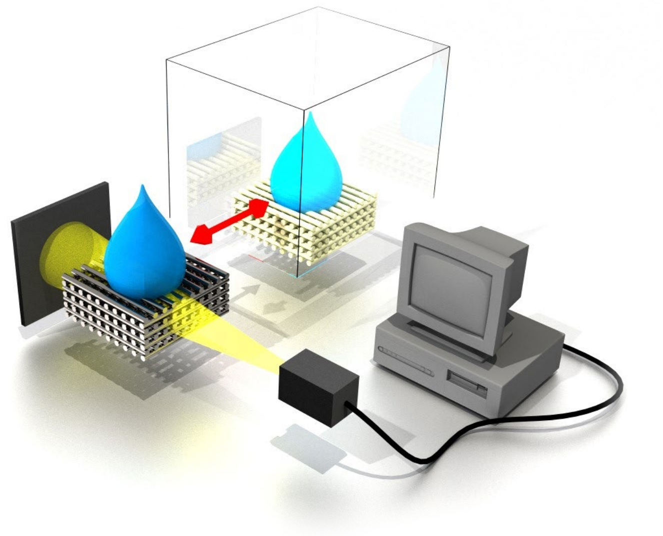


Figure 1: Schematic Imaging setup and comparison with simulation data for the imbibition of a droplet in an idealized porous media

BENEFITS

Within this project you will:

- Acquire in-depth knowledge of advanced experimental techniques and numerical methods
- Work in an international team addressing the current challenges for the energy-transition
- Advance our understanding of multiphase fluid dynamics
- Contribute to solving fundamental challenges for the transition to a sustainable energy sector

REFERENCES

[1] Rücker et. al The Origin of Non-thermal Fluctuations in Multiphase Flow in Porous Media doi: 10.3389/frwa.2021.671399

Supervisor	Paul Grassia
2nd supervisor	Paul Grassia
Starting date	Flexible
Exp./Num./Design	Modelling/Numerical

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Bubble Trains Flowing in a Channel

Paul Grassia*
p.s.grassia@tue.nl,

INTRODUCTION

There are many scenarios in which trains of bubbles flow along narrow channels (e.g. foam-based gas storage, foam-based soil remediation). As throughput is increased in such processes, there is a risk that viscous drag forces will break the train of bubbles apart. However it is also possible that the structure can stay together provided foam films between bubbles flatten out [1]. This project will explore the geometry of such flat film states.

GOALS

The goal is to develop models establishing limits on bubble sizes that can stack into a flat film state as a function of the number of bubbles within a train. This will in turn identify the domain of bubble sizes that admit rapid throughput within a channel or porous medium.

BENEFITS

You will be studying a system which admits a rich physical behaviour, but which simultaneously can be used in engineering practice. You will also be studying an unconventional class of models in which dynamics is largely replaced by geometry.

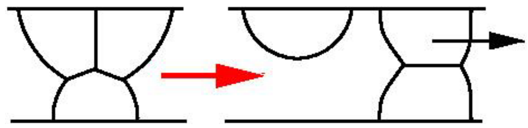


Figure 1: A bubble train that breaks up

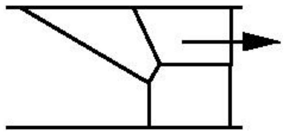


Figure 2. A flat film state that does not break

PROFILE

The project requires a student with an interest in foams and an understanding of and liking for geometry. Programming experience is also an advantage.

REFERENCES

[1] C. Torres-Ulloa and P. Grassia. Viscous froth model applied to the motion and topological transformations of two-dimensional bubbles in a channel: Three-bubble case. Proc. Roy. Soc. London Ser. A, 478:20210642, 2022 doi: 10.1098/rspa.2021.0642.

Supervisor	Michael Abdelmalik
2nd supervisor	Victorita Dolean (M&CS)
Company	N/A
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Numerical

ETFD

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Neural Operators for Preconditioning Iterative Solvers

Michael Abdelmalik*, Victorita Dolean

*E-mail:m.abdel.malik@tue.nl

Keywords: *Machine Learning, Neural Networks, Partial Differential Equations, Preconditioners*

INTRODUCTION

While partial differential equations (PDEs) play a fundamental role in the way we mathematically describe physical phenomena, the resolution of such equations is restricted by our capability of computing discrete solutions to the linearized system of equations. When the number of such equations becomes large, direct matrix inversion methods become prohibitively expensive, and the use of iterative methods becomes necessary. A key factor for effective use of iterative solvers is the availability of a *precondtioner* which approximates the action of the inverse.

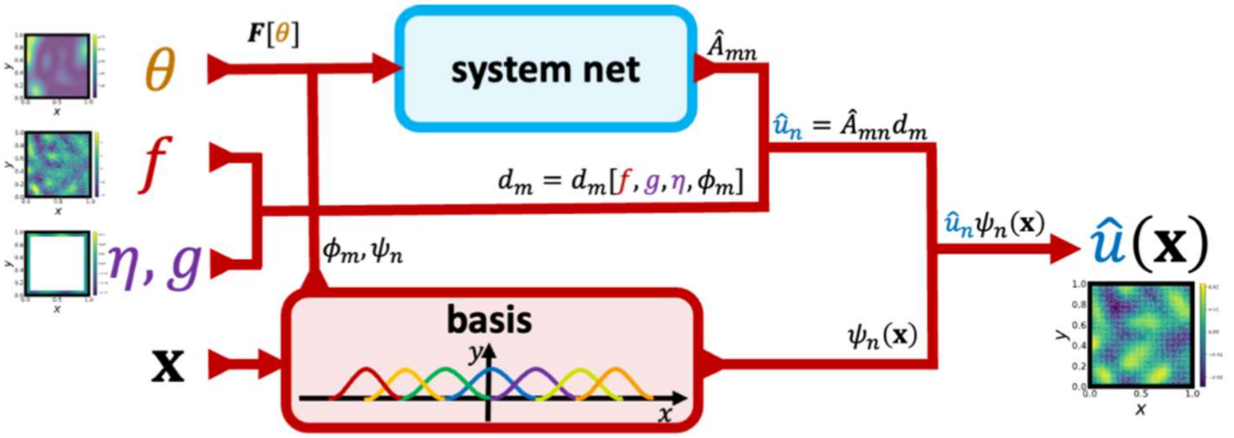
TASKS

- Formulate suitable objective/loss function(s)
- Generate training and validation datasets,
- Construct tailored Neural Operator architectures,
- Train and validate network
- Use neural operator to accelerate iterative solvers

STUDENT PROFILE

We are looking for a MSc student who is interested in:

- machine learning and neural networks,
- mathematical modelling of physical phenomena,
- practical algorithms for mathematical models,
- programming (e.g., Python) and improving coding skills.



Neural Operator for Parametric PDEs

OBJECTIVE

The aim of this MSc project is to explore architectures for neural operators that can approximate the solution operator to a PDE. Moreover, we aim to use such an (approximate) solution operator to i) construct a reduced-order/surrogate model which can provide generalized, accurate and fast solutions; ii) to construct precondtioners to accelerate iterative solvers.

REFERENCES

[1] Neural Green's Operators for Parametric Partial Differential Equations (2024) . arXiv preprint arXiv:2406.01857.

[2] Variationally mimetic operator networks (2024). Computer Methods in Applied Mechanics and Engineering.

Supervisor	David Rieder
2nd supervisor	Revanth Sharma
Starting date	Asap
Exp./Num./Design	Numerical

ETFD

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

High-fidelity upscaling of gas flow in porous media – Stepping from kinetic gas theory to Pore Network Models

David Rieder+, Revant Sharma*
+d.r.rieder@tue.nl , *r.k.sharma@tue.nl,

INTRODUCTION

The performance of a variety of key technologies for the transition to a sustainable society is highly dependent on the flow in very narrow pore spaces, i.e. for carbon capture and storage, in electrodes of electrolyzers or application of supported catalyst. However, predicting gas flow in highly porous media is still riddled with uncertainties, besides decades of research [1].

Especially the influence of the contact of solid wall and gas molecules is considered to be the dominating effect in those small pores. Recently, highly performant state-of-the-art solvers allow for high-fidelity predictions of the gas flow under such regimes. This allows the study so called 'slip'-effects and their incorporation in application-scale pore network models.

A successful incorporation of those 'slip'-effects then allows rapid upscaling for predicting gas flows in real applications and lays the foundation for the modeling of complex multiphase flows.

GOALS

Study the gas flow in nano- and mesopores with state-of-the art kinetic gas solvers and employ pore network models to derive continuum scale properties.

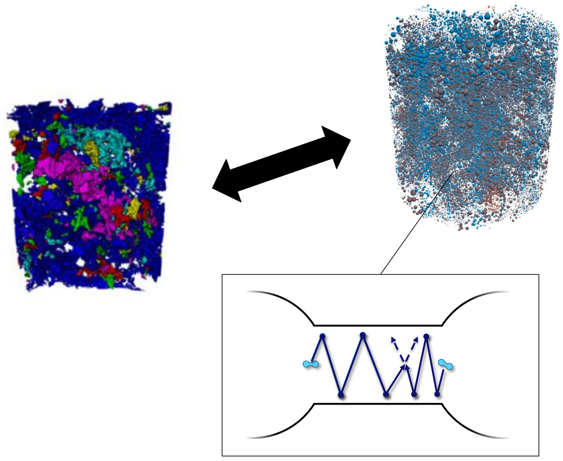


Figure 1 A porous material may be approximated by a network of pores and throats. Accurate predictions of flow in such porous media highly depends on the capturing the relevant transport phenomena, e.g. the wall contact.

BENEFITS

- You will be working with an international team of scientist on a highly challenging and relevant topic
- Gain insights into multiple models at different scales
- Contribute to the fundamental challenges of transitioning to a sustainable economy

PROFILE

We are looking for a highly motivated student who is not afraid to ask critical questions. Prior experience with modelling of porous media is a plus, but not a requirement. Do you feel up to such a challenge? Let's have a talk!

REFERENCES

[1] V. Pavan, L. Oxarango *A New Momentum Equation for Gas Flow in Porous Media: The Klinkenberg Effect Seen Through the Kinetic Theory* **2007** J. Stat. Phys. DOI:10.1007/s10955-006-9110-2

Supervisor	**Dr. Azahara Luna-Triguero**
2nd supervisor	**Dr. Monica E. A. Zakhari**
Mentor	
Company	**Internal**
Starting date	**Any time**
Exp./Num./Design	**Numerical**

CHILLING WITH NANOFLUIDS: Atomistic Insights

A. Luna-Triguero, M. E. A. Zakhari

E-mail: a.luna.triguero@tue.nl, m.e.a.zakhari@tue.nl

INTRODUCTION

The pursuit of energy-efficient and environmentally friendly refrigeration and heat transfer technologies has become paramount due to the escalating demands for cooling in various industrial, residential, and commercial sectors. Conventional refrigerants, such as hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs), have raised significant environmental concerns due to their high global warming potential (GWP) and ozone-depleting properties. As a result, there is an urgent need to explore alternative approaches that can enhance cooling and heat transfer performance and mitigate the environmental impact of refrigeration systems.

One promising alternative in the quest for innovative refrigeration and heat transfer solutions involves the use of nanofluids [1]. Nanofluids are engineered suspensions of nanoparticles in conventional heat transfer fluids, such as water or refrigerants. Incorporating nanoparticles, particularly Metal-Organic Frameworks (MOFs) and zeolites, into these fluids has garnered significant attention for their exceptional thermal properties and potential applications in advanced cooling systems. [2,3]

GOAL

Compute using molecular simulations and ML potentials relevant properties of nanofluids (Fig. 1) for cooling applications.

TASK

In this project, you are expected to:

- Review relevant literature on nanofluids MOFs@Rx pairs.
- Compute relevant properties of the species e.g. heat capacity and thermal conductivity.
- Assess the performance and efficiency of the systems.

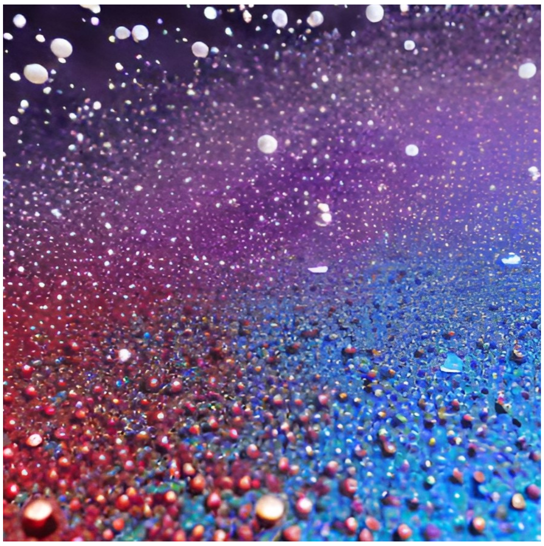


Fig. 1. Nanoparticle suspension in refrigerant. Schematic representation.

STUDENT PROFILE

We are looking for a high-motivated MSc student who has:

- An interest in fundamental and computational work.
- Hands-on attitude toward new challenges.
- Analytical capacity
- Eager to participate as an active member of the group
- Experience with linux os and bash command lines is desired but not mandatory

REFERENCES

[1] McGrail, B. P., Thallapally, P. K., Blanchard, J., Nune, S. K., Jenks, J. J., & Dang, L. X. (2013). Metal-organic heat carrier nanofluids. Nano Energy, 2(5), 845-855.

[2] Nandasiri, M. I., Liu, J., McGrail, B. P., Jenks, J., Schaef, H. T., Shutthanandan, V. (2016). Increased thermal conductivity in metal-organic heat carrier nanofluids. Scientific Reports, 6(1), 27805.

[3] Hu, J., Liu, C., Li, Q., & Shi, X. (2018). Molecular simulation of thermal energy storage of mixed CO_2/IRMOF-1 nanoparticle nanofluid. International Journal of Heat and Mass Transfer, 125, 1345-1348.

Supervisor	Dr. Clemens Verhoosel
2nd supervisor	Dr. Stein Stoter
Mentor	Dr. Stein Stoter
Company	N.A.
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Numerical

Available for ME

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number: 2023 Q2-01

Trimmed explicit dynamics: a non-linear Kirchhoff-Love shell model

Clemens Verhoosel, Stein Stoter
E-mail: k.f.s.stoter@tue.nl

Keywords: *Explicit dynamics, Trimming, Non-linear Kirchhoff-Love shell, Isogeometric analysis*

INTRODUCTION

Explicit analysis forms the backbone of impact and crash-test simulation software (see Fig. 1). These simulations often involve shell-type components. Trimmed isogeometric analysis streamlines the design-to-analysis pipeline for these types of simulations. In isogeometric analysis, the CAD-based spline geometry representation of the shells is used directly in the analysis software.

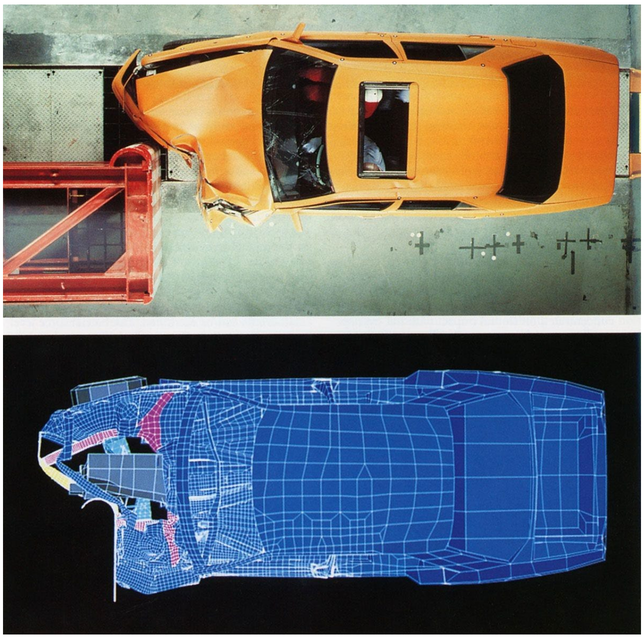


Fig 1: Crash-test simulation. Credit: Cray Research Inc.

PROBLEM STATEMENT

The trimming operation in CAD can lead to elements with very small support. In explicit dynamics, these small cuts may severely limit the permissible time step size. In our group, we have developed methods an analysis procedures for mitigating this adverse effect (see Fig. 2). In this MSc project, you will implement and investigate the performance of this approach for the non-linear variant of the Kirchhoff-Love shell model.

/ ENERGY TECHNOLOGY AND FLUID DYNAMICS

WORK PACKAGE

- Develop a familiarity with shell models and explicit time-stepping methods.
- Extend the existing linear Kirchhoff-Love shell code to a code that can handle the non-linear variant.
- Study the effect of the proposed solution method.
- Depending on the students own learning goals, subsequent research may focus on a shift to the Reissner-Mindlin shell model, or efficient implementation

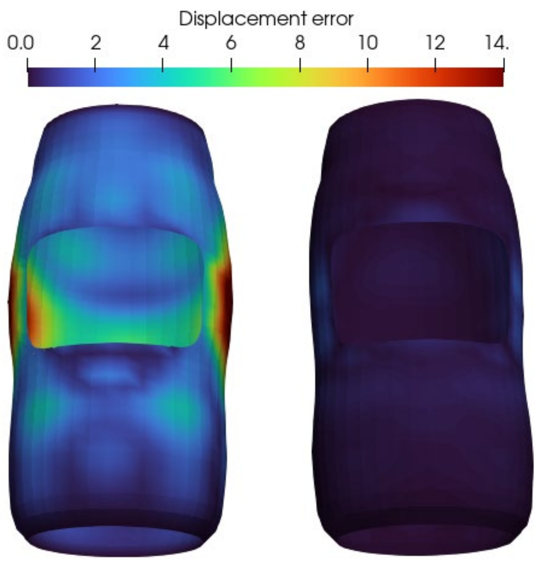


Fig 2: Error in the predicted displacement for the *linear* Kirchhoff-Love shell model, without and with the proposed solution method.

