Master Thesis project proposals

Q2 2025-2026

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).

Bachelor/Master/Internship Project

TU/e Technische Universiteit Eindhoven University of Technology

Direct numerical simulation of homogeneous isotropic premixed turbulent ammonia combustion

Rob Bastiaans

Background

In the beginning of this millenium a Direct Numerical Simulation computational fluid dynamics code was developed at TU/e by de Lange and Bastiaans. It consists of discrete, implicit, compact high order (6th) numerical schemes for spatial derivatives (Lele) and a high 3-step order Runge-Kutta time advancement algorithm. For the case of advection a 5th order upwind scheme was developed. For the combustion FGM was implemented. The development stopped and after a while the code was picked up again by PhD students and detailed chemical kinetics was added successfully under the guidance of Jeroen van Oijen.

Recently interest was picked up again by a contact at Embry-Riddle Aeronautical University (Dr. Scott Martin) at Daytona Beach in Florida. They want to perform data analysis of results generated by our code for a cubical geometry with homogeneous turbulence in which CH4 is burned with air on a mean flow.

Assignment

A previous BEP student worked already successfully on this code for simulations of methane combustion. Results of this study in dying turbulence can be seen in the figure below.

We have gained renewed interest in using the code ourselves for obtaining results on ammonia combustion. In the intermediate period we have noticed that what was developed has a very high fidelity and can be used for many interesting studies. Up until now the code has not been documented and documentation might need to be added.

We are looking for a bachelor/graduate candidate to pick up the Fortran source code of the software again. The student should make the right preparations/modifications to arrive at our kinetic needs needed for ammonia combustion and prove that it works properly, also on many CPU cores. If needed, computer infrastructure at Embry-Riddle may be used (for methane cases).

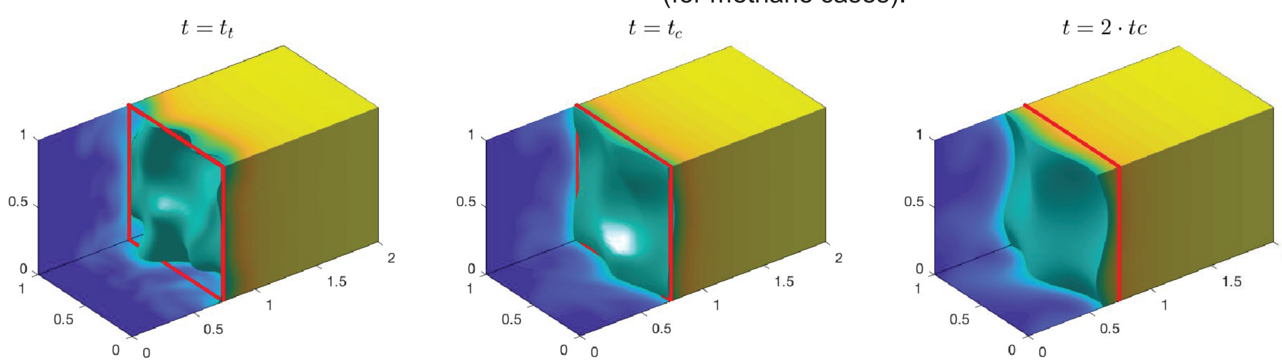

Fig 1. Results of turbulent premixed methane combustion in dying turbulence

From the DNS we would like to obtain e.g. the scalar dissipation, PDF shape, closure for the progress variable variance equation and understand the the effect turbulence has on reaction rates.

References

[1] A. J. Aspden, M. S. Day, and J. B. Bell. Three-dimensional direct numerical simulation of turbulent lean premixed methane combustion with detailed kinetics". In: Combustion and Flame 166 (2016), pp. 266{283.

Contact: Rob Bastiaans, P&F, GEM-Z 2.141, r.j.m.bastiaans@tue.nl

MSc Project

Supervisor	**Dr. Yali Tang**
Mentor	**MSc. Ding Ge**
Internal / External	**Internal, Power and Flow group**
Exp./Num./Design	**Exp.**

Production of high-purity iron powder via low-temperature electrolysis of Steelmaking waste

***Contact: Yali Tang(y.tang2@tue.nl)**

BACKGROUND

The global steel industry is undergoing a major transition toward carbon neutrality, which necessities revolutionary ironmaking technology using renewable energy. Meanwhile, green ironmaking is the key in the design concept of recyclable metal fuel cycle by using iron powder, meaning the electricity from Renewable Energy sources is required to recover the combusted iron. By this concept, the CO2-free emission full cycle of Iron Powder is expected.