STUDENT PROFILE

We are looking for a MSc student who has:

- Affinity towards (advanced) numerical solution methods,
- Interest in programming and eager to improve upon their existing programming skills (e.g., Python).

REFERENCES

[1] Stoter, S.K.F. et al. (2022). *Variationally consistent mass scaling for explicit time-integration schemes of lower- and higher-order finite element methods*, Computer Methods for Applied Mechanics and Engineering, 399, 115310.

Supervisor	Dr David Rieder
2nd supervisor	Dr Maja Rücker
External Collaborator	Dr Catherine Spurin (Stanford Univ.)
Company	Internal
Starting date	Any time
Exp./Num./Design	Analysis

ETFD

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Catching CO_2 entrapment and abrupt permeability changes in partially saturated porous rocks using CFD and 3D in-situ measurements from the Swiss Light Source

David Rieder*, Maja Rücker, Catherine Spurin
*d.r.rieder@tue.nl

INTRODUCTION

The interaction of multiple fluids in the subsurface is a complex and multi-faceted problem of great importance due to its presence in a broad range of applications including carbon sequestration (Figure 1) and aquifer contaminant containment.

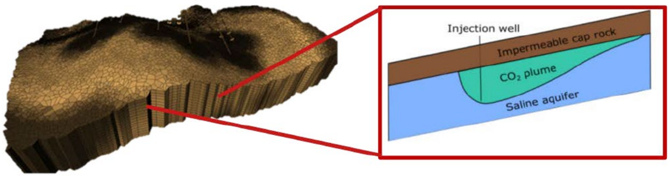


Figure 1: Subsurface CO_2 storage

Recent advances in X-ray imaging has allowed fluids to be imaged in-situ, and a range of flow phenomena have been identified [1-3] that will influence the propagation and trapping of fluids within a rock. These flow dynamics will control how much CO2 can be stored safely underground, or the necessary steps to remediate groundwater contamination.

A key parameter for flow dynamics is the viscosity ratio (this is the ratio of the viscosities of the fluids present). To understand how viscosity ratio controls the change in dynamics is of great importance, and provides the potential to engineer CO2 storage using novel injection strategies to maximize CO2 saturation and decrease the size of the CO2 plume in the subsurface. Fast X-ray imaging conducted at the Swiss Light Source (Villigen, Switzerland) was used to explore the role of the viscosity ratio of flow dynamics. For these experiments, two fluids were injected simultaneously into a carbonate rock sample. Then the viscosity of one of the fluids (the water) was altered to change the viscosity ratio (M). This led to a large change in the flow dynamics, qualitatively shown in Figure 2.

Quantifying the changes caused by the viscosity ratio in this state-of-the-art data set will provide a unique opportunity to understand how changes in viscosity cause flow patterns to evolve and what this means for potential trapping.

GOALS

Quantify the influence of the entrapments on the flow inside the rock by simulating the flow in OpenFOAM.

BENEFITS

- You will be working with an international team of scientists addressing current challenges for sustainable utilization of subsurface resources
- Gain experience in computational fluid dynamics and large data processing
- Advancing our understanding of fluid dynamics in porous systems

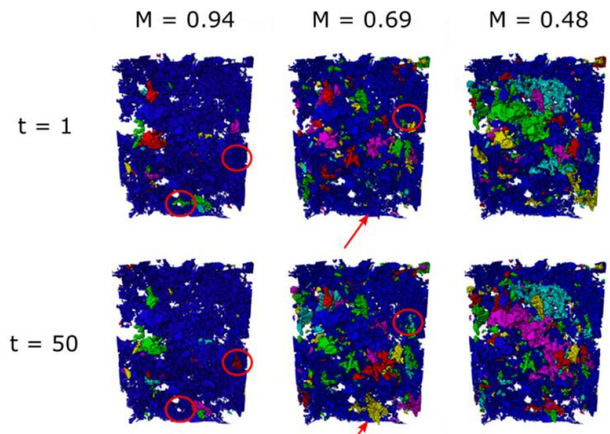


Figure 2: The distribution of the oil phase (rock and water transparent) for different viscosity ratios (M) at two different times t). Each connect region of oil has been assigned a different colour to show the connectivity.

REFERENCES

[1] Spurin, C., Bultreys, T., Rücker, M., Garfi, G., Schlepütz, C.M., Novak, V., Berg, S., Blunt, M.J. and Krevor, S., 2020. Real-Time Imaging Reveals Distinct Pore-Scale Dynamics During Transient and Equilibrium Subsurface Multiphase Flow. Water Resources Research, 56(12), p.e2020WR028287.
[2] Spurin, C., Bultreys, T., Rücker, M., Garfi, G., Schlepütz, C.M., Novak, V., Berg, S., Blunt, M.J. and Krevor, S., 2021. The development of intermittent multiphase fluid flow pathways through a porous rock. Advances in Water Resources, 150, p.103868.
[3] Rücker, M., Berg, S., Armstrong, R.T., Georgiadis, A., Ott, H., Schwing, A., Neiteler, R., Brussee, N., Makurat, A., Leu, L. and Wolf, M., 2015. From connected pathway flow to ganglion dynamics. Geophysical Research Letters, 42(10), pp.3888-3894.

Supervisor	David Rieder
2nd supervisor	Maja Rücker
Daily supervisor	
Company	---
Starting date	asap
Exp./Num./Design	Numerical & Experimental

ETFD

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Uncovering the perplexing effects of efflorescence on the drying processes of porous media

David Rieder, Maja Rücker

*Email: d.r.rieder@tue.nl

INTRODUCTION

Drying is a critical step in a variety of industrial processes, either due to its inherently high energy demand or its impact on the product quality. Especially during drying of porous objects with a non-volatile dissolved component, the dynamics of the deposition inside the pore space may be the performance limiting influence. As an example, the longevity of bricks strongly depends on the salt deposition during drying, the cost of supported catalysts is heavily influenced by the distribution of the catalytic component inside its pellet and pharmaceutical products may never reach application due to lacking control over the drying step.

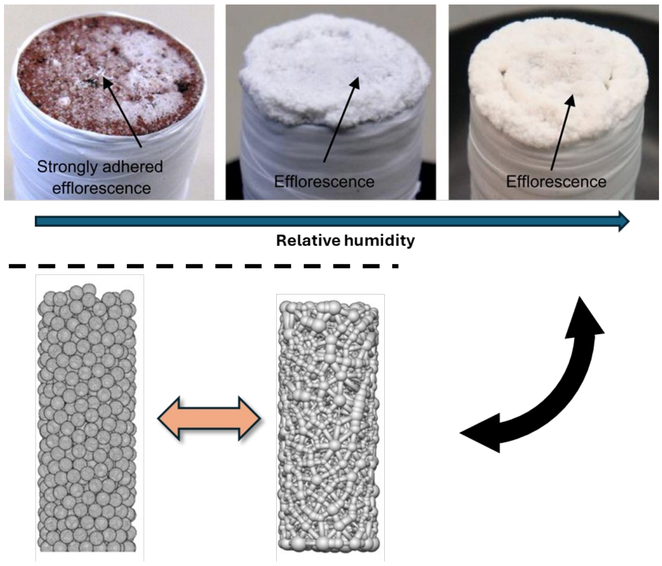
One of the still poorly understood aspects is the interplay between the change of the pore space and the progress of the drying, clearly visible in the form of efflorescence [1,2].

GOALS & TASKS

Your goal is to investigate the influence of mass-transport and precipitation during drying by use of a pore-network model. Further, you will evaluate your model by validation against complementary experimental data.

As part of this work you will:

- Develop a pore-network drying model
- Measure the change in pore space with state of the art 3D µCT machine



The quality of the salt deposition is heavily influenced by the drying condition. You will investigate this fascinating phenomena via pore network modeling and experimental tools. Images taken from [1] and [3]

STUDENT PROFILE

We are searching for a highly motivated student, who:

- wants to dive deeply into the challenging aspects of efflorescence
- is able to work independently
- has initial experience in formulating and solving transport models
- Has worked with Matlab, Python or C/C++ before

REFERENCES

[1] Gupta et al. *Paradoxical Drying of a fired-clay brick due to salt-crystallization* doi:10.1016/J.CES.2014.01.023

[2] Rieder et al. *Modeling the drying process of porous catalysts - impact of viscosity and surface tension* doi:10.1016/j.ces.2023.119261

[3] Eghbalmanesh et al. *CFD-validated pore network modeling of packed beds of non-spherical particle* doi:10.1016/j.ces.2023.119396

Supervisor	Guang Hu
2nd supervisor	Maja Rucker
Daily supervisor	David Rieder, Mohammad H. Khoeini
Company	Internal
Starting date	Anytime
Exp./Num./Design	Numerical & Experimental

ETFD

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Machine Learning for high efficiency analysis of complex chromatographs

Mohammad Hossein Khoeini*, David Rieder, Maja Rucker, Guang Hu

*Email: m.h.khoeini@tue.nl

INTRODUCTION

Porous media are encountered almost everywhere to in science, industry and daily life, e.g. in batteries, chemical reactors, filters or concrete. Knowledge of their characteristic properties is crucial for a successful application design.

Gas chromatography allows the determination of a variety of the relevant properties [1]. However, classical evaluation of the chromatographs is often challenging, especially in the case of complex pore spaces with non-ideal surface properties. Either detailed modeling and subsequent fitting have to be conducted or empirical behavior determined from multiple chromatographs.

We are currently developing methods for expanding the standard evaluation routines and intend to utilize machine learning to maximize the knowledge gain per experiment and increase the fidelity of the derived parameters.

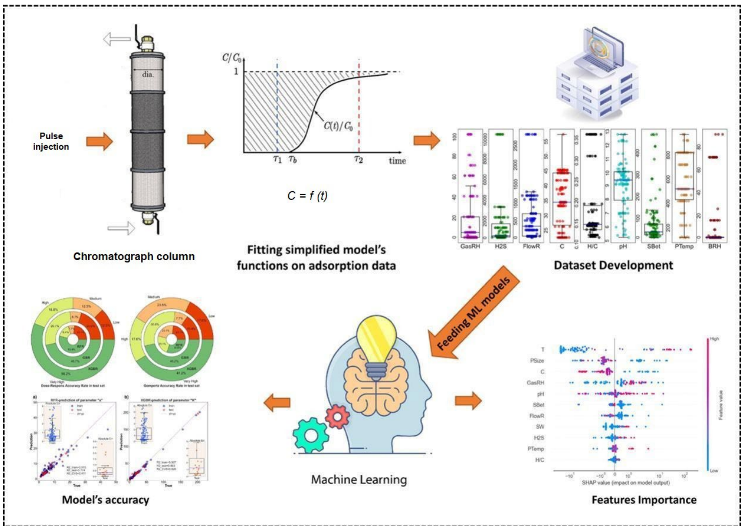


Fig. 1. Schematic representation of using ML approaches in gas chromatography column (adapted from [2])

TASKS

As part of this work you will:

- Train a neural network on an existing data-base of chromatographs
- Build a computational model to compute ideal chromatographs
- Conduct a sensitivity analysis on the machine learning model

GOALS

Develop a machine learning model, which is able to analyze a chromatograph and process parameters and determine otherwise difficult to estimate properties, i.e.

- Isotherms
- Tortuosity
- Surface energy distribution

STUDENT PROFILE

We are searching for a highly motivated student, who has:

- interest in possibilities of machine learning
- a hands-on mentality towards unexpected challenges
- Initial experience in formulating and solving transport models
- Experience with Matlab/Python is of advantage but not strictly necessary
- Analytical skills

REFERENCES

[1] H. Balard, Estimation of the Surface Energetic Heterogeneity of a Solid by Inverse Gas Chromatography, Langmuir 1997 13 (5), 1260-1269.

[2] F.Qaderi, et. Al , A novel machine learning framework for predicting biogas desulfurization breakthrough curves in a fixed bed adsorption column, Bioresource Technology Reports, 2024, 25, 101702.

Supervisor	t.b.d.
2nd supervisor	
Daily supervisor	Marijn van den Heuvel
Company	De Blauwe Feniks
Starting date	T.B.D.
Exp./Num./Design	

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Technical – Financial Analysis for Innovative Heat Pump: Thermoacoustic Heat Pump (TAWP)

Marijn van den Heuvel – De Blauwe Feniks
marijn.vandenheuvel@deblauwe-feniks.nl

INTRODUCTION

District heating networks are an important solution for heating homes without natural gas, but many existing networks still rely on fossil heat sources. That's why, at De Blauwe Feniks — together with partners such as TNO — we are working on innovative technologies to accelerate the transition to fully sustainable district heating.

A promising technology is the thermoacoustic heat pump (TAWP). To better understand the potential of this technology, it is necessary to research the market potential and the technical and financial conditions for implementing the TAWP.

TASKS

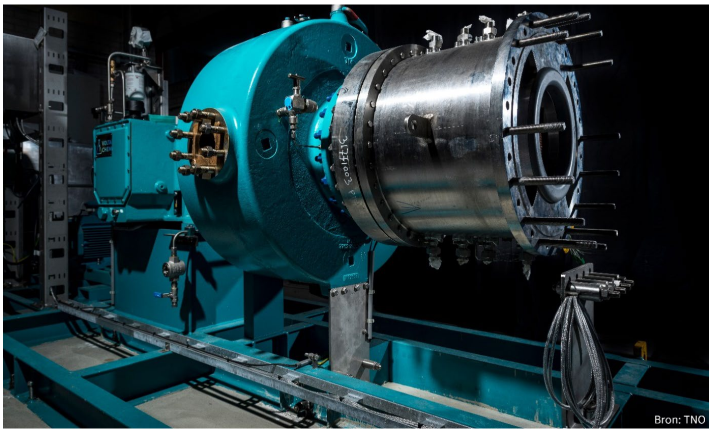
During your project, you will contribute to the research on practical examples and market potential of TAWP. Your focus will be on:

- Comparing the **performance** of the TAWP with existing heat pumps in different district heating scenarios;
- Conducting a **SWOT analysis** for the application of the TAWP in district heating;
- Mapping the **potential market** through literature research and interviews;
- Analyzing how the TAWP can help **reduce peak load** on the electricity grid in collaboration with thermal energy storage.

GOALS

The primary objectives and research questions of this project include:

- Conducting a technical and financial analysis of the TAWP
- Exploring the market potential and adoption opportunities for the TAWP



Bron: TNO

STUDENT PROFILE

- You have strong analytical skills and can report clearly and in a structured manner;
- You have an entrepreneurial mindset and are able to spot opportunities that others might overlook;
- You are independent, proactive, and have an interest in innovative research that makes a real-world impact;
- Experience with data analysis, market research, or energy systems is a plus, but not a requirement.

REFERENCES

Read more: https://deblauwe-feniks.nl/stagiair-gezocht-onderzoek-naar-innovatieve-warmtepomp/

Master Thesis project proposals

Q4 2025

Power & Flow

Department of Mechanical Engineering

Eindhoven University of Technology

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Preface

This is an overview of all the Master Graduation project proposals available in the Power and Flow section.

Please select 3 choices of different projects in order of preference and write a short motivation for your first choice to Giulia Finotello (G.Finotello@tue.nl). Something like:

- My first preference is project…because I am very motivated to work on…
- Second preference is…(no motivation needed)
- Third preference is.. (no motivation needed)

If you need more information on a proposal you can contact directly one of the supervisors (the emails are in each project proposal).

Supervisor	Asst. Prof. Claudia-F. López Cámara
2nd supervisor	TBD
Company supervisor	Prof. Hartmut Wiggers
Company	EMPI, University Duisburg-Essen
Starting date	Anytime
Exp./Num./Design	Experimental

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Plasma synthesis of ultra-pure graphene for electrochemical applications

Claudia-F. López Cámara
c.f.lopez.camara@tue.nl

Introduction

Electrochemical devices (e.g., batteries or sensors) depend on the rapid exchange of charges to achieve their optimum performance. Including reduced graphene oxide or carbon nanotubes as an additive on the nanomaterials used on these devices has shown to enhance their conductivity and therefore, overall performance [1,2]. However, scalability of high performance materials is still an issue. To overcome that, plasma synthesis is shown as a promising alternative for an industrially scalable production, with the advantage of operating in continuous mode and producing ultra-pure free-standing few-layer graphene (FLG) [5-7]. Yet, the synthesis and testing of plasma-produced FLG for electrochemical applications is still limited.

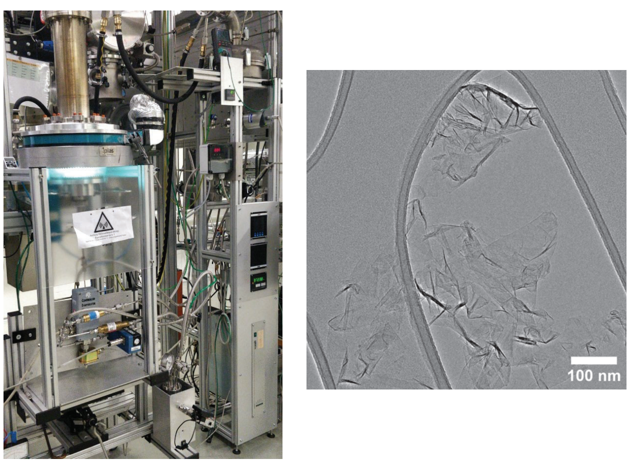


Figure 1. Left: Reactive zone of the microwave plasma reactor at the University Duisburg-Essen. Right: Few-layer graphene as seen under the transmission electron microscopy.

Project description

The focus of the proposed project is on the production of ultra-pure few-layer graphene using gas-phase microwave plasma synthesis and its further characterization and preliminary testing for electrochemical applications.

Goals

1. Synthesize freestanding few-layer graphene via plasma reactor in a consistent and repeatable manner.
2. Characterizing the produced graphene and its attributes (by e.g., Raman, TEM, BET).
3. Preliminary testing of the synthesized graphene for future electrochemistry applications (e.g., batteries).

Requirements

- **The experimental part of this work will be conducted at the University Duisburg-Essen (Germany).** Thus, the student should consider commuting or living in Duisburg for most of the project period.
- The student should be motivated to learn and carry a hands-on project. No previous knowledge is required.

Benefits

The student will be working in a fast-paced collaborative environment and performing his/her work on industry-standard laboratories. S/he will be acquiring hands-on skills on:

- Operation of microwave plasma reactors.
- Safety regulations related to handling powder-form nanomaterials.
- Characterization techniques and analysis of the data.
- Basics on electrochemistry and nanomaterial electrochemical performance.

References

[1] L. Fu et al, Chem. Front. (2021)
[2] D. Pandel et al., ACS Appl. Mater. & Interfaces (2022)
[3] J. Gonzalez-Aguilar et al., J. Appl. Phys. (2007)
[4] A. Dato et al., Nano Lett. (2008)
[5] C.-F. López-Cámara et al., Combust. Flame (2023)
[6] P. Fortugno, C.-F. López-Cámara et al., Appl. Energy Combust. Sci. (2023)
[7] C.-F. López-Cámara et al., Carbon (2024)

Supervisor	Dr. Ir. Yunus Tansu Aksoy
2nd supervisor	
Company	
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Experimental

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Gentle collection of virus-laden droplets:

Droplet impact on oblique surfaces suppressing splashing

Yunus Tansu Aksoy
e-mail: y.t.aksoy@tue.nl

INTRODUCTION

Quantification of infectious viruses in air and assessing their transmission potential via small or large respiratory droplets is crucial for risk assessments of pandemic outbreaks which is notoriously difficult to perform. Whether the air contains infectious virus in sufficient amounts to infect new hosts, and whether this virus is present in small or large droplets that stay dispersed in air for long versus short time periods respectively, is almost impossible to demonstrate (Coleman, 2021). Environmental factors such as temperature and humidity may change droplet dynamics, droplet sizes and number density (through evaporation or condensation) (Bourouiba, 2021) and virus infectivity very rapidly (Herfst, 2017). We want to collect those virus-laden droplets without changing their infectivity as gentle as possible. The collection process requires droplet impact on a solid substrate without harming the droplet. It is already known that the droplet impact dynamics significantly change when nanometer-sized particles are present in the fluid (Aksoy 2022). In this project, the student will study droplet impact on a solid substrate for droplet collection for virus quantification purposes.

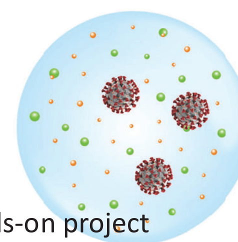
PROJECT DESCRIPTION & APPROACH

The student will build an experimental setup for characterizing post-impact droplet dynamics via high-speed camera. The impact conditions will include several droplet release heights ,i.e., Weber numbers, different surface conditions, e.g., hydrophobic/hydrophilic, and different droplet sizes. Initially, milimeter-size droplets are foreseen, yet smaller droplets can be preferred to match real conditions in the final stages of the project. For safety reasons, we will use test fluids with colloidal particles to mimic virus-laden droplets. Tests with real viruses will be performed by our collaboration partners at the Viroscience Department of the Erasmus Medical Center.

REQUIREMENTS

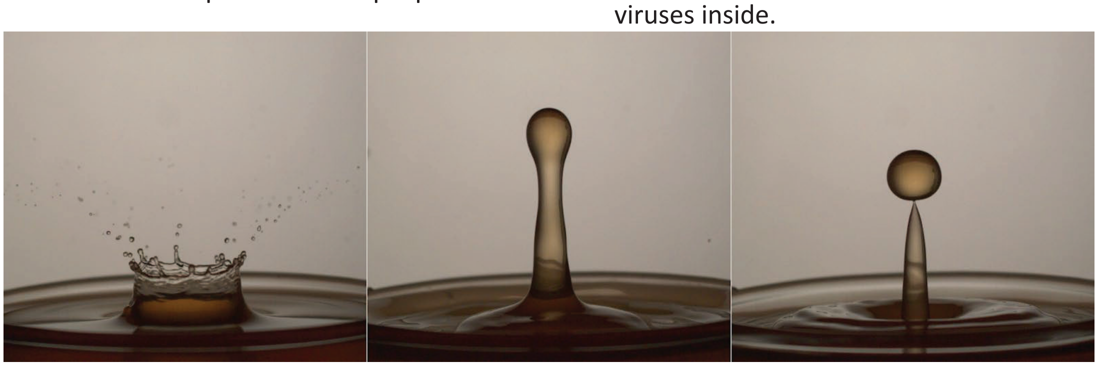
Interest in

- Experimental work
- Fluid mechanics
- Motivation to carry on hands-on project



OBJECTIVE

The main objective of this thesis is to identify the droplet impact conditions allowing users to gently collect the deposited droplets without harming the viruses inside.



REFERENCES

Aksoy (2022) *Journal of Colloid and Interface Sciences* 606 pp 434-443

Bourouiba (2021) *Annual Review of Fluid Mechanics* 53:1 pp 473-508

Coleman et al. (2022) *Clinical Infectious Diseases* 74:10 pp 1722-1728

Herfst et al. (2017) *Current Opinion in Virology* 22 pp 22-29

Supervisor	Xiaoxing Li
2nd supervisor	Prof. Hans Kuerten
Daily supervisor	Xiaoxing Li
Company	Canon Printing Company
Starting date	Any time
Exp./Num./Design	Numerical

Power &Flow

EINDHOVEN UNIVERSITY OF TECHNOLOGY

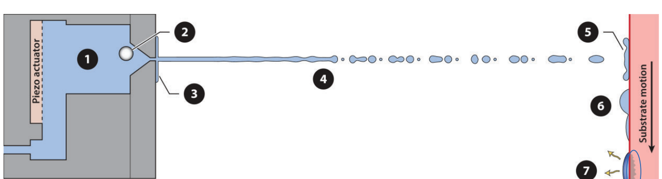
Absorption and Evaporation of Ink in Paper Sheets

Xiaoxing Li, Hans Kuerten
x.li5@tue.nl

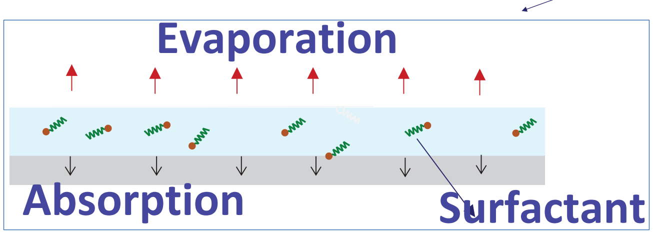
INTRODUCTION

Inkjet printing technology is a common deposition technique with many applications, such as print-based advertising and books. A significant fluid dynamics challenge in inkjet printing is the absorption and evaporation of ink in paper [1-2]. Fast penetration of the ink is desirable to minimize the time droplets remain on the paper [3]. Additionally, fast evaporation can save time and improve efficiency. However, much uncertainty still exists about how to control the absorption and evaporation process of surfactant-laden ink liquid.

Our project has collaborations with Canon printing company.



Lohse D. 2022, Annu. Rev. Fluid Mech.

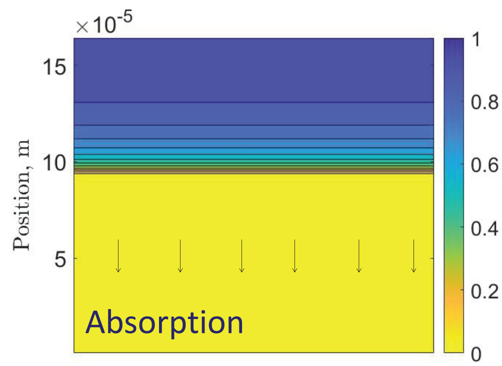


GOALS

The objective of this research is to numerically simulate and study absorption and evaporation of surfactants-laden ink in thin paper sheets.

TASKS

- Develop the evaporation model in porous media.
- Integrate the evaporation model into existing models, which govern the absorption process and surfactant transport in unsaturated porous media.
- Write a computer program to solve the mathematical equations developed using the finite volume method in space and an explicit method in time.



STUDENT PROFILE

- Knowledge of MATLAB or similar programming languages.
- Knowledge of mass transport equations

REFERENCES

[1] Lohse, D. (2022). Fundamental fluid dynamics challenges in inkjet printing. Annual review of fluid mechanics, 54(1), 349-382.

[2] Stenström, S. (2020). Drying of paper: A review 2000–2018. Drying technology.

[3] Daniel, R. C., & Berg, J. C. (2006). Spreading on and penetration into thin, permeable print media: Application to ink-jet printing. Advances in colloid and interface science, 123, 439-469.

Supervisor	Dr. Yuriy Shoshin
2nd supervisor	Dr. Viktor Kornilov
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Experimental

EINDHOVEN UNIVERSITY OF TECHNOLOGY

SYNTHESIS OF METAL OXIDE NANOPARTICLES BY METAL AEROSOL COMBUSTION

Yuriy Shoshin*, Viktor Kornilov

***E-mail: y.s.shoshin@tue.nl**

INTRODUCTION

Nano-particles of metal oxides are widely used in industrial, biomedical, and other applications due to their high specific area and other unique properties. ***The global market of metal-oxides nanoparticles is expected o grow by ~ 9% a year and reach about US$ 10 billion by 2026.***

There are multiple chemical and physical methods exist to produce nano-oxides, and each method has its own advantages and drawbacks. The current technologies face a dilemma: To achieve high purity and well-controlled nano-particle sizes, high energy consumption and expensive equipment are required. The Power & Flow Group is now exploring a more economical way to produce metal-oxide nanoparticles of high qualities—***Generate oxide nanoparticles from vapor condensation via directly burning metal powders in air or other oxidizing gases***.

Keywords: *Metal combustion, nano-particles synthesis, metal oxides*

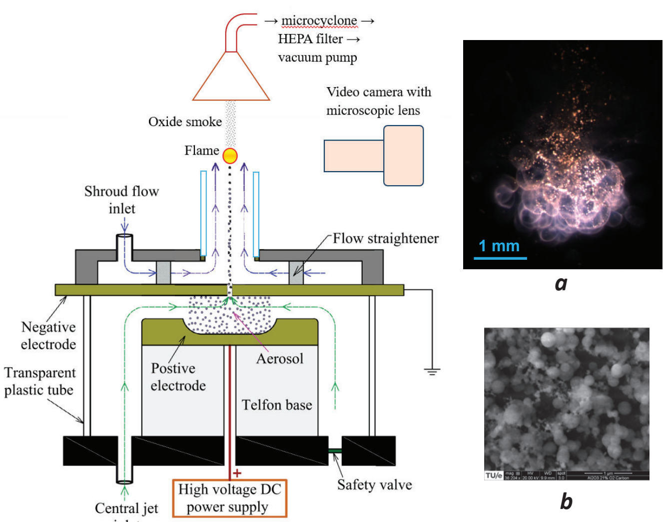


Fig 1. ***a)*** *Schematic of the electrodynamic burner.* ***b)*** *Al aerosol* ***c)*** *Al_2O_3 nano-particles generated by the flame.*

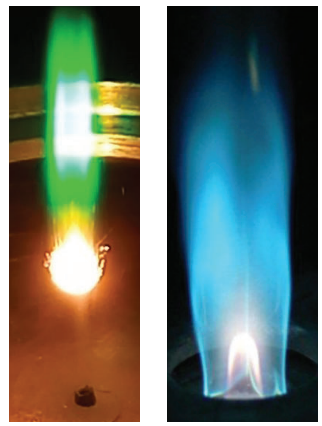


Fig 2.
a) *Iron aerosol micro-flame burning in oxygen. Combustion products (iron oxide nanoparticles) are illuminated with a green laser.*
b) *Hybrid propane-oxygen-zinc dust flame. The blue luminous zone is produced by the own thermoluminescence of condensing ZnO nanoparticles.*

GOALS

- To explore the possibility of synthesizing metal-oxide nanoparticles by direct combustion of (micrometric) metal powders. The prime focus is on iron oxide, while other metals can also be considered.
- To modify the existing micro-burner so that nano-oxide synthesis in hybrid hydrogen-oxygen-metal aerosol flames can be studied.
- To determine the properties (e.g., morphology, size distribution, phase, and elemental composition) via material characterization techniques including X-ray Diffractometry (XRD) and Scanning Electron Microscopy combined with Energy Dispersive Spectroscopy (SEM-EDS).

Achieving all the above goals is not necessary, while the proposed project assumes performing a significant step toward these goals. The proposed project is flexible and the concrete project plan can be adjusted to the preferences of a candidate.

BENEFITS

- Opportunity to get thorough training for material characterization—a highly demanded skill set by many industries.
- Well prepare you for a PhD research on combustion and material synthesis.
- International collaboration opportunities.

Supervisor	Tahsin Berk Kiymaz
2nd supervisor	Dr. ir. Nijso Beishuizen, Prof. Dr. Jeroen van Oijen
Company	BOSCH Thermotechniek
Starting date	Anytime
Exp./Num./Design	Numerical

Power &Flow

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Numerical Analysis of Pressure Effect on Hydrogen Flame Quenching

Tahsin Berk Kiymaz, Nijso Beishuizen, Jeroen van Oijen

E-mail: t.b.kiymaz@tue.nl

INTRODUCTION

There has been an increased interest in the research of hydrogen as a fuel in recent years since it is a promising alternative to fossil fuels with the aim of decarbonization. However, this transition comes with its own challenges. The characteristics of hydrogen are significantly different than conventional fuels such as hydrocarbons. During this transition, the essential point is to make hydrogen combustion safe. Our aim is to investigate the hydrogen flame characteristics and understand the quenching behavior numerically. To design safety equipment, it is essential to determine the quenching distances under pressurized environment. Additionally, it is important to understand the physics behind the change in quenching distances with pressure. These findings will be used to develop fully hydrogen-fueled domestic boilers.

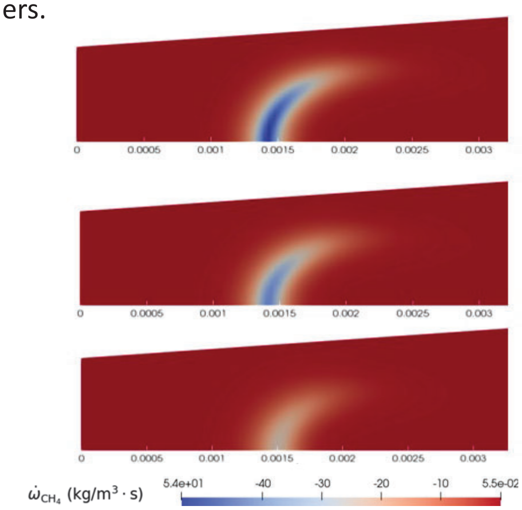


Figure 1: Quenching process of a CH4-air flame for ϕ = 1 at T = 300K

GOAL

Modeling the quenching process of laminar hydrogen flames, with a focus on understanding how does pressure changes effects the flame quenching and establishing a relationship between fundamental flame properties and quenching distance.

TASKS

-Literature study on flame quenching and fundamental flame properties

-Modeling of laminar hydrogen flames using computational fluid dynamic (CFD) approach

-Building a numerical framework to obtain quenching distance of hydrogen flames with changing pressure

- Investigating the relationship between the pressure, flame thickness and laminar flame speed on quenching distance

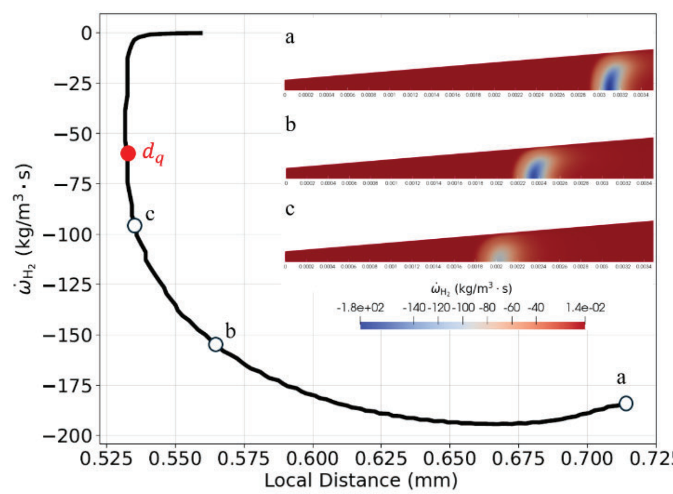


Figure 2: Transient quenching behavior of H2-air flame in a slit for ϕ = 1 at T = 300 K , Φ=1. Quenching distance (d_q) is marked with a red dot.

REQUIREMENTS

- Basic knowledge on fluid dynamics and heat transfer
- Fundamental MATLAB/ Python skills

BENEFITS

-Understand the fundamentals of hydrogen combustion

-Learn how to model reacting flows using CFD methods

-Get hands-on experienced on one of the most widely used CFD software in the industry

-Be a part of the clean energy transition

-Get familiar with the fuel of the future

Supervisor	Asst. Prof. Claudia-F. López Cámara
2nd supervisor	TBD
Company supervisor	Prof. Hartmut Wiggers
Company	EMPI, University Duisburg-Essen
Starting date	Anytime
Exp./Num./Design	Experimental

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Spray-flame synthesis and performance testing of cathode materials for sodium ion batteries

Claudia-F. López Cámara
c.f.lopez.camara@tue.nl

Introduction

Batteries are crucial for the energy transition and helping on creating a more sustainable future. Sodium ion batteries emerge as an alternative to lithium ion batteries. Moreover, the electrode materials in any battery play a critical role on the battery performance and feasibility, having shown that polyanion structures are promising cathode material for sodium ion batteries.