The reduction of iron oxide to metallic iron using direct electricity is known as the "Iron Electrowinning" process. Electrowinning is a conventional technology for production of many metals and alloys such as zinc and aluminum. Recently Iron Electrowinning technology has drawn increasing attention to both academy and industries due to its huge potential in decarbonizing iron & steel sector as well as novel production of iron fuel.

However, the state-of-art research are done using either pure iron oxide or high-grade ore (high Fe content) as feedstock. In principle, this electrochemical method offers advantage over other ironmaking technologies on accommodation of low-grade ore, thus reducing production cost and solving an urgent environmental issue at mining site. This project is to explore the feasibility and efficiency of electrolytic iron production using low-grade iron ores and/or steelmaking waste.

This project is within the scope of the ERC starting grant of Prof. Tang on low temperature electrolysis for green ironmaking.

OBJECTIVES

- To experimentally assess the feasibility and efficiency of iron production/recovery from low-grade ore and/or waste via low-temperature electrolysis.

APPROACHES:

- Literature review on the state-of-the-art on DER of iron oxide/ore
- Material characterization (particle size analysis, XDR, SEM)
- DER experiments: effect of chemical composition (presence of non-ferrous gangue materials) and particle size on the current efficiency of iron electrodeposition
- Data analysis and discussion
- Report writing

BENEFITS:

- Gain experience in this cutting-edge research topics
- Learn and experience lab experiments
- Possibly to be involved in scientific publication

STUDENT PROFILE:

We are looking for a high-motivated student who has passion to do some real scientific research. Some general requirements are expected:

- Strong interest in lab exercise.
- Comfortable in using chemicals.
- Creative, independent, and high curiosity.

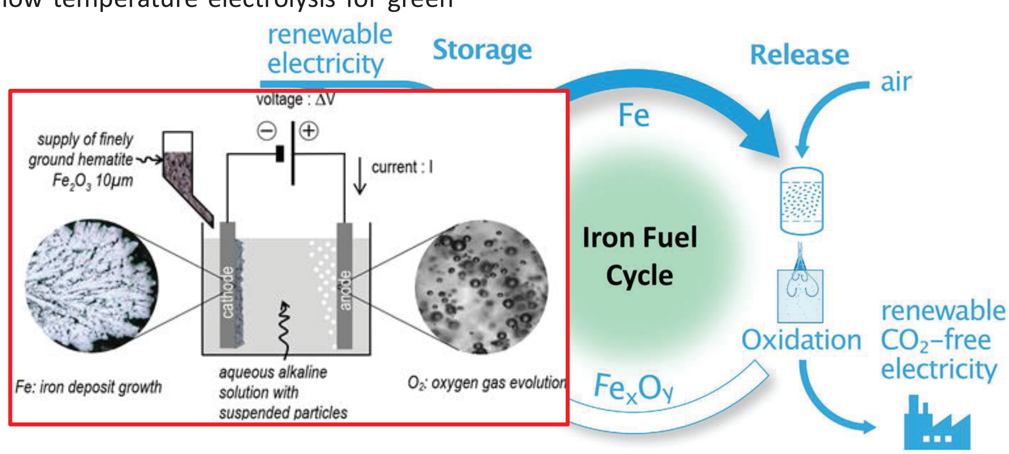

Fig. 1. Illustration of the iron electrowinning process and its position in the Iron Power cycle

Supervisor	Niels Deen
2nd supervisor	
Mentor	Ruud Fieret (Founder)
Company	N.A.
Internal / External	External
Starting date	Any time
Exp./Num./Design	Numerical / Design

Available for ME

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Validation of an Innovative Wind Energy Concept: The Hollandse Windwal

NIels Deen,Ruud Fieret

E-mail:N.G.Deen@tue.nl, ruud.fieret@gmail.com

Keywords: *DAWT, CFD, Aerodynamics, Venturi Effect, Grid Congestion, Renewable Energy*

INTRODUCTION

The Dutch energy transition is facing a critical barrier: grid congestion. This makes it increasingly difficult for the SME sector and agricultural businesses to achieve their sustainability goals, as they are often unable to secure a connection for renewable energy. The solution requires a new approach: decentralized energy generation that is efficient, has a low profile, and is easy to maintain. From this vision, the Hollandse Windwal concept was designed.

Project description

The Hollandse Windwal is a low-profile, rotating multi-turbine platform, surrounded by a specifically designed aerodynamic enclosure (a 'shroud' or 'duct'). The concept is based on a combined 'push-pull' mechanism to significantly increase the mass flow rate through the turbines:

Push: The inlet captures the wind and accelerates it towards the turbines through the Venturi effect.

Pull: The convex exterior of the enclosure creates a low-pressure zone at the rear, actively drawing the airflow through the system.