Given the potential large battery materials demand, industrially-scalable methods should be considered when creating electrode materials. Hence, spray-flame reactor processes are considered as a suitable method as they can produce polyanionic-based materials in a highly-reproducible and scalable manner, continuously, and in a cost-effective way. The standardized SpraySyn burner also permits for using a wider variety of reactants, facilitating the investigation of multiple polyanion-based compositions.

Figure 1. Top: Spray-flame from the University Duisburg-Essen. Bottom: T-battery for performance testing.

Project description

The focus of the proposed project is on the production, characterization, and testing of cathode material for sodium ion batteries using spray-flame synthesis.

Goals

1. Synthesize polyanion-based materials in powder form via spray-flame reactor in a consistent and repeatable manner.
2. Characterizing the produced materials and its attributes (by e.g., BET, XPS, FTIR, Raman, TEM, BET).
3. Preliminary performance testing of the synthesized materials on T-cell batteries (e.g., capacity measurements and cyclic voltammetry).

Requirements

- **The experimental part of this work will be conducted at the University Duisburg-Essen (Germany).** Thus, the student should consider commuting or living in Duisburg for most of the project period.
- The student should be motivated to learn and carry a hands-on project.
- No previous knowledge on flame synthesis, cathode materials, or batteries is required.
- No previous experimental experience is required.

Benefits

The student will be working in a fast-paced collaborative environment and performing the experimental work on industry-standard laboratories. By the end of the project, the student will be:

- Capable to operate a spray-flame reactor equipped with a SpraySyn burner.
- Familiar to high-standards on safety regulations.
- Competent on nanomaterial characterization techniques and analysis of the data.
- Knowledgeable on the basics on battery electrochemistry and testing of electrochemical performance.

Supervisor	Xander Seykens (TNO, TU/e)
2nd supervisor	Bart Somers (TU/e)
Company	TNO
Internal / External	External
Starting date	1/9/2024
Exp./Num./Design	Numerical

Available for ME-SET-AT

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Development and validation of a phenomenological H2-HPDI Combustion Model

XANDER SEYKENS

EMAIL: X.L.J.SEYKENS@TUE.NL

INTRODUCTION

Hydrogen is considered as an important (future) fuel for heavy duty combustion engines for mobility and power generation. The hydrogen-diesel High Pressure Direct Injection (HPDI) combustion concept is considered as a feasible combustion concept with high performance potential (power output, load response). This combustion concept is driven by the direct injection of hydrogen which is ignited using a small pilot fuel (e.g. diesel) injection. For engine optimization, fast-computing models with predictive capabilities ("phenomenological model") simulating the HPDI combustion process are desired. These models allow performing iterative engine simulations for systematic optimization, engine concept and controls/diagnostics development. Main focus is on simulating in-cylinder pressure, heat flows and NO emissions.
Currently, a base H2-HPDI fuel injector and a H2-HPDI in-cylinder combustion model, built in the Matlab® environment, are available. These models will serve as the starting point of this assignment.

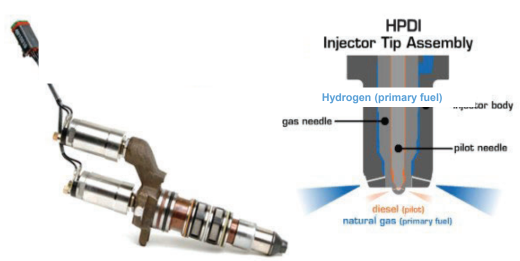


Figure 1: High Pressure Direct Injection of hydrogen is a promising hydrogen engine concept. .

/ POWER AND FLOW

OBJECTIVES

- Development and validation of a phenomenological Hydrogen High Pressure Direct Injection Injector and combustion model. Extension of the model with NOx emission formation.

APPROACH

- Literature study on HPDI (hydrogen) injection and combustion[1]
- Get acquainted with the available H2-HPDI injector and combustion model
- Linking HPDI injector model to the HPDI combustion model and validate simulation results against measurements
- Identify possible model improvements and design, implement and validate solutions
- Extend validated H2-HPDI model with NO formation model
- Validate H2-HPDI model for NOx emissions using available measurement data
- HPDI combustion model sensitivity study towards optimizing efficiency and emissions
- Writing report and presenting results

REQUIREMENTS

- Affinity with combustion engines and numerical work
- Good Matlab modellig skills

LOCATION AND SUPERVISION

The master thesis work will be executed at TNO Powertrains Department located on the Automotive Campus in Helmond. You will be assigned a TNO and TU/e supervisor.

REFERENCES

1. *Literature on high pressure direct injection combustion, E.g. consult the SAE Mobilus database*

Supervisor	Xander Seykens
2nd supervisor	Bart Somers
Company	TNO
Internal / External	External
Starting date	01/09/2024
Exp./Num./Design	Numerical, Experimental

Available for ME-SET-AT

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Aftertreatment for hydrogen internal combustion engine

XANDER SEYKENS
EMAIL: X.L.J.SEYKENS@TUE.NL

INTRODUCTION

Hydrogen is considered as an important (future) fuel for heavy duty combustion engines for mobility and power generation. Hydrogen internal combustion engines (H2-ICE) have high potential for ultra-low engine-out NOx emissions. However, for certain applications, aftertreatment technology is anticipated to be used for first generation of hydrogen engines. The impact of hydrogen on the performance of available aftertreatment technology is not fully clear. At TNO measurements on hydrogen combustion engines with and without aftertreatment have been performed. The goal of this assignment is twofold: On the basis of this data, the impact of hydrogen can be quantified. Next to this, the aftertreatment models used as part of current aftertreatment controls needs to be updated based on these findings.

OBJECTIVES

- Updating available aftertreatment component models and controls to capture main impact of the use of hydrogen as fuel in a heavy duty internal combustion engine

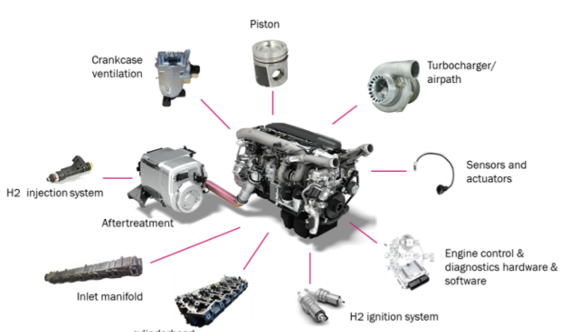


Figure 1: Hydrogen internal combustion engine and use of aftertreatment.

/ POWER AND FLOW

APPROACH

- Literature study on hydrogen as fuel for combustion engines and aftertreatment technology [1]
- Review of available aftertreatment component models
- Evaluation of available measurement data on aftertreatment components used on an heavy duty H2-ICE
- Updating available aftertreatment component models to capture main impact of hydrogen fuel
- Model validation on basis of available measurement data
- Assessment of impact use of hydrogen on aftertreatment controls with use of updated aftertreatment component models
- Verification of available the performance of aftertreatment controls using updated aftertreatment component models
- Writing report and presenting results

REQUIREMENTS

- Affinity with combustion engines and aftertreatment technology
- Interest in numerical work and hands-on experience with Matlab-Simulink®

LOCATION AND SUPERVISION

The master thesis work will be executed at TNO Powertrains department at the Automotive Campus in Helmond. You will be assigned a TU/e and TNO supervisor.

REFERENCES

1. *Literature on high pressure fuel injection systems and measurements of fuel injection rate, mass and momentum. E.g. consult the SAE Mobilus database*

Supervisor	Dr. Ir. Yunus Tansu Aksoy
2nd supervisor	Tess Homan
Company	
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Experimental

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Gentle collection of virus-laden droplets:

Droplet impact on oblique surfaces suppressing splashing

Yunus Tansu Aksoy
e-mail: y.t.aksoy@tue.nl

INTRODUCTION

Quantification of infectious viruses in air and assessing their transmission potential via small or large respiratory droplets is crucial for risk assessments of pandemic outbreaks which is notoriously difficult to perform. Whether the air contains infectious virus in sufficient amounts to infect new hosts, and whether this virus is present in small or large droplets that stay dispersed in air for long versus short time periods respectively, is almost impossible to demonstrate (Coleman, 2021). Environmental factors such as temperature and humidity may change droplet dynamics, droplet sizes and number density (through evaporation or condensation) (Bourouiba, 2021) and virus infectivity very rapidly (Herfst, 2017). We want to collect those virus-laden droplets without changing their infectivity as gentle as possible. The collection process requires droplet impact on a solid substrate without harming the droplet. It is already known that the droplet impact dynamics significantly change when nanometer-sized particles are present in the fluid (Aksoy 2022). In this project, the student will study droplet impact on a solid substrate for droplet collection for virus quantification purposes.

REQUIREMENTS

Interest in

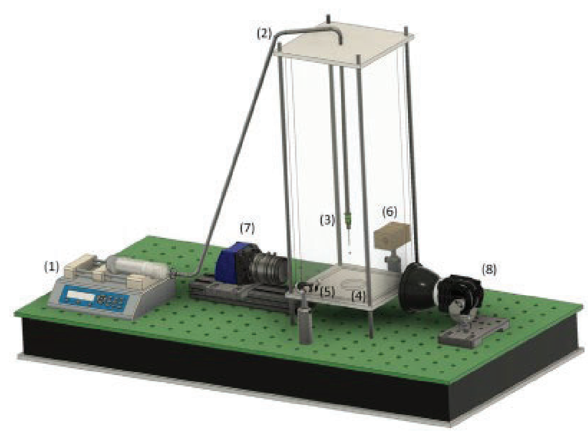
- Experimental work
- Fluid mechanics
- Motivation to carry on hands-on project

OBJECTIVE

The main objective of this thesis is to identify the droplet impact conditions allowing users to gently collect the deposited droplets without harming the viruses inside.

PROJECT DESCRIPTION & APPROACH

This experimental project starts with a literature study. Based on the motivation and literature knowledge, the student will build an experimental setup for characterizing post-impact droplet dynamics via high-speed camera. The impact conditions will include several droplet release heights ,i.e., Weber numbers, different surface conditions, e.g., hydrophobic/hydrophilic, and different droplet sizes. Initially, milimeter-size droplets are foreseen, yet smaller droplets can be preferred to match real conditions in the final stages of the project. No real virus will be used during the experiments due to safety reasons!



Typical experimental setup (Aksoy, 2022)

REFERENCES

Aksoy (2022) *Journal of Colloid and Interface Sciences* 606 pp 434-443

Bourouiba (2021) *Annual Review of Fluid Mechanics* 53:1 pp 473-508

Coleman et al. (2022) *Clinical Infectious Diseases* 74:10 pp 1722-1728

Herfst et al. (2017) *Current Opinion in Virology* 22 pp 22-29

Supervisor	Xander Seykens (TNO)
2nd supervisor	Bart Somers (TUe)
Company	TNO
Internal / External	External
Starting date	01/09/2024
Exp./Num./Design	Experimental, numerical

Available for ME-SET-AT

TNO innovation for life

Modeling of exhaust water recovery model for H2-ICE

XANDER SEYKENS
EMAIL: X.L.J.SEYKENS@TUE.NL

INTRODUCTION

The Hydrogen internal combustion engine is expected to play an important role in realizing sustainable heavy duty transport and meeting 2050 climate goals. At TNO, located on the Automotive Campus in Helmond, research and development on hydrogen internal combustion engines is on-going. For lean burn Spark-Ignited hydrogen engines the use of port water injection, in which water is injected into the intake ports of the engine, is an attractive solution to mitigate NOx emissions and maintain combustion stability during dynamic engine operation. The high exhaust water content of hydrogen engines offers the possibility to realize a self-sustaining system, using water recovered from the exhaust gases for the port water injection. This assignment targets the further development of a phenomenological model of the exhaust water recovery system that allows sizing of such system and development of dedicated water recovery/injection strategies. As a starting point you will use a base model built in the Matlab® simulation environment. Initial focus will be on the further development of a water condenser model including modeling of two-phase flow and liquid water extraction/collection.

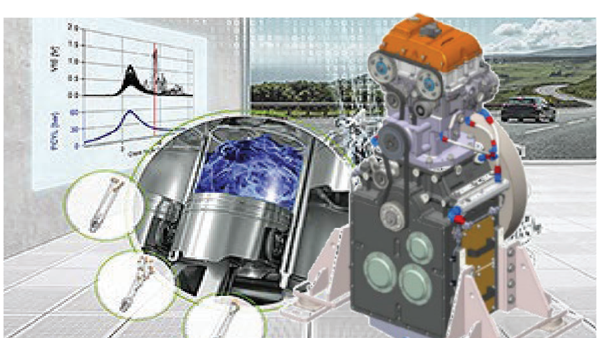


figure 1: Hydrogen Internal Combustion Engine research and development using single-cylinder research engine at TNO [1].

/ POWER AND FLOW

OBJECTIVES

- Further development of a phenomenological exhaust water recovery system model enabling system sizing and water injection strategy development.

APPROACH

- Short literature study on hydrogen combustion engines, water injection and water recovery
- Review of available model and identification of required model extensions.
- Develop and implement model extensions
- Functional demonstration of extended model capabilities on a selected use-case and demonstration of main sensitivities
- Writing report and presenting results

REQUIREMENTS

- Affinity with combustion engines
- Good understanding of thermodynamics
- Experience with Matlab®

PERIOD

Start possible from September 2024. This Master thesis assignment can be converted into 14 week internship.

LOCATION

The project will be executed at TNO Powertrains department at the Automotive Campus in Helmond. You will be assigned a TU/e and TNO supervisor.

REFERENCES

1. *TNO, https://www.tno.nl/en/focus-areas/traffic-transport/roadmaps/sustainable-traffic-and-transport/sustainable-vehicles/how-hydrogen-can-accelerate-energy-transition-in-the-transport-sector/*
2. *Literature on hydrogen combustion engines. E.g. consult the SAE Mobilus database*

Supervisor	Dongliang Liu
2nd supervisor	Dr. Yuriy Shoshin
Starting date	Anytime
Exp./Num./Design	Experimental

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Experimental Investigation on Hydrogen Flame Propagation Pattern in a Confined and Tapered Channel

Dongliang Liu, Yuriy Shoshin
E-mail: d.liu2@tue.nl

Introduction

Hydrogen is a promising clean and renewable energy source. One benefit of hydrogen fuel is that its combustion product is water vapor, which has fewer environmental impacts.

However, using hydrogen as a fuel presents technical challenges and safety concerns. One challenge in a hydrogen burner design is flashback. **Flame Quenching** is an important aspect in preventing flashback processes, representing the minimum channel size that allows a flame to pass. Understanding the quenching process is essential for designing safer hydrogen combustion systems.

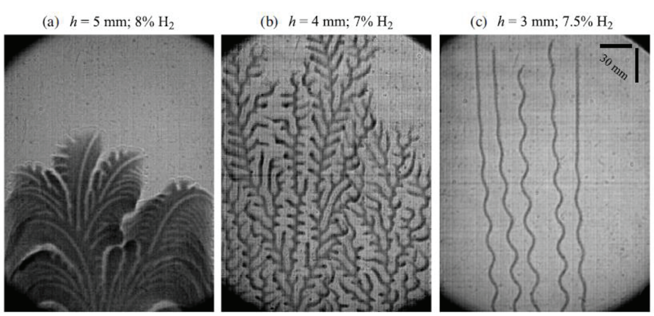


Fig. Images of lean hydrogen flame propagating in a narrow channel (F. Veiga-López, et al., "Unexpected Propagation of Ultra-Lean Hydrogen Flames in Narrow Gaps," May 2020)

Objectives

The primary objective of this master's project is to *investigate the flame propagating behavior and quenching behavior in a converging flat channel* (where the wall distance gradually reduces). Specific goals include:

- Conduct a **literature review** on hydrogen flame propagation in confined spaces, hydrogen flame quenching, and hydrogen flame visualization techniques.
- Modify an experimental setup to **visualize** the flame propagation pattern in a converging channel. While the (optically accessible) converging channel has already been manufactured, your task is **to identify and deploy the most effective measurement technique**.
- **Investigate** the hydrogen flame propagating behavior and the quenching behavior.

Achieving all the outlined goals is not mandatory, but the proposed project aims to make substantial progress toward these objectives. The project plan is adaptable and can be adjusted according to the candidate's preferences.

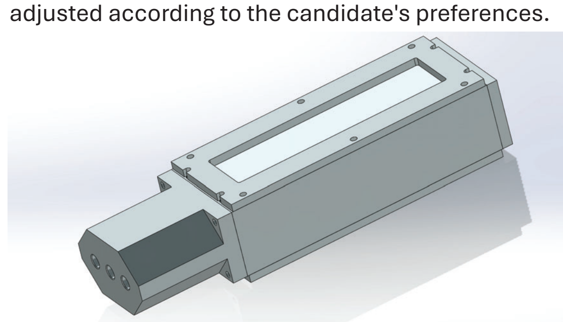


Fig. The tapered converging propagating channel.

Your Profile

We are looking for a motivated student:

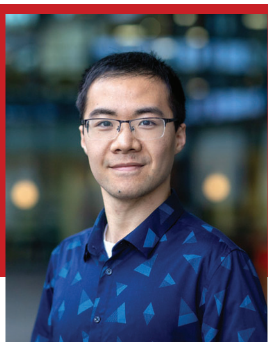
- The ideal candidate will possess some experience in fluid dynamics, combustion processes, and experimental techniques.
- Additionally, the candidate should have good problem-solving skills, the ability to work independently.

This project offers a unique opportunity to contribute to the advancement of hydrogen combustion technology, with the potential to significantly impact the development of safer and more efficient hydrogen fuel systems.

Supervisor	Boyan Xu
2nd supervisor	R.J.M.Bastiaans
Daily supervisor	Boyan Xu
Company	N.A.
Starting date	Anytime
Exp./Num./Design	Numerical

Power &Flow

EINDHOVEN UNIVERSITY OF TECHNOLOGY



The Effect of Conjugate Heat Transfer on Near Lean Blow-off Bluff-body Stabilized Flame

Boyan Xu
b.xu1@tue.nl

Keywords: Turbulent combustion, Heat transfer, Emission

INTRODUCTION

Current simulation results based on bluff body stabilized $NH_3/H_2/N_2$ flame show that lean blow-off is very sensitive to the thermal boundary condition of bluff body. The conjugate heat transfer(CHT) of the bluff body needs to be considered for predicting accurate extinction.

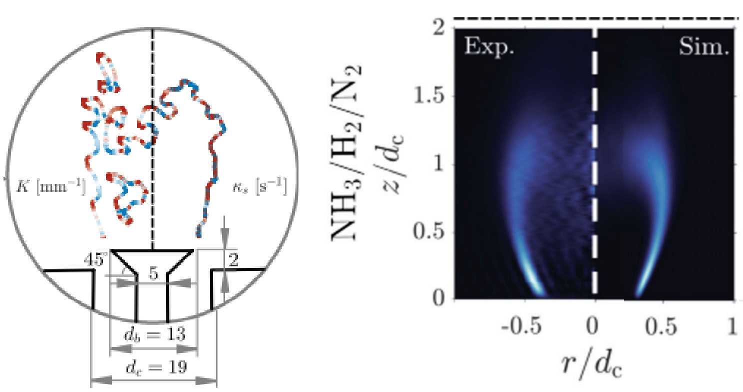


Figure1. a) Schematic of the bluff-body burner with transient flame surface; b) The comparison between experimental measurement and current simulation result(time averaged)

GOALS

- Revise the current 3-D simulation model with including CHT and explore whether CHT plays an important role on the near lean blow-off NH3/H2/N2 flame.

TASKS

- Learn the using of CONVERGE CFD(Similar to FLUENT) software and its setting about Conjugate Heat Transfer(CHT) and implement it on current simulation case.
- Process the simulation data and export them to picture or movie with **Paraview/MATLAB/Python**.
- Compare the flame characteristics and predict lean blow-off with CHT & without CHT.
- Implement FGM combustion model and analyze emission.

BENEFITS

- Freedom for further researches to you interest
- Potential to participate in scientific paper writing

REFERENCES

[1] Su, T., Xu, B., Bastiaans, R. J. M., and Worth, N. A. "Lean Blow-Off Behaviour of Premixed Bluff-Body Stabilized Hydrocarbon-Air Flames and Ammonia/Hydrogen/Nitrogen-Air Flames." ASME. J. Eng. Gas Turbines Power. November 2024; 146(11): 111011.

[2] G. Generini et.al. COMBUSTION MODELLING OF THE T100 MICRO-GAS TURBINE BURNER INCLUDING THE INFLUENCE OF THE STRETCH AND HEAT LOSS/GAIN EFFECTS ON THE FLAME, Proceedings of ASME Turbo Expo 2024.

Supervisor	Xander Seykens (TNO)
2nd supervisor	Bart Somers (TUe)
Company	TNO
Internal / External	External
Starting date	01/09/2024
Exp./Num./Design	Experimental, numerical

Available for ME-SET-AT

innovation for life

Modeling lean burn SI H2-ICE with water injection for NOx reduction in H2-ICE

XANDER SEYKENS
EMAIL: X.L.J.SEYKENS@TUE.NL

INTRODUCTION

The Hydrogen internal combustion engine is expected to play an important role in realizing sustainable heavy duty transport and meeting 2050 climate goals. At TNO, located on the Automotive Campus in Helmond, research and development on hydrogen internal combustion engines is on-going. The spark-lean burn ignited hydrogen engine is characterized by extremely low engine-out NOx in steady state operation. Main NOx dominantly results from dynamic engine operation. Here, the use of port water injection is an attractive solution to reduce combustion temperatures and reduce NOx formation rates. Furthermore, reduction of in-cylinder temperature is a means to stabilize the combustion process avoiding uncontrolled combustion (knock, pre-ignitions). This internship targets to model the impact of the injected water on the combustion process and more specifically on the NOx formation rates and tendency towards unstable combustion. Starting point is a base phenomenological Spark Ignition (SI) Hydrogen combustion model simulating in-cylinder heat release. Matlab® will be used as the modelling environment. Measurement data is available to support model development.

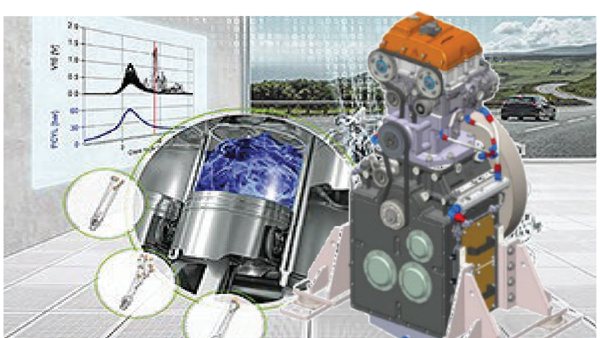


figure 1: Hydrogen Internal Combustion Engine research and development using single-cylinder research engine at TNO [1].

/ POWER AND FLOW

OBJECTIVES

- Extend the available PFI SI In-cylinder hydrogen combustion model to include the impact of water injection on NOx emission formation and to quantify the tendency towards unstable combustion.

APPROACH

- Short literature study on hydrogen combustion engines and water injection
- Analysis of available model and measurement data
- Develop and implement a model for the inclusion of the impact of water injection on NOx emissions and combustion stability.
- Functional demonstration of extended model capabilities and demonstration of main sensitivities
- Writing report and presenting results

REQUIREMENTS

- Affinity with combustion engines
- Good understanding of thermodynamics
- Experience with Matlab®

PERIOD

Start possible from September 2024. This Master thesis assignment can be converted into 14 week internship.

LOCATION

The project will be executed at TNO Powertrains department at the Automotive Campus in Helmond. You will be assigned a TU/e and TNO supervisor.

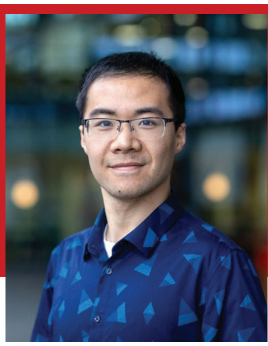
REFERENCES

1. *TNO, https://www.tno.nl/en/focus-areas/traffic-transport/roadmaps/sustainable-traffic-and-transport/sustainable-vehicles/how-hydrogen-can-accelerate-energy-transition-in-the-transport-sector/*
2. *Literature on hydrogen combustion engines. E.g. consult the SAE Mobilus database*

Supervisor	Boyan Xu
2nd supervisor	R.J.M.Bastiaans
Daily supervisor	Boyan Xu
Company	N.A.
Starting date	Anytime
Exp./Num./Design	Numerical

Power &Flow

EINDHOVEN UNIVERSITY OF TECHNOLOGY



Transitioning from Methane to Ammonia-Hydrogen Fuels for Gas Turbine Combustion: Performance and Emissions Analysis

Boyan Xu
b.xu1@tue.nl

Keywords: Combustion, Hydrogen, Ammonia, Gas Turbine

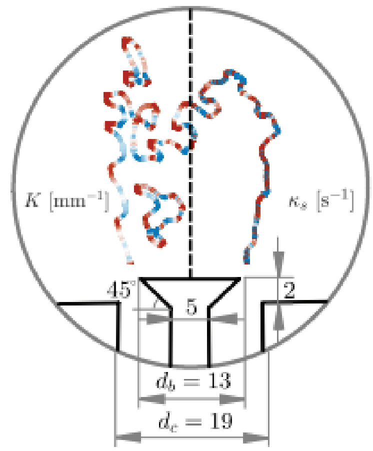


Figure 1. Schematic of the bluff-body burner.

INTRODUCTION

- To achieve carbon neutrality target, alternative fuels (e.g., NH_3/H_2 mixture) with zero carbon emissions have emerged as promising candidates due to their potential for carbon-free combustion in gas turbine.

TASKS

- Calculate 1D flame properties of NH3/H2 flames for different equivalence ratios (lean to rich).
- Design the NH3/H2 ratio and equivalence ratio which has <u>similar flame properties as CH4 and has lower NOx</u>.
- 3D Simulation for NH3/H2 and CH4 flames based on bluff-body stabilized flame and compare flames and their emissions.
- Pressure effect on flame and emissions.

BENEFITS

- Freedom for further associated researches to you interest.

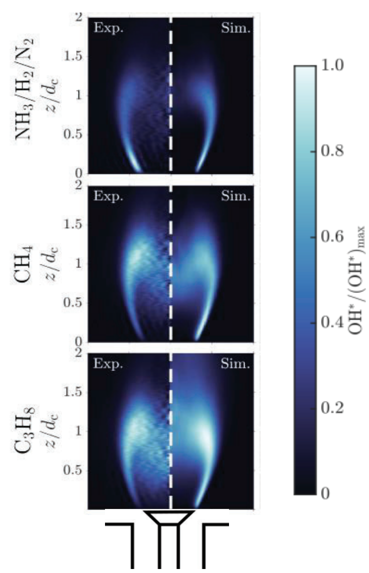


Figure 2. . The Normalized OH* for NH3/H2/N2 flame, CH4 flame and C3H8 flame.

REFERENCES

[1] Su, T., Xu, B., Bastiaans, R. J. M., and Worth, N. A. "Lean Blow-Off Behaviour of Premixed Bluff-Body Stabilized Hydrocarbon-Air Flames and Ammonia/Hydrogen/Nitrogen-Air Flames." ASME. J. Eng. Gas Turbines Power. November 2024; 146(11): 111011.

Supervisor	Michel Cuijpers
2nd supervisor	Noud Maes
Company	TU/e & Progression Industry
Internal / External	Internal/external
Starting date	TBD
Exp./Num./Design	Experimental

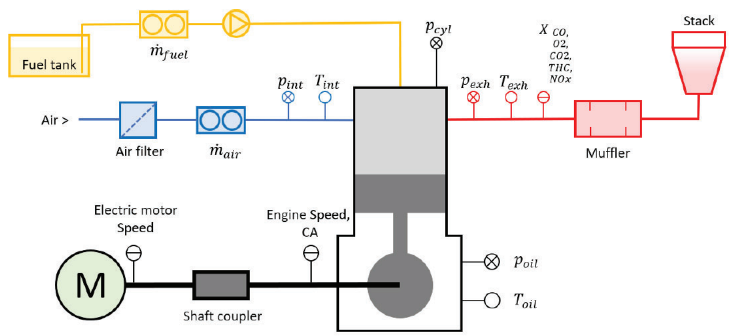
Available for ME

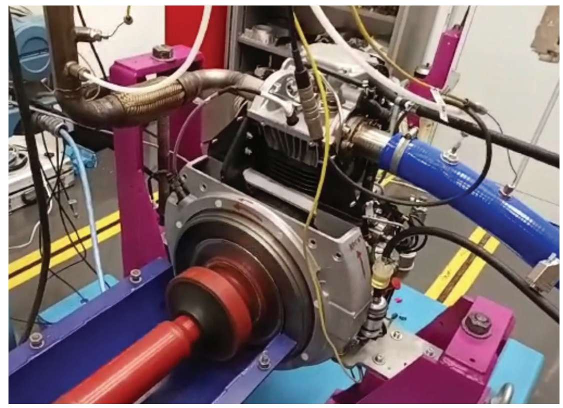
EINDHOVEN UNIVERSITY OF TECHNOLOGY

Progression-Industry
"GREEN" out of the box technologies

Investigating and programming injection strategy possibilities using an open ECU on a single-cylinder CI research engine

Michel Cuijpers, Noud Maes





Introduction

The energy transition from fossil- to E-fuels (renewable fuels produced by clean energy) and biobased fuels will not be an overnight transition. While a future energy surplus from sustainable sources is expected, the availability of E-fuels is still limited to small batches. This means that the world will have to wait for the availability of these fuels, but the engines need to be ready! In this work, particular focus will be given to a newly-commissioned single-cylinder CI research engine, equipped with a so-called open (programmable) ECU. This ECU will allow for modifying the injection strategy towards the fuels of interest.

Subject

The open ECU is used to investigate several fuels regarding combustion properties and emissions by optimizing injection strategy. The student will investigate functions of the Motec M142 open ECU, which is connected to a single cylinder CI engine.

Experimental apparatus

Newly commissioned Hatz 1D90E 4-stroke CI engine with an open ECU to control injection strategy.

Initial activities

- Literature study, familiarization with subject: what are important combustion properties?
- Assist regular experiments, learn to use the set-up (including safety aspects)
- Understanding ECU variables
- Determine data acquisition possibilities
- Initial test runs to check data-acquisition
- Get familiar with Design of Experiments (DoE) for creating an efficient measurement matrix
- Baseline and future fuels testing
- Data analysis

Where

TU/e, Mechanical Engineering, Power and Flow

Type

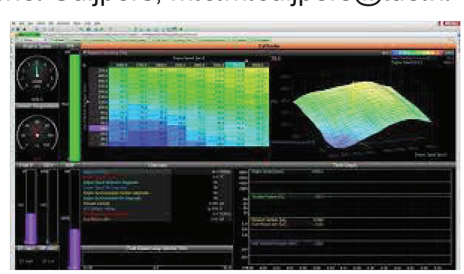
Experimental project

Keywords

Future fuels – Injection strategy – Combustion parameters – Open ECU

Contact

Michel Cuijpers, m.c.m.cuijpers@tue.nl



Supervisor	DAF supervisor
2nd supervisor	Xander Seykens (TU/e)
Company	DAF
Internal / External	External
Starting date	1/06/2024
Exp./Num./Design	Numerical

Available for ME-SET-AT

DAF

A PACCAR COMPANY

Diesel and Hydrogen ICE SCR deNOx NH3 virtual sensing embedded model for ultra-low NOx

XANDER SEYKENS
EMAIL: X.L.J.SEYKENS@TUE.NL

INTRODUCTION

The research it about development of robust SCR controls for Diesel and Hydrogen ICE exhaust gas aftertreatment systems that are capable of meeting EPA 2027 NOx and NH3 slip requirements. What improvements can be done to get more robust control design over 650 kmile emission life time?

Embedded models for the SCR deNOx system are using systems (virtual) sensors, e.g. temperature, exhaust flow and NOx sensors system in and out. Ultra low emission legislation EPA 2027 require NOx emission levels in tailipipe ranging 0-2 ppm, while the NOx sensor has an accuracy of +/- 5 ppm. Meeting these requirements is a challenge from model and control perspective and requires fundamental understanding of SCR catalyst dynamics flow and temperature, chemistry and ageing behaviour.

Since mid 2023 a proof of concept is running and first sensitivity studies are performed on the engine dynamometer. These test data can be used and applied in current SCR embedded model (S-function) simulation environment to assess the system capabilities and determine further model and control improvements to make the system more accurate on NOx and NH3 slip prediction and applying DEF (NOx reductant) compensations to correct for system biases.

OBJECTIVES

The main objective of this assignment is the development of robust SCR model for virtual sensing of NH3 storage and control objective to meet EPA 2027 35mg/bhph NOx emission requirements.

/ POWER AND FLOW

APPROACH

The complete assignment comprises 3 phases of which phase 1 is considered as part of the (extended) internship assignment.

Phase 1 (internship or master thesis):

- Literature study on deNOx aftertreatment technology, modelling (virtual sensing) for diesel and hydrogen combustion engines
- Literature/IP study on control algorithm and sensor architecture for SCR deNOx aftertreatment
- Propose improved model and control design
- Provide preliminary simulation results to fund the proposed control design

Phase 2 + 3 (master thesis):

- Design Rapid Prototyping SCR model and Controls in Matlab-Simulink®
- Vehicle demonstrator

REQUIREMENTS

- Affinity with combustion engines and aftertreatment technology
- Interest in numerical work and hands-on experience with Matlab-Simulink®

LOCATION AND SUPERVISION

The master thesis work will be executed at DAF Trucks in Eindhoven. You will be assigned a TU/e and DAF supervisor.

Further information

- Marc van Aken – Principal Engineer Aftertreatment Systems – Paccar Global Engines
- E-mail: Marc.van.Aken@Paccar.com
- Phone: +31 (0)40 – 214 3964

REFERENCES

1. *Literature on Selective Catalytic Reduction (SCR) deNOx Catalysts, SCR dosing controls, model-based control E.g. consult the SAE Mobilus database*

General information	
Supervisor	Nico Dam
Mentor	Youri van den Brink
Internal/External	Internal
Exp./Num./Design	Experimental / Design

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Experimental Acoustic Field Measurement: Technique Development and Validation

Youri van den Brink*, Nico Dam
*E-mail: y.v.d.brink@tue.nl

INTRODUCTION

Preventing the release of microplastics (< 100 µm) into the environment is a significant challenge, particularly in wastewater treatment [1]. High-frequency acoustics offers a promising avenue for capturing these particles by establishing standing waves that guide them towards collection points (acoustophoresis). However, optimizing this process hinges on accurately understanding and controlling the complex acoustic fields generated within the fluid.