The primary goal of this project is to answer the central research question:

Can the proposed aerodynamic architecture achieve a significant increase in energy density under realistic wind conditions?

The student will use Computational Fluid Dynamics (CFD) to model the concept and validate its technological potential. This project is a unique opportunity to contribute to the fundamental R&D of a new technological concept, in direct collaboration with the founder.

RESEARCH TOPICS

- Literature Review & Theoretical Validation: Research existing 'Diffuser Augmented Wind Turbine' (DAWT) concepts to establish a theoretical performance baseline.
- Geometry Definition & Parametric Modeling: Create a parametric 3D model of the Hollandse Windwal where the core design variables (e.g., inlet curve, throat diameter, diffuser angle) are flexible.
- Computational Fluid Dynamics (CFD) Analysis: Perform simulations to quantify the airflows, pressure zones, and velocity increases within the model at various relevant wind speeds.
- Results Analysis & Validation: Calculate the net performance gain (the 'Concentration Factor') and form a well-founded judgment on the technological viability of the concept.

STUDENT PROFILE

We are looking for a MSc student who has:

- A strong affinity for Fluid Mechanics and Aerodynamics.
- Interest in programming and CFD simulations.
- An independent, proactive, and entrepreneurial mindset.

MSc Project

Supervisor	Dr. Yali Tang
Mentor	MSc. Ding Ge
Internal / External	Internal
Exp./Num./Design	Numerical

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Multiphase Multiphysics Modelling of Iron Electrowinning

*Contact: Yali Tang(y.tang2@tue.nl)

BACKGROUND

In the design concept of recyclable metal fuel cycle by using iron powder, the electricity from Renewable Energy sources is required to recover the combusted iron. By this concept, the CO2-free emission full cycle of Iron Powder is expected.

The reduction of iron oxide to metallic iron using direct electricity is known as the “Iron Electrowinning” process (see Fig. 1). Electrowinning is a conventional technology for production of many metals and alloys such as zinc and aluminum. However, the underlying physics of this process is poorly understood in the scientific community. In this project, we opt for a numerical approach to model the Multiphysics of iron electrowinning, shedding lights to the technological development. This project is within the scope of the ERC starting grant of Prof. Tang on low-temperature electrolysis for green ironmaking.

OBJECTIVES

- To simulate the electric and magnetic field in the system and understand their response to changes in power supply and cell configurations.
- To performed Multiphase CFD simulations coupled with resolved electric and magnetic field to understand the interplay between fluid mechanics and electromagnetics in this system. (see Fig. 2)
- To simulate the iron electrodeposition process and understand its interplay with system parameters such as solids concentration, current density, etc.

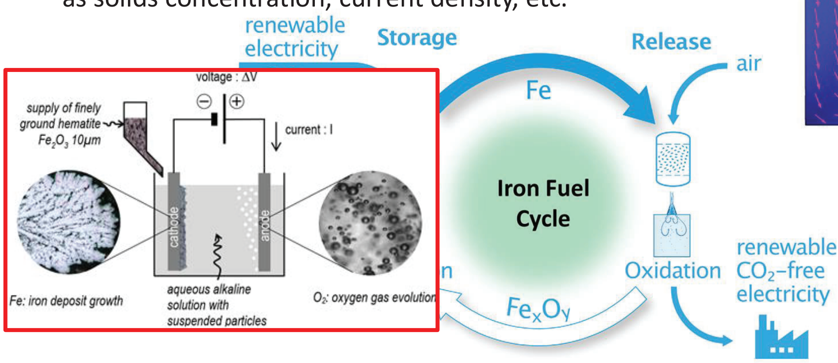

Fig. 1. Illustration of the iron electrowinning process and its position in the Iron Power cycle.

APPROACHES:

- Learning COMSOL Multiphysics software (Electromagnetics module and CFD module)
- Define the simulation geometry and parameters
- Perform Electromagnetics simulations
- Perform coupled CFD and Electromagnetics simulations
- Perform iron electrodeposition simulations

BENEFITS:

- Gain experience in this cutting-edge research topics
- Learn and experience numerical modelling with a commercial software
- Possibly to be involved in scientific publication

STUDENT PROFILE:

We are looking for a high-motivated student who has passion to do some real scientific research. Some general requirements are expected:

- Strong interest in numerical modelling.
- Creative, independent, and high curiosity.
- General knowledge in electrolysis or CFD is beneficial.