We currently have a water tank equipped with a programmable, multi-axis moving arm. This setup provides a versatile platform for acoustic experiments, but currently lacks a dedicated, standardized method for measuring the acoustic pressure fields generated by high-frequency transducers.

This project addresses the need to develop, implement, and validate a reliable acoustic field measurement methodology utilizing the existing water tank and moving arm infrastructure. The goal is to create a system capable of characterizing the acoustic fields essential for optimizing microplastic manipulation.

TASKS & GOALS

Design, implement, and validate an acoustic field mapping system using the existing tank and moving arm, and use it for initial transducer characterization.

Research & Conceptualize: Investigate and propose suitable acoustic measurement techniques for the setup.
Design & Build: Develop and assemble the sensor attachment and interfacing hardware for the moving arm.
Integrate & Test: Combine probe with arm/data acquisition, test functionality, and validate the system.
Measure & Analyze: Map acoustic fields from transducers using the developed system; analyze data (e.g., MATLAB/Python).

STUDENT PROFILE

- Enjoys hands-on design, building, and measurement.
- An interest in learning how to acquire and analyze experimental data (tools like MATLAB/Python are nice to know).
- Enthusiasm for working with mechanical setups and sensors. Prior specific experience in acoustics is not required.

BENEFITS

- Gain practical experience in setting up and testing a measurement system.
- Develop skills in handling experimental equipment and analyzing the resulting data.
- Learn about acoustic measurement principles and their application.

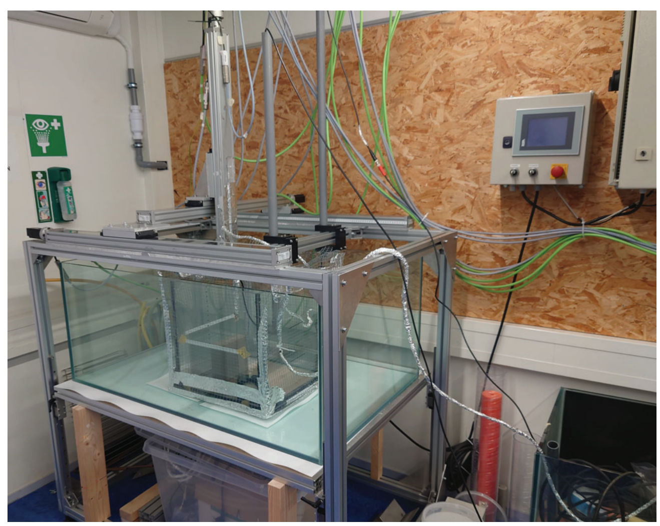


Figure 1: Image of the water tank with multi-axis moving arm

REFERENCE

[1] Talvitie et al., (2017). Water Research, 123. DOI: 10.1016/j.watres.2017.07.005.

Supervisor	dr.ir. Noud Maes
2nd supervisor	dr.ir. Michel Cuijpers, Zhongcheng Sun, Benjamin Haefele (Shell), Tom Lewis (Shell)
Company	Shell
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Experimental

Available for ME-AT

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Ultra-clean engines using sustainable bio-fuel blends

Noud Maes, Michel Cuijpers, Zhongcheng Sun, Benjamin Haefele*, Tom Lewis*
*Shell Global Solutions (Deutschland) GmbH

Introduction

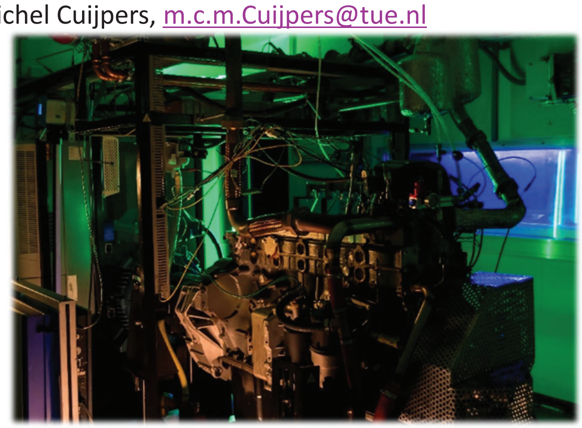
The energy transition from fossil- to bio-fuels (and eventually E-fuels produced by clean oversupply energy) will not be an overnight transition. While a future energy surplus from sustainable sources is expected, the availability of E-fuels is still limited to small batches. On the shorter term, the share of bio-fuels needs to be investigated to facilitate a faster decarbonization rate. In this work, particular focus will be given to different bio-fuel blends which have a lower CO_2 impact when compared to the standard EN590 B7 fuel that passenger cars, light-duty transport, but especially heavy-duty trucks currently use. In initial tests, however, some of these fuels showed opposite effects on other emissions such as soot (PM vs PN) and NO_x. Using a design-of-experiments (DOE) approach, the optimum between blend ratios for reduced global emissions (CO_2), and local emissions (soot and NO_x) should be determined.

Project description

1. Investigate properties of different bio-components
2. Determine combustion properties of selected fuels
3. Follow measurement matrix based on DOE
4. Focus on post-processing of existing and new data, including repeatability and error analysis

Contact

Noud Maes, n.c.j.maes@tue.nl
Michel Cuijpers, m.c.m.Cuijpers@tue.nl



Photograph of the MX13 test engine

/ POWER AND FLOW

Experimental apparatus

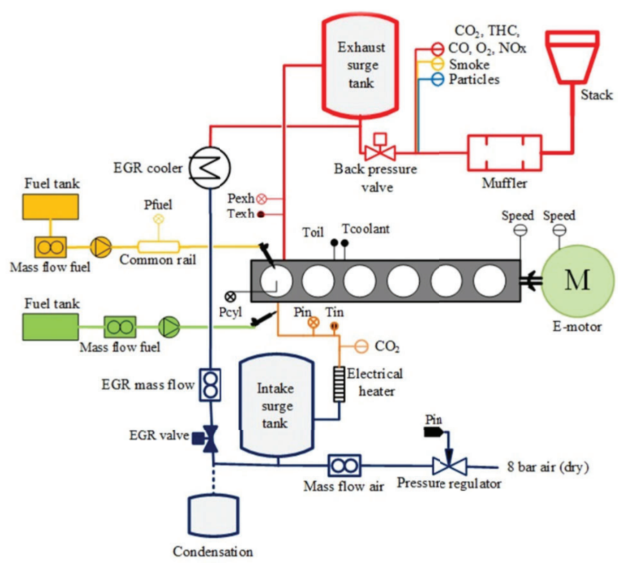
The goal of this project is to conduct experiments on a dedicated single-cylinder research engine. This engine is equipped with a state-of-the-art fuel-flexible injection system, pressure- & temperature sensors, and advanced emission analysis systems. The power generated by the engine is delivered back to the electricity grid via an electric motor. This motor is used both as a dynamometer and to motor the test cylinder when no fuel is injected.

Tasks

- Literature study, getting familiar with the fuels, engines, combustion properties, and analytic methods
- Involvement with preparing the engine setup
- Benchmark engine testing using conventional fuels
- Benchmark engine testing using different blends
- Analysis of the data to write a concise report, with the goal of publishing the final result

Requirements

- Affinity with experimental work & combustion engines
- Background knowledge on internal combustion engines
- Motivation and a hands-on mentality
- Matlab programming & data analysis skills



Schematic layout of the MX13 test engine

Supervisor	Rob Bastiaans
2nd supervisor	
Company	N.A.
Internal / External	Internal
Starting date	2025
Exp./Num./Design	Theoretical & numerical

Available for ME-SET-AT-AIES

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number: 2025 Q3-01

Finding a usable entropy of turbulence information

Rob Bastiaans,
EMAIL: r.j.m.bastiaans@tue.nl

INTRODUCTION

From his Stanford 2023 summer research your supervisor on premixed turbulent combustion kernels he conjectured the existence the associated phenomenon of 'white holes', [1]. Of course, this was applied to a carbon free fuel and using DNS with detailed chemistry to reveal the truth.

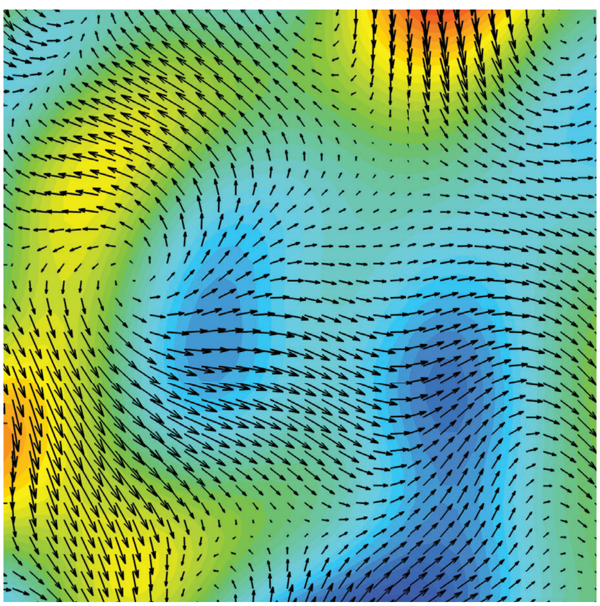


Figure 1: Snapshot of a section of an ideal turbulent field. Colors indicate the velocity in perpendicular direction.

Your task will be to investigate the concept of entropy of the turbulence connected to the conjecture as proposed in the article. You will take an ideal turbulent case from a DNS simulationas a first step.

/ POWER AND FLOW

figure 2: Leonardo da Vinci detected it but how can we define this complex information, in a single scalar?

APPROACH

- You will study information in an earlier MSc study [2]
- You will study associate literature, e.g. [3]
- The intention is to find a suitable definiotion and associated algorithm for turbulence entropy.
- Possibly connect turbulence information to the thermodynamic entropy in combustion

PREFERENCES

- Interested in complex phenomena
- Familiarity with turbulent phenomena
- No freight of mathematics

REFERENCES

[1] R.J.M. Bastiaans & X. Liu, Turbulent, premixed, spherical NH_3/H_2 combustion; Simulation optimalization and the existence of 'white holes'. CTR Annual rResearch Briefs 2023, Stanford, pp 69-82.

[2] R. van Ginkel, Analytical and Numerical Analysis of Entropy, Structures, and Turbulence Dynamics, MSc thesis, To appear 2024.

[3] H. Yao, P.K. Yeung, T.A Zaki & C. Meneveau, Forward and Inverse Energy Cascade in Fluid Turbulence Adhere to Kolmogorov's Refined Similarity Hypothesis, PHYSICAL REVIEW LETTERS 132, 164001 (2024).

Supervisor	Rob Bastiaans
2nd supervisor	Xiaocheng Mi
Company	N.A.
Internal / External	Internal
Starting date	??/??/2024
Exp./Num./Design	Theoretical & numerical

Available for ME-SET-AT-AIES

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number: 2025 Q3-01

Estimating the effect of interparticle radiation in iron combustion

Rob Bastiaans, Xiaocheng Mi
EMAIL: r.j.m.bastiaans@tue.nl

INTRODUCTION

In combustion of iron particles, which is a promising carbon free and circular energy provider, the effect of interparticle radiation on heat transfer is yet not researched in detail. We will start the research with looking at the total ensemble of possible interparticle distances if they are randomly distributed. Later also possible iron particle size distributions should be involved. It is possible to test the theory and assumptions in 3D simulations as well as a condensed version in 1D CFD approaches.

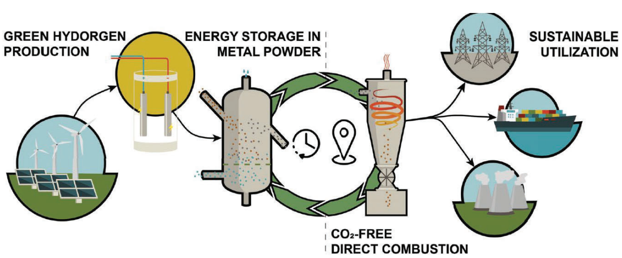


figure 1: Schematic depiction of the metal fuel cycle. Green energy from wind and solar can be used to reduce metal-oxides into metals. Which can be used as an energy transport and storage medium. When energy is demanded, the metals can be burned without CO2-emissions, and the heat can be used for various purposes. The combustion product - metal-oxides - should be captured and re-used, creating a closed cycle.

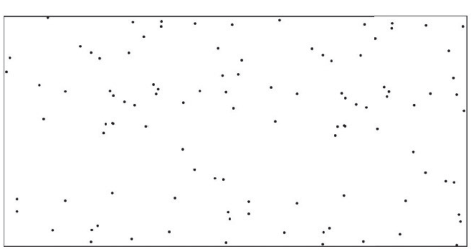


figure 2: Randomly distributed particles

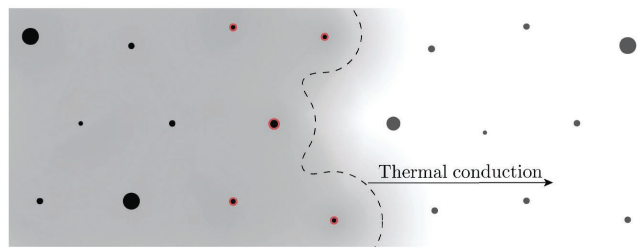


Figure 3: Randomly distributed particles with differences in size and only consideration of thermal conductivity. The burning particles are indicated by the red reaction layer at their surface. The gray color indicates the temperature of the gas, and the dashed line an arbitrary thermal isoline to indicate the local curvature of the flame front when defined by thermal isolines.

APPROACH

- You will study information of a PhD study [1]
- You will look into the distance distribution of randomly located particles using the associated Poisson distribution.
- You will look to iron particle size distribution as well.
- Comparison with CFD approaches

PREFERENCES

- Interested in complex phenomena
- No freight of mathematics

REFERENCES

[1] M.R. Hulsbos, The Heat Flux Method for Flat Hybrid Iron-Methane-Air Flames. PhD thesis, Eindhoven University of Technology, 2024, To appear.

General information	
Supervisor	Nico Dam
Mentor	Youri van den Brink
Internal/External	Internal
Exp./Num./Design	Experimental / Design

EINDHOVEN UNIVERSITY OF TECHNOLOGY

3D Particle Tracking in an Acoustic Device using Defocusing Particle Tracking

Youri van den Brink*, Nico Dam
*E-mail: y.v.d.brink@tue.nl

INTRODUCTION

Preventing the release of microplastics (< 100 µm) into the environment is a significant challenge, particularly in wastewater treatment [1]. High-frequency acoustics offers a promising avenue for capturing these particles by establishing standing waves that guide them towards collection points (acoustophoresis). Optimizing the design and performance of these acoustic devices is greatly aided by accurately understanding the complex, three-dimensional particle motion induced by the acoustic fields. While conventional microscopy provides valuable 2D information, it cannot capture the full out-of-plane movement critical for analysis.

General Defocusing Particle Tracking offers an elegant solution. Its key advantage lies in reconstructing 3D particle positions using only a single camera and standard optics, analyzing the characteristic shape changes in defocused particle images (See Figure 1) [2]. This simpler setup eases the integration compared to multi-camera setups. This project aims to develop and implement a defocused tracking system (imaging setup and post processing) to investigate particle dynamics within acoustic devices, enabling device optimization and validation of COMSOL simulation models.

TASKS & GOALS

Design, build (imaging setup & analysis scripts), and validate a defocused tracking system to measure 3D particle motion under acoustic actuation.

Design & Setup: Design and assemble the optical measurement setup compatible with existing equipment.
Processing (MATLAB): Implement core defocused tracking and calibration functions in MATLAB.
Experimentation & Analysis: Record particle motion in acoustic devices; analyze 3D trajectories and potentially compare with COMSOL model results.

STUDENT PROFILE

- Interest in creating measurement systems, involving both hardware setup and MATLAB programming.
- Desire to learn advanced image processing and data analysis techniques.
- Interest in the process of measurement and interpreting experimental findings. Prior optics/tracking experience is beneficial but not essential.

BENEFITS

- Gain hands-on experience building and calibrating an optical imaging system.
- Improve your skills in MATLAB programming, particularly for image processing and data analysis.
- Learn a novel 3D particle tracking technique and apply it to acoustic manipulation.