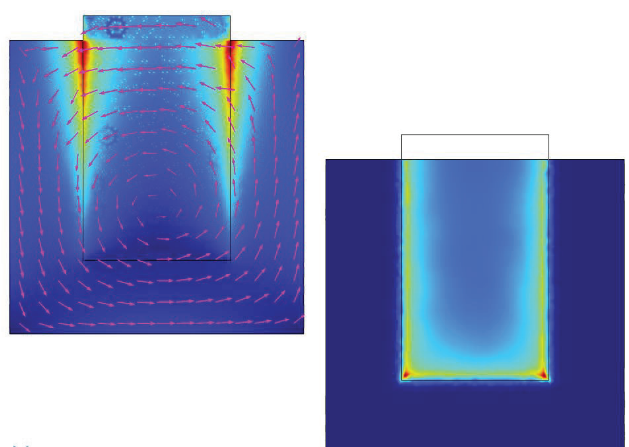

Fig. 2. 2D snapshots of Magnetic field (Left) and Ionic concentration (Right) near the cathode from simulations of an iron electrolysis cell.

Supervisor	Yali Tang
2nd supervisor	Jan Hendrik Cloete (@SINTEF)
Company	SINTEF, Norway
Internal / External	External
Starting date	Q2
Exp./Num./Design	Numerical

Available for ME, SET

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Wall-particle heat transfer modelling in Two-Fluid Simulations

YALI TANG, JAN HENDRIK CLOETE
EMAIL: Y.TANG2@TUE.NL

INTRODUCTION

Heat transfer between the particle bed and heat exchanger walls plays an important role in numerous fluidized bed reactor concepts that are proposed for more sustainable processes, such as adsorption-based CO_2 capture [1]. Somewhat surprisingly then, there are no suitable models to account for particle-wall heat transfer in the most commonly used computational fluid dynamics (CFD) method for simulating fluidized bed reactors [2], the two-fluid model (TFM). Based on a previous MSc work, this project therefore aims to further develop a recently proposed approach for including particle-wall heat transfer in TFM simulations [3].

Project

The first part of the project will require running TFM simulations in Ansys Fluent for a variety of experimental fluidized bed setups for which particle-wall heat transfer data exist in literature. Data generated from the simulations will then be used to optimize the parameters in a particle-wall heat transfer closure to achieve the best possible match with experimental data. An existing Matlab script will be upgraded and utilised for this purpose. The student will also be expected to improve the formulation of an existing particle-wall heat transfer closure based on physical arguments. This study will be performed in collaboration with researchers from SINTEF Industry, a non-profit research institute based in Norway, and the student will spend part of the project time in Trondheim, Norway. There are possible funding to support the staying of the student in Trondheim.

OBJECTIVES

- To further develop a recently proposed wall-particle heat transfer model
- To improve the model formulation based on physical arguments
- To contribute to a journal paper writing

APPROACH

- Perform TFM simulations using Ansys Fluent
- Optimize model parameters using Matlab
- Analyse and discuss the results

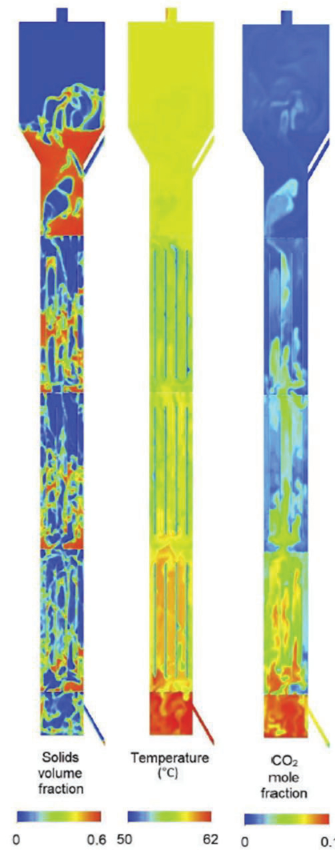

Figure 1: An example of a TFM simulation of a fluidized bed CO_2 adsorption reactor with particle-wall heat transfer included

REFERENCES

1. Dhoke C. et al. Review on Reactor Configurations for Adsorption-Based CO_2 Capture. Industrial & Engineering Chemistry Research. 2021
2. Alobaid F, et al. Progress in CFD Simulations of Fluidized Beds for Chemical and Energy Process Engineering. Progress in Energy and Combustion Science. 2021
3. Cloete J.H, et al. Developing a novel approach for modelling particle-wall heat transfer in fluidized bed reactors for CO_2 capture. In: 24th Fluidized Bed Conversion conference; 2022. Available from: bit.ly/3aaO4t7

Supervisor	Conrad Hessels
2nd/3rd supervisor	Angèle Reinders, Roy Hermanns
Company	N.A.
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Numerical/Design

Available for ME & SET

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Life-cycle assessment (LCA) of Iron Power

What is the impact of storing sustainable energy in iron?

CONRAD HESSELS, ANGÈLE REINDERS, ROY HERMANNS

EMAIL: C.J.M.HESSELS@TUE.NL

WHAT IS IT ABOUT

In the iron power cycle, we would like to harness the power of iron for sustainable energy storage and transport. By converting sustainable energy into hydrogen, we can convert (reduce) iron-oxide into iron, which can be used as a fuel for adapted coal fired power plants. That means that we can power our world by burning iron (see figure 1)!

While the concept sounds very promising and quite some (techno-economic) feasibility studies have been performed showing its competitiveness in comparison to other carriers like H_2, NH_3, LOHC (see e.g. 1-3), research is lacking on a full life-cycle assessment of the process, accounting for cradle-to-grave environmental impact. These results might influence the decision on which energy carrier aught to be used for specific use cases.

<u>**Your tasks**</u> will be to (1) Study the literature and get familiar with LCA and the concept of Iron Power (2) Setup an Iron Power framework using the SimaPro LCA software, (3) Define specific use cases for which Iron Power is a good candidate, (4) Compare the LCA of different energy carriers for this use case.

WHAT YOU WILL LEARN

- How the combustion/reduction of iron powder can be used to store sustainable energy.
- What a life-cycle assessments is and how important it is for comparing the environmental impact of new technologies

WHY SHOULD YOU CHOOSE THIS

- You are an enthusiastic student and interested in reducing societies environmental impact.
- You are interested in “bigger picture” research going on at TU/e

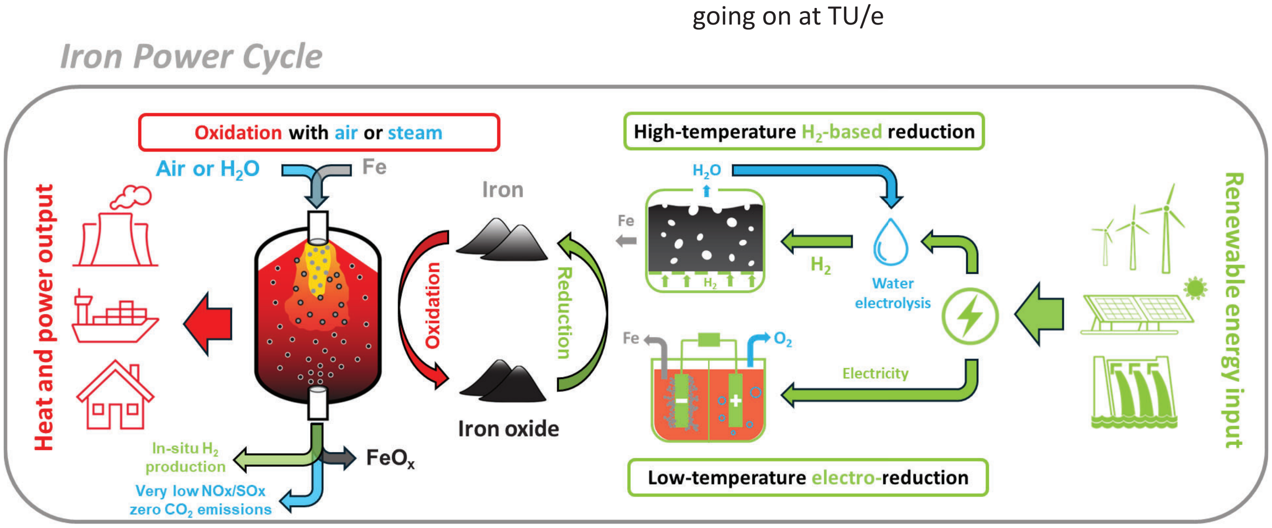

figure 1: The conceptual overview for the iron power cycle (courtesy of Xiaocheng Mi).

/ THERMO-FLUIDS ENGINEERING

[1] J. Neumann et al. Applications in Energy and Combustion Science 14 (2023) 100128
[2] Roland Berger. Iron power vision document. https://www.metalot.org
[3] J. Schuler et al. Energy Conversion and Management 342 (2025) 120125

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

Available for ME & SET

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GAS TEMPERATURE INSIDE A METAL FLAME USING O_2 LASER INDUCED FLUORESCENCE

GILIAM VAN DER WIELEN, CONRAD HESSELS (& NICO DAM)