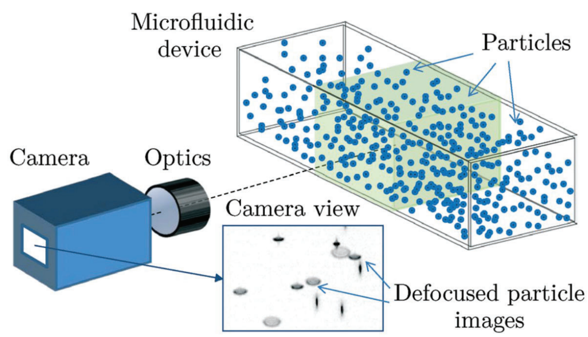


Figure 1: Schematic of the defocused tracking setup showing the camera view capturing defocused particle images within the microfluidic device. [3]

REFERENCE

[1] Talvitieetal.,(2017).WaterResearch,123. DOI:10.1016/j.watres.2017.07.005.
[2] Rossi, M., & Barnkob, R. (2020). A fast and robust algorithm for general defocusing particle tracking. Measurement Science and Technology, 32(1), 014001. DOI: 10.1088/1361-6501/abad71
[3] Barnkob, R., Kähler, C. J., & Rossi, M. (2015). General defocusing particle tracking. Lab on a Chip, 15(17), 3556-3560. DOI: 10.1039/c5lc00562k

Supervisor	Noud Maes
2nd supervisor	Michel Cuijpers
Company	Progression Industry and TU/e
Internal / External	Internal and external
Starting date	TBD
Exp./Num./Design	Experimental

Available for ME

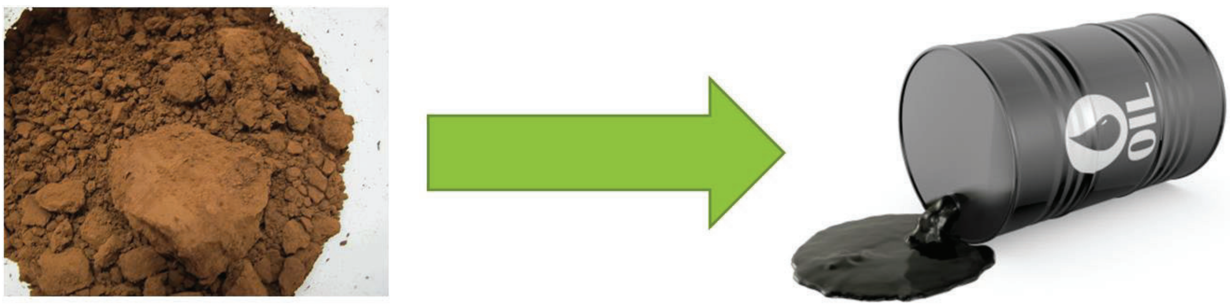
EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number: 2025

Progression-Industry
"GREEN" out of the box technologies

Bio-based future fuels for CI engines

Michel Cuijpers, Noud Maes
EMAIL: M.C.M.Cuijpers@tue.nl



Source Challenge Target

Introduction

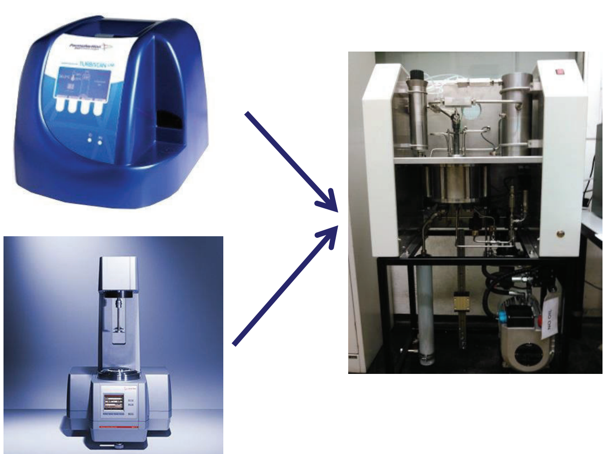
The energy transition from fossil- to biomass fuels (renewables) will not be an overnight transition. The availability of suitable biomass is still insufficient and therefore, mixtures of bio- and fossil fuels, that meet (emission) legislation requirements, are being pursued as an intermediate step.

Subject

Designing future fuel solutions by optimizing combinations of bio-mass derived products with conventional transportation fuels. Determine fuel- and combustion- properties of the designed fuels.

Experimental apparatus

Rheometer MCR 302, Turbiscan Lab expert, Flash 2000 elemental analyzer and a Combustion research unit (CRU).



First weeks action

- literature study, reading into subject, what are important fuel- and combustion- properties
- Assist regular experiments, learn to use set-up including safety aspects
- Blending, preparation bio-based fuels
- Analyses
- Improvement
- Possible engine testing, if above properties are within range.

Where

Eindhoven university of Technology, Mechanical Engineering, Dept. Power and Flow

Type

Experimental project

How

Analyzing fuel properties with help of available analyze equipment

When

Negotiable

Keywords

Biomass – Energy transition –Fossil fuels- Stability - Lubricity

Skills

Hands on mentality, experimental interest

Note

Experimental approach based on literature

Contact

Michel Cuijpers, m.c.m.cuijpers@tue.nl

Supervisor	Boyan Xu
2nd supervisor	R.J.M.Bastiaans
Daily supervisor	Boyan Xu
Company	N.A.
Starting date	Anytime
Exp./Num./Design	Numerical

Power &Flow

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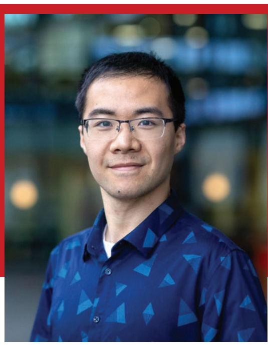

Modelling bluff-body stabilized flame with FGM model

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Keywords: Turbulent combustion, FGM

INTRODUCTION

- Current Large eddy simulation for bluff body stabilized premixed $NH_3/H_2/N_2$ flame needs long simulation time(5+days for a 50ms case).
- Flamelet-Generated Manifolds(FGM) model uses a lookup table to quickly retrieve thermochemical information therefore reduce computational time(order-of-magnitude speedups).

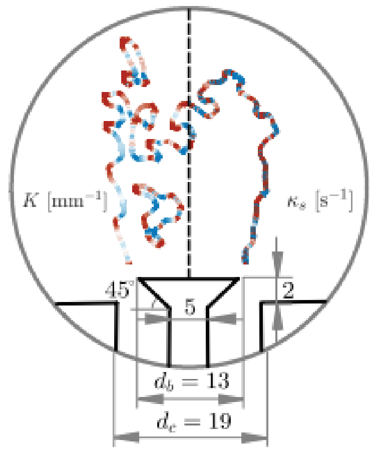

Figure 1. Schematic of the bluff-body burner.

TASKS

- Learn the using of CONVERGE CFD (ANSYS-FLUENT like commercial software, easier)
- Build 1-D flamelet(FGM table) for premixed NH3/H2/N2/O2 flame.
- Implement FGM based on original case. Make records for the simulation time.
- Compare the result(flow field & flame position) with previous simulation/experiment.

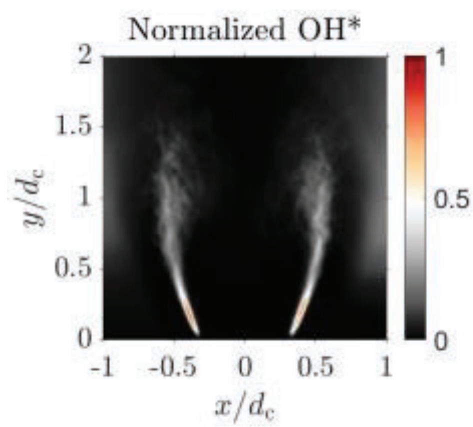

Figure 2. Simulation result(time-averaged) with detailed chemistry model.

BENEFITS

- Freedom for further associated researches to you interest
- Potential to participate in scientific paper writing

REFERENCES

[1] Su, T., Xu, B., Bastiaans, R. J. M., and Worth, N. A. "Lean Blow-Off Behaviour of Premixed Bluff-Body Stabilized Hydrocarbon-Air Flames and Ammonia/Hydrogen/Nitrogen-Air Flames." ASME. J. Eng. Gas Turbines Power. November 2024; 146(11): 111011.

Supervisor	Dr. Stein Stoter
2nd supervisor	N.A.
Mentor	Dr. Stein Stoter
Company	N.A.
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Numerical

Available for ME

EINDHOVEN UNIVERSITY OF TECHNOLOGY

The sound of turbulence

Stein Stoter
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Keywords: *Turbulence modelling, Fourier representation*

INTRODUCTION

Turbulent flow is characterized by the interaction between large-scale and small-scale flow structures, which together govern the transfer of energy and momentum. These structures often exhibit repeating, periodic patterns, providing an opportunity to better understand the flow by "listening" to its dominant frequencies.

RESEARCH TOPICS

- Search for available turbulent flow datasets.
- Analyze a suitable turbulent flow datasets, perform a discrete Fourier Transform, and search for the prevalent modes.
- Investigate how well a hand-full of modes can reproduce the important characteristics.

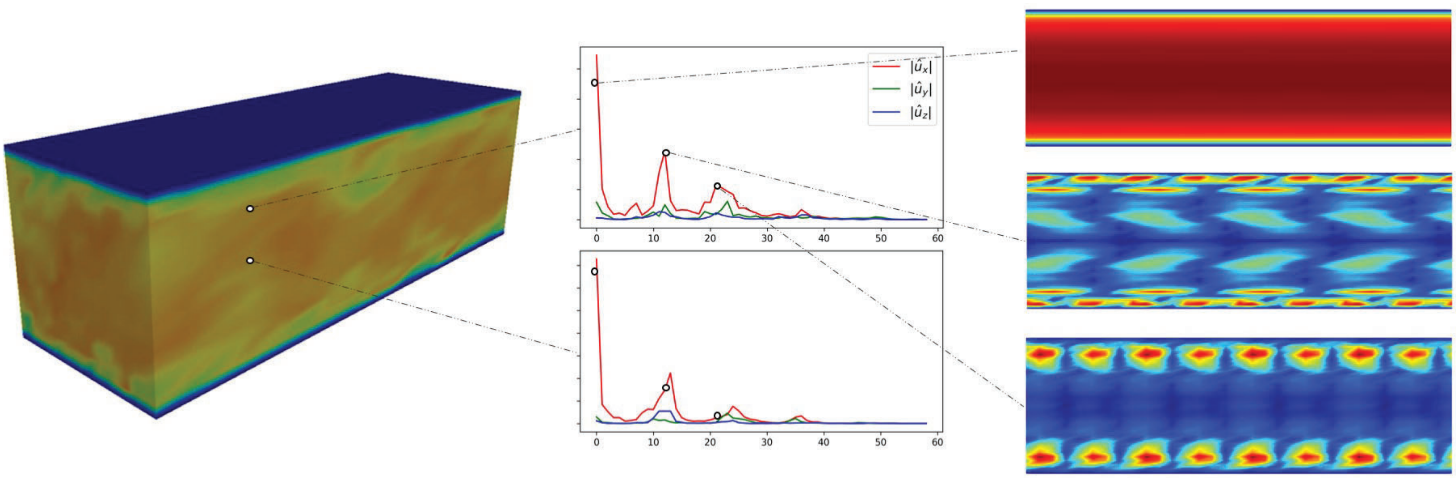

Fig 1: Turbulent flow decomposed into its dominant mode shapes.

Project description

In this project, you will dig into a turbulent flow solution to obtain the fundamental modes that make up the flow field. By you will transfer this information to a sound profile. Performing different band-pass filters, enables you to intuitively investigate the intensity and characteristics of specific frequency components within the flow-induced sound. This approach allows for a clearer understanding of the relationship between flow structures and their acoustic signatures.
Next, you investigate how only a few acoustic modes can preproduce most of the sound of the turbulent flow. This opens the door to model reduction in turbulence models.

STUDENT PROFILE

We are looking for a MSc student who has:

- Affinity towards Fluid Mechanics.
- Interest in programming.

REFERENCES

[1] Pope, S.B. (2000). *Turbulent flows*

Supervisor	Rob Bastiaans
2nd supervisor	MohammadReza Kohansal
Mentor	-
Company	N.A.
Internal / External	Internal
Starting date	01 Sep 2025
Exp./Num./Design	Experiment & Simulation

Available for ME-SET-XX

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number: xx

Laminar Burning Velocity Measurement of NH3/H2 using Heatflux Burner

MohammadReza Kohansal, Roy Hermanns, Rob Bastiaans

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What is it About?

AmmoniaDrive is a project that introduces an innovative power system, integrating a Solid Oxide Fuel Cell (SOFC) with an Internal Combustion Engine (ICE). This hybrid system operates on renewably produced NH3/H2. To design and optimize an internal combustion engine, fundamental chatacteristics of the fuel are needed.

Laminar Burning Velocity is one of the most important combustion properties. It is essential for calculating turbulent properties, e.g., turbulent flame velocity. More importantly, it is used for validating and optimizing chemical mechanisms.

In this Master's project, laminar burning velocity of NH3/H2 is measured using **Heatflux Burner** method to be used by our colleagues in the AmmoniaDrive project for designing the integrated Internal Combustion Engine.

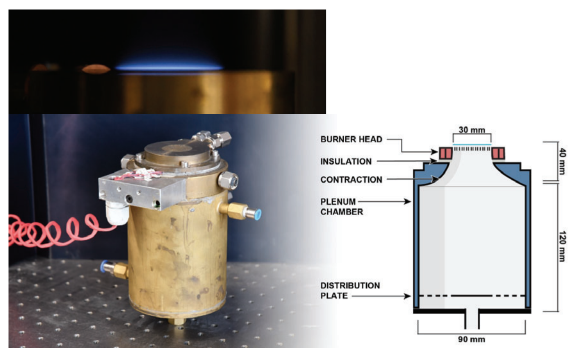
Modeling is essential for designing/optimizing industrial combustion processes

Chemical Mechanism is needed for modeling combustion

No global mechanism

Optimized mechanisms for specific conditions

Importance of chemical mechanism in combustion processes



Heatflux burner setup. *Images are taken from Mark Hulsbos PhD thesis*

What Are You Going to Do?

i. Measuring Laminar Burning Velocity of NH3/H2 using **Heatflux Burner**
ii. Performing simulation using Chem1d/Cantera
iii. Comparison of experiments and simulations results

Who Are We Looking For?

i. Passionate about science (Combustion preferably ;))
ii. Basic knowledge of coding (if not, we will learn together!)
iii. Prior experience with experimental measurement is a plus

Why This Project?!

i. You are a part of big AmmoniaDrive project
ii. With close supervision, learn how to start and continue a research project, e.g., literature review, finding research gap, etc.
iii. Aquire fundamental knowledge of combustion related to Laminar Burning Velocity
iv. Gain experience working with a experimental setup
v. Learn more coding
vi. Solidify your expertise in combustion doing experiment and simulation

Supervisor	Conrad Hessels
2nd/3rd supervisor	Noud Maes, Nico Dam
Company	N.A.
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Experimental

Available for ME, AT, SET

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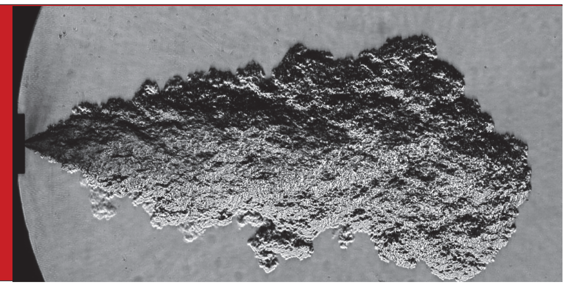
Measuring the temperature field of a high-pressure H_2 injector using spontaneous Raman scattering.

C.J.M. Hessels*, N.C.J. Maes, & N.J. Dam
*E-mail: c.j.m.hessels@tue.nl



Background

During the last decades, the need for efficient and clean combustion has been growing steadily. With increasing emission legislation and sustainability in mind, hydrogen, along with other renewable fuels, seems viable for the internal combustion engines of the future.

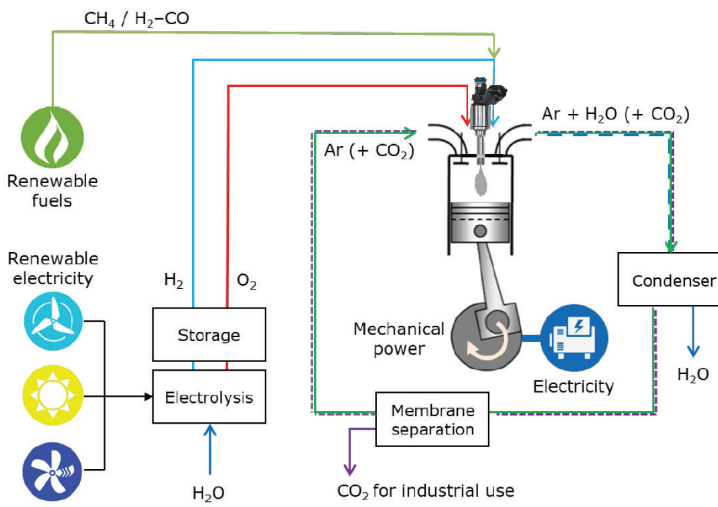


Figure 1: Schematic layout of the Argon Power Cycle.

To increase the efficiency for all these renewable fuels, the revolutionary Argon Power Cycle is investigated. Using Argon instead of air as the working fluid, the cycle efficiency could increase by about 25%, reaching values above 80%!

Working together with Noble Thermodynamic Systems (Berkeley, CA, USA) and IFP Energie nouvelles (Paris, France), non-intrusive temperature measurements of a modified Gasoline Direct Injection (GDI) injector need to be investigated. Earlier research (inverse-LIF & Rayleigh scattering) indicated the importance of compressibility effects inside the jet.

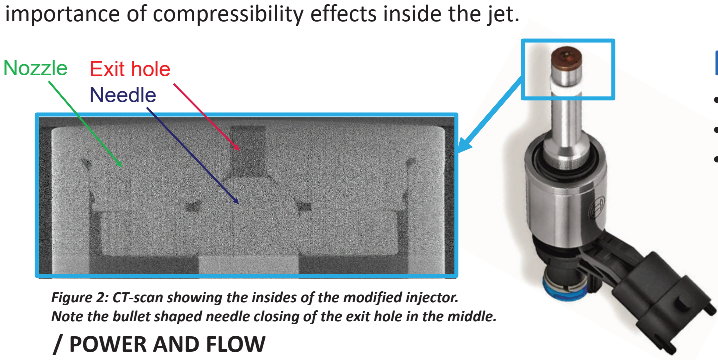


Figure 2: CT-scan showing the insides of the modified injector. Note the bullet shaped needle closing of the exit hole in the middle.

/ POWER AND FLOW

Objective

The decompression of high-pressure hydrogen (during injection) into a lower pressure environment will lead to a drop in temperature and pressure in the barrel shock until the Mach disk is reached. These temperature/density effects influence the mass flow through the nozzle and characterizing them can lead to valuable insights in the needed assumptions/corrections for various optical diagnostics, i.e., Rayleigh scattering (TU/e) and inverse LIF (IFP+TU/e). Raman scattering is selected to perform non-intrusive temperature measurements in the jet.