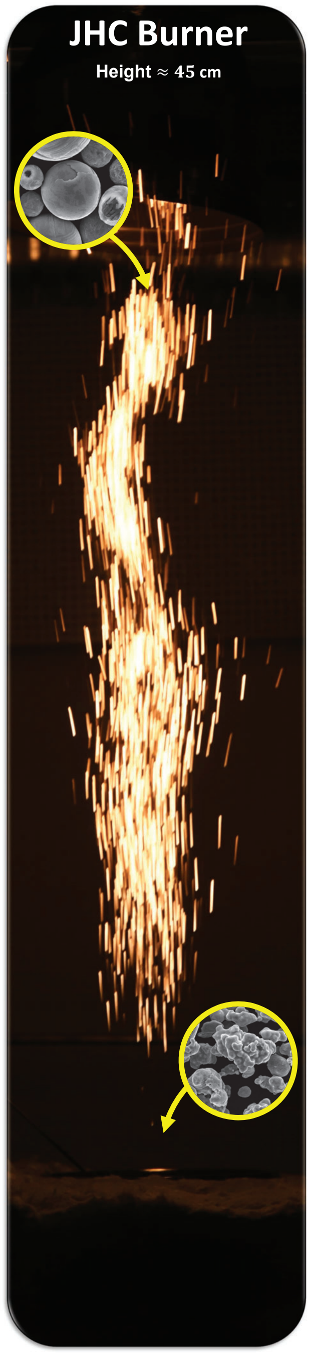
EMAIL: G.G.W.V.D.WIELEN@TUE.NL

WHAT IS IT ABOUT

The stability of an iron powder flame is dependent on a combination of the three types of heat transfer: radiation (particle-particle), conduction (particle-gas), and convection (gas-gas). For the design of industrial iron powder burners and as validation/improvement of combustion models, an accurate measurement of both the particle and gas temperature would be ideal. Thermocouples don't work, since they clog-up with powder, so we need to use optical methods (lasers & camera's). While the particle temperature is relatively easy[1] by looking at the light emitted by the flame, the temperature of the gas is a lot trickier.

One rather exotic method is to perform laser induced fluorescence (LIF) on the oxygen molecule. In LIF, a powerful laser is operated at a specific wavelength to "excite" molecules, and from the subsequent emitted light the temperature (and concentration) can be derived both spatially and temporally. An example of the captured light (fluorescence) can be seen in figure 1. The ratio between the two graphs contains the gas temperature.

__Your tasks__ will be to (1) obtain hot O2-LIF spectra with and without the presence of burning iron particles, (2) extract the gas temperature from this data (3) validate the method, and (4) evaluate the influence of iron flame properties on the gas temperature by simultaneous open-slit pyrometry.



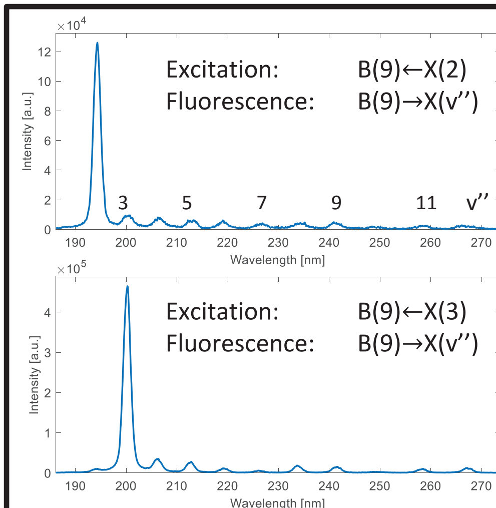


figure 1: Fluorescence spectrum for two excitation wavelength (195 nm top and 200 nm bottom). The numbers refer to the vibrational quantum numbers.

WHAT YOU WILL LEARN

- How iron powder combustion helps us to reach net zero CO_2 emissions.
- How to operate lasers and spectrographs to perform LIF[2]
- How to interpret spectroscopic data

WHY SHOULD YOU CHOOSE THIS

- You are an enthusiastic student wanting to work on sustainable energy storage.
- You are interested in laser diagnostics and optics (spectroscopy, cameras, lasers, etc.) and are not afraid to learn some basics of quantum mechanics.[3,4]
- You are interested in experimental research going on at TU/e[5]

POWER AND FLOW / GROUP HESSELS

[1] After much blood, sweat and tears, see Hameete *et al.* Combust. Flame 264 (2024) 113435
[2] And how sensitive/fragile/expensive this laser diagnostics equipment is.
[3] Students good at taking selfies do not get preferential treatment.
[4] Having followed the MSc course 4BM40 is highly recommended.
[5] This project __will__ include experimental work, from building, testing, validating, to using.

Supervisor	Conrad Hessels
2nd/3rd supervisor	Xiaocheng Mi, Willem Boon
Company	TNO energetic materials
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Experimental

Available for ME & SET

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Single particle combustion of coated metallic particles

CONRAD HESSELS, XIAOCHENG MI, WILLEM BOON

EMAIL: C.J.M.HESSELS@TUE.NL

WHAT IS IT ABOUT

The energy released by the combustion of metallic particles such as aluminium can be used for various applications: e.g. pyrotechnics (fireworks), propulsion (rocket fuel), and metal fuels (sustainable energy storage). The burn time for these particles is determined both by the time to ignition and mass transfer of oxidizer to the particle. To decrease this burn time, thus increasing the heat release rate, one could imagine coating these particles with a reactive material. This would theoretically lower the ignition time and increase burn rate. While this concept in theory sounds very promising, little experimental data exists showcasing its effectiveness.

For this purpose, we would like to study the combustion of individual coated particles in our single particle burner (figure 1). By looking at the light emitted, one can obtain the characteristic timescales for combustion (figure 2).

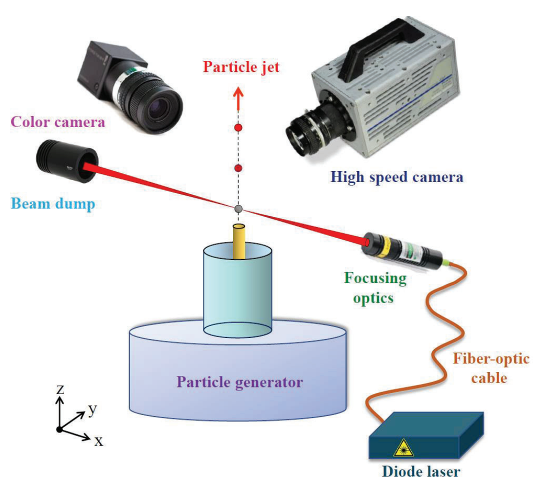


figure 1: Schematic setup of our single particle burner.[1]

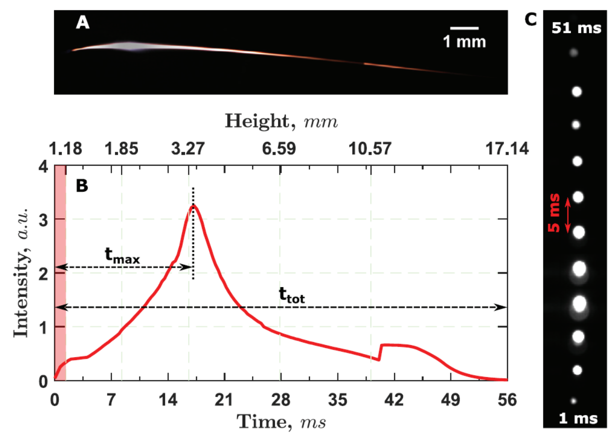


figure 2: Intensity of emitted light of a combusting single iron particle, following laser ignition.[1]

Your tasks will be to (1) perform benchmark experiments measuring characteristic burn time on uncoated single particles (2) Perform similar measurements on coated particles (3) Try to find the optimal coating.

WHAT YOU WILL LEARN

- How metal particles burn
- How to operate single particle burner
- How to capture and analyse high speed camera results
- Opportunity for producing the coatings yourself using wet colloidal synthesis

WHY SHOULD YOU CHOOSE THIS

- You are an enthusiastic student and interested in metal combustion
- You are interested in experimental research going on at TU/e[3]

[1] See Ning *et al.* Combust. Flame 230 (2021) 111424.
[3] The project will include experimental work, from building, testing, validating, to using.

Supervisor	Xiaocheng Mi
External supervisors	Marc van Genderen & Ben Kaiser
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Exp./Design

Available for ME-SET

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Project number: 2025 Q2-##

Measurement of the iron concentration in air

Marc van Genderen, Ben Kaiser, and Xiaocheng Mi*

*E-mail: x.c.mi@tue.nl

INTRODUCTION

Iron is a promising energy carrier for long-term energy storage and long-distance transport, due to its high energy density and its ability to provide high-temperature industrial heat without CO_2 emissions. In the renewable energy cycle illustrated in Fig. 1, iron is oxidized to release energy and subsequently reduced using renewable hydrogen, enabling a closed-loop, carbon-free process. To ensure the efficient and reliable operation of this cycle, effective process monitoring is essential. ***Continuous and real-time measurement of iron particle flow*** remains challenging and is rarely implemented, despite its potential to provide valuable insights into the combustion process, particularly with respect to particle dynamics and reaction behavior under varying operating conditions.