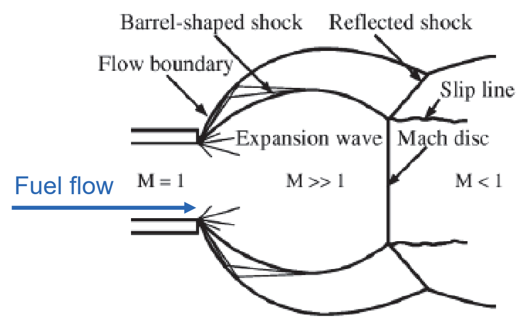


Figure 3: Classical model by Ewan and Moodie[1] on the injection of a compressible fluid.

Approach

You will:

- Study literature and get familiar with Raman scattering on underexpanded jets and earlier performed research.
- Start with Nitrogen through an always-open fuel injector, using an existing & documented setup. (HPVB[2])
- Perform experiments on hydrogen jets and process and analyze the measured data using (existing) MATLAB routines.
- Compare the results with literature and existing Rayleigh & inverse-LIF measurements.

Recommended courses:

- *Optical diagnostics for combustion and fluid flow (4BM40)*
- *Clean engines and future fuels (4AT020)*
- *Experimentation for Mechanical Engineering (4BM20)*

References

1) Structure and velocity measurements in Underexpanded Jets, Ewan & Moodie [1986]
2) Spectroscopy on the verge of soot formation, Robin Doddema [2023]

Supervisor	Giulia Finotello
2nd supervisor	Wen Jin
Company	N.A
Starting date	Anytime
Exp./Num./Design	Experimental

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Ultrasonic Atomization for Efficient and Sustainable Metal Powder Production in 3D Printing

Wen Jin*, Giulia Finotello, Joris Remmers, Niels Deen
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Introduction

Ultrasonic atomization has gained significant attention due to its potential to produce high-quality metal powders for additive manufacturing (AM). The idea assumes that the ultrasonic vibrations are used to disintegrate the molten metal and create fine metal or metal alloy droplets, which later, after the solidification, form fine and spherical powder particles. However, little is known yet about atomization mechanisms and droplet/powder size prediction in the ultrasonic atomization of liquid metal because of significant challenges, both in terms of feasibility and safety due to high temperatures and reactivity.

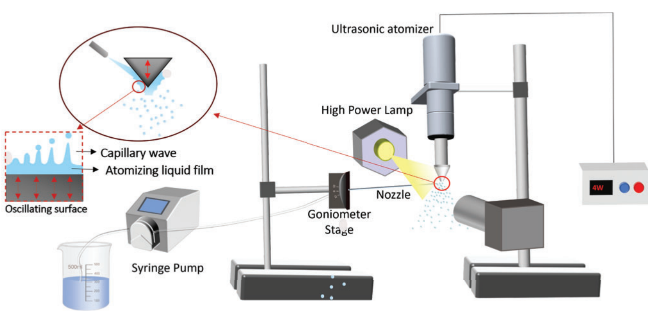

Figure 1. Ultrasonic atomization set-up

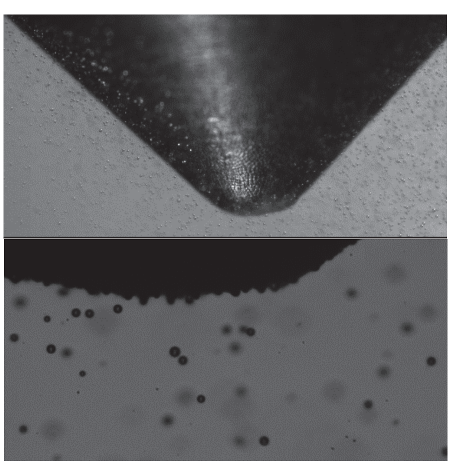

Figure 2. Droplets near the atomizer tip

Tasks

1. Investigate the Effects of Liquid Properties: Analyze how non-Newtonian behavior influences the dynamics of droplet formation during ultrasonic atomization. Examine the effect of varying flow rates on droplet velocity, size uniformity, and spray patterns, identifying optimal operating conditions for atomization.
2. Study Secondary Breakup Mechanisms: Explore the second stage of the spray, focusing on secondary breakup phenomena caused by aerodynamic forces and liquid inertia. Investigate the coalescence of droplets during flight and its effect on particle size distribution. Analyze the evolution of particle velocities and sizes as the spray progresses, identifying key factors influencing overall spray behavior.
3. Particle Size Prediction: Develop empirical correlations to predict particle size distribution, considering factors such as liquid film thickness and atomization tip shape, to advance the optimization of ultrasonic atomization techniques for molten metals.

Goals

- Analyze how varying operating parameters affect droplet characteristics and spray patterns.
- Investigate fundamental ultrasonic atomization mechanisms, focusing on capillary waves and cavitation.
- Conduct preliminary testing of liquid properties for future molten metal applications and develop predictive models.

Benefits

- Gain expertise in high-speed imaging and ultrasonic atomization techniques, valuable for metal powder production.
- Build a strong foundation for advanced research or a PhD in metal processing and materials science.
- Opportunity to collaborate with industry experts and advance metal powder technologies.

Supervisor	Dr. Stein Stoter
2nd supervisor	N.A.
Mentor	Dr. Stein Stoter
Company	N.A.
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Numerical

Available for ME

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Machine learning for scale interaction in turbulent flow

Stein Stoter

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Keywords: *Machine-learning, Finite element method, Scale interaction*

INTRODUCTION

With the finite element method, we can approximate solutions to partial differential equations. These can be interpreted as 'coarse-scale' representations of the true solution, and the approximation error can be interpreted as the missing 'fine-scale' contribution. For transport equations, the effect of the fine scales must be taken into account (modeled) while computing the coarse scales to obtain stable results. The quality of this scale interaction model dictates the quality of the coarse-scale approximation, as seen in the figure below. The ultimate application area of this research lies in the multiscale modeling of turbulent flow (Fig 1.)

PROBLEM STATEMENT

The scale interaction can be computed exactly but this costs a lot of computational power, making it unfeasible to do so during the simulation of transport phenomena. Instead, one could learn the scale interaction with a machine learning algorithm during a training phase, and then use the machine learning model during the simulation of the transport problem.

RESEARCH TOPICS

- Perform a literature study to learn about the state-of-the-art of machine learning for scale interaction, and about the types of machine learning techniques used for similar tasks.
- Develop a code that can compute the exact scale interaction function.
- Develop a machine learning code that can predict these functions.
- Study the effectiveness of the machine-learned model of the scale interaction.

STUDENT PROFILE

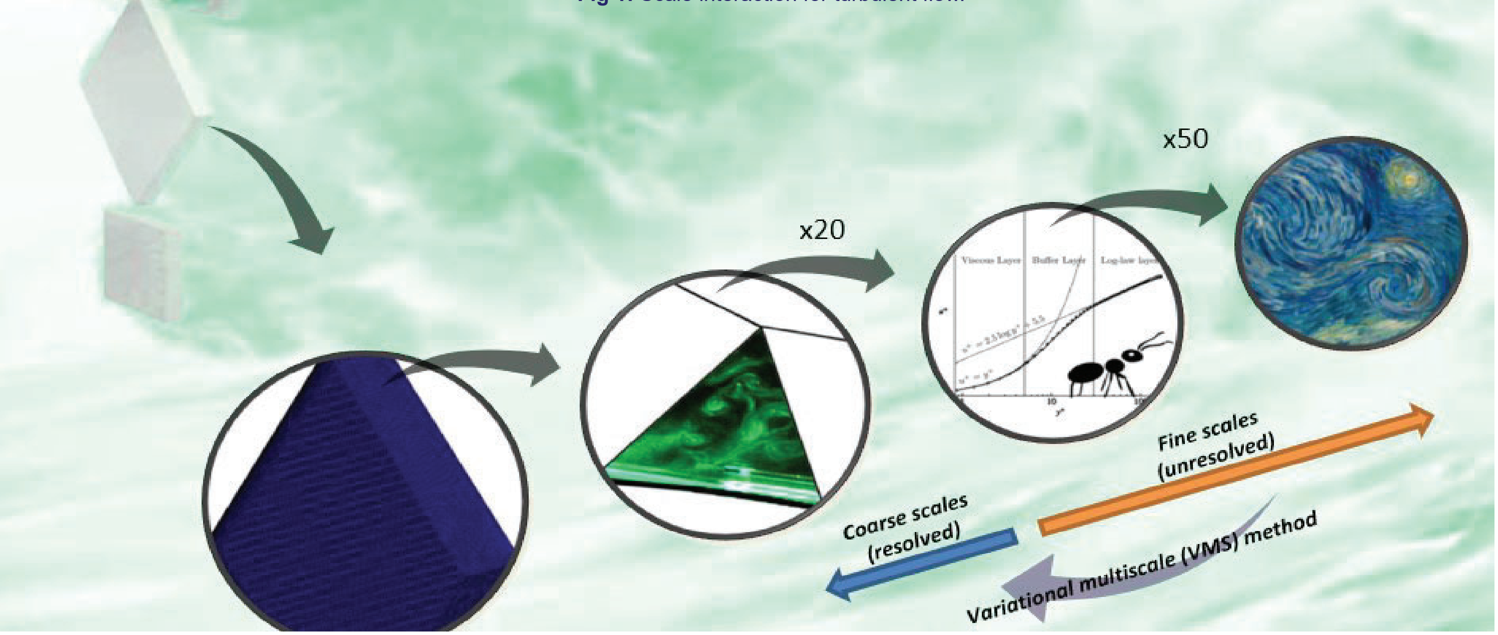
We are looking for a MSc student who has:

- Affinity towards (advanced) numerical solution methods,
- Strong interest in programming and eager to improve upon their existing programming skills (e.g., Python).

REFERENCES

[1] Stoter, S.K.F. et al. (2022). *Discontinuous Galerkin methods through the lens of variational multiscale analysis*, Computer Methods for Applied Mechanics and Engineering, 388, 114220.

Fig 1: Scale interaction for turbulent flow.



Supervisor	Rob Bastiaans
2nd supervisor	
Company	N.A.
Internal / External	Internal
Starting date	2025
Exp./Num./Design	Theoretical and numerical

Available for ME-SET-AT-AIES

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number: 2025 25-02

LES subgrid scale analysis and using FGM from DNS for premixed turbulent combustion

Rob Bastiaans
EMAIL: r.j.m.bastiaans@TUE.NL

INTRODUCTION

Turbulent combustion is a very common large scale energy generation method, e.g. in gas turbines. Nowadays we concentrate on the combustion of carbon free fuels, here NH_3/H_2 mixtures. Design is very difficult as experiments are always small scale and expensive. Therefore, we try to simulate these events efficiently, though accurately. Reduction of grid sizes with large eddy simulation (LES) is inevitable. Academically we perform direct numerical simulations (DNS) of canonical cases to establish a reference ‘truth’, by resolving everything. In LES modelling one must model subgrid scale (SGS). See figure 1 for the different approaches.

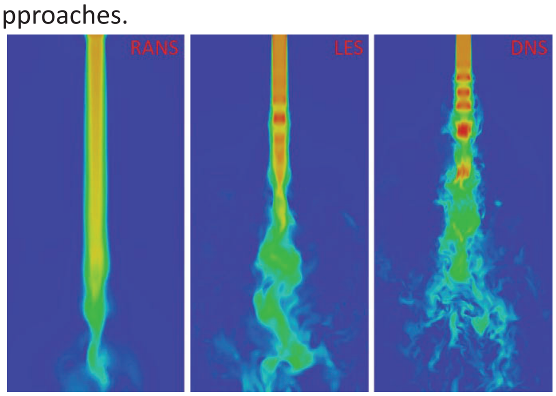


Figure 1: Results of ways to simulate turbulence.

Currently we are interested in SGS conributions of subgrid species fluxes compared to the chemical source term contribution. Additionally, we are interested in anisotropy of these fluxes and ways to take this into account in LES. This might be important in e.g. boundary layers and boundary layer flash back events. For a DNS result of a turbulent combustion kernel see figure 2.

/ POWER AND FLOW

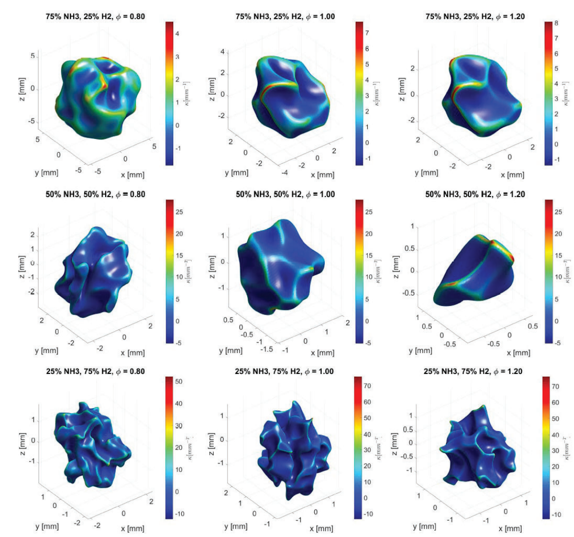


Figure 2: Turbulent premixed NH_3/H_2 combustion kernel.

OBJECTIVES

- Find good literature on SGS modelling of turbulent premixed combustion
- Analyse DNS simulations with respect to hypothetical SGS by filtering (convolution)
- Make a combustion manifold from the DNS and try to use it.
- Propose LES SGS modelling approaches

Candidate

- Has knowledge of combustion and CFD
- Has analytical skills
- Is interested in fundamental research

REFERENCES

[1] T. Poinsot and D. Veynante, Theoretical and numerical combustion. 2022

Supervisor	Dr. Stein Stoter
2nd supervisor	N.A.
Mentor	Dr. Stein Stoter
Company	N.A.
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Numerical

Available for ME

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A turbulence modeling framework for means and oscillating flow fields

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Keywords: *Turbulence modelling, RANS, Fourier representation*

INTRODUCTION

Turbulence modeling frameworks based on the Reynolds-averaged Navier-Stokes (RANS) equations are the main workhorse in CFD-industry turbulent flow solvers. Their popularity stems from computational efficiency and ease of use. Yet they lack in predictive capability, i.e., accuracy. This is due to the underlying models, which necessarily replace the unknown turbulence quantities with expressions based on mean quantities.

Project description

In this project, you will develop a new RANS framework, that not only aims to retrieve the mean quantities, but also the lower-order oscillations of the turbulent flow field. The expectation is that this fuller description of the complete physics alleviates the model deficiencies of classical RANS models.

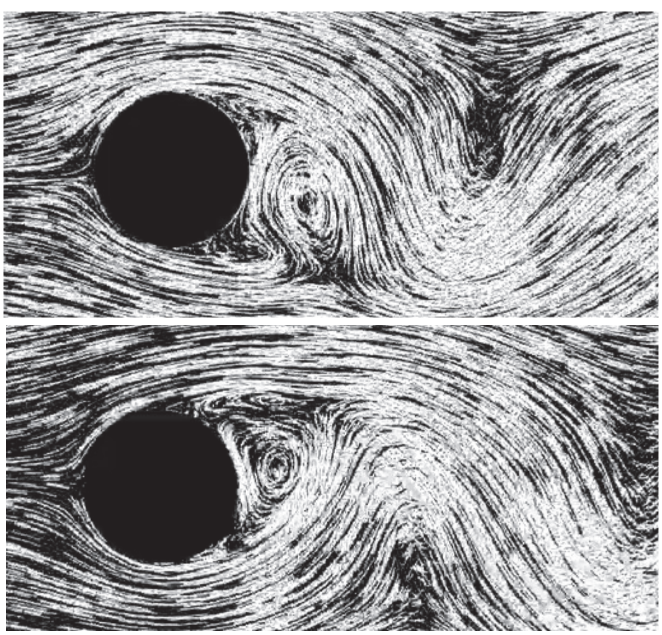

Fig 1: RANS simulation with clear low-frequency oscillation components.

RESEARCH TOPICS

- Perform a literature study to learn about the advanced RANS models.
- Develop a suitable model based on the RANS equations for the means and oscillations.
- Implement this model in an in-house turbulent flow solver, for turbulent channel flow (see below).
- Analyze the accuracy of the obtained solutions in comparison to a typical eddy-viscosity RANS model.

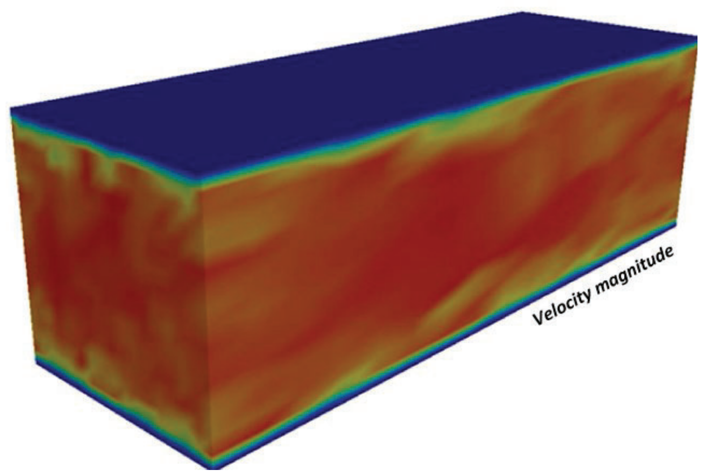

Fig 2: Main testcase: turbulent channel flow

STUDENT PROFILE

We are looking for a MSc student who has:

- Affinity towards (advanced) numerical solution methods,
- Strong interest in programming and eager to improve upon their existing programming skills (e.g., Python).

REFERENCES

[1] Pope, S.B. (2000). *Turbulent flows*