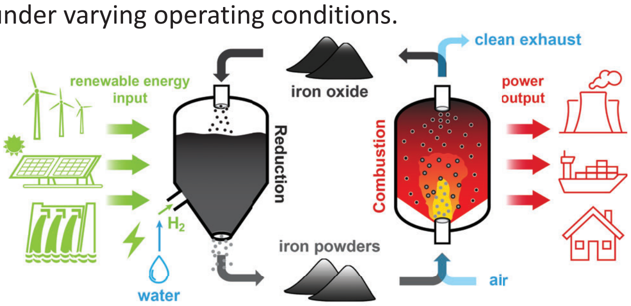


Fig. 1. Carbon-free iron-based cycle of renewable energy

Within the research department of **Demiron**, a first prototype leveraging the magnetic and conductive properties of iron demonstrates a promising new method for the continuous, real-time measurement of iron concentration in air. The device has been successfully calibrated for one type of powder, based on an analytically derived model. Continuous calibration with load cells, which provide a reliable indication of the average flow rate over several minutes, could be used to automatically adjust the device for varying powders. However, the model should ideally be extended to account for the differing properties of the powders used, e.g. particle size and composition, so that no additional sensors are required.

TASK

- Literature review on the apparent magnetic permeability of iron and its oxides under varying conditions. (particle size, temperature, composition)
- Implement available relations in a predictive model
- Evaluate the predictive model in static and dynamic flow tests.
- Formulate new relations, if applicable, and evaluate the feasibility of developing a predictive model.

GOALS

- Calibrate the continuous flow measurement on a variety of different iron powders.
- Evaluate the feasibility of a predicative model based on powder characteristics.

BENEFITS

- Acquire highly transferable skills in powder analysis.
- Exposure to the state-of-the-art research on metal combustion, and thus, an adequate preparation for potential PhD opportunities at TU/e.
- An exciting opportunity for candidates with a strong interest in experimentation and physics.

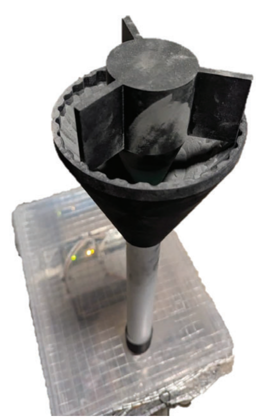


Fig. 2. The setup used to calibrate the first prototype

General Information	
Supervisor	Noud Maes
Mentor	Stan Latten
Internal/External	Internal
Exp./Num./Design	Experimental

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Experimental study on diesel / H_2 dual-fuel operation in a heavy-duty engine

Stan Latten*, Noud Maes

*E-mail: s.latten@tue.nl

INTRODUCTION

The usage of hydrogen as a fuel for Internal Combustion Engines (ICEs) can reduce or even eliminate carbon-related emissions such as CO_2 or soot. However, this fuel also presents several challenges such as NO_x emissions, pre-ignition, high auto-ignition temperature, and low fuel density.

One way of implementing H_2 in existing heavy-duty diesel engines consists of installing H_2 Port-Fuel Injectors (PFI) into the intake manifold, allowing the engine to run purely on diesel if necessary or to substitute a certain amount of diesel for H_2, in which case the diesel acts as a pilot to ignite the H_2-air mixture.

EXPERIMENTAL SETUP

The goal of this project is to run experiments on the single-cylinder MX13 engine setup, which will be modified to include a H_2-PFI system. This setup contains various pressure, temperature, and emission sensors to study the combustion and emissions, and to achieve certain engine operating conditions. These experiments will also serve as a benchmark for a dedicated optical H_2 engine, which is currently being built.

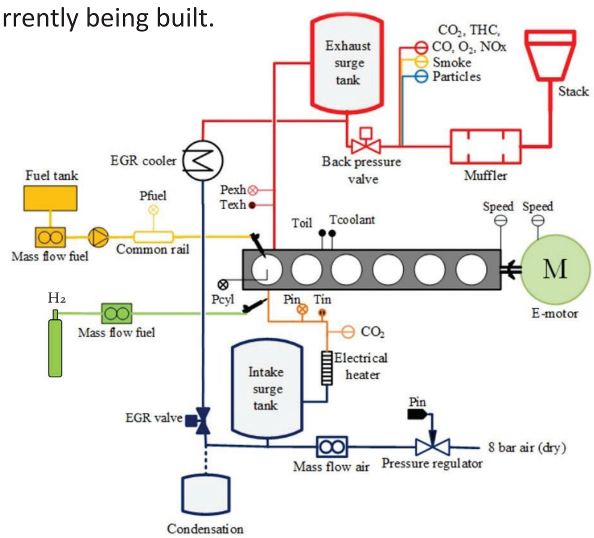


Figure 1: Schematic overview of the modified MX13 engine setup

OBJECTIVE

Exploring the possibilities and limitations of H_2-PFI systems in heavy-duty diesel engines in terms of engine-out emissions and performance.

APPROACH

- Literature study on (H_2) engines, getting familiar with the setup and analytical methods
- Involvement with preparing the engine setup
- Running benchmark tests on diesel fuel
- Progressively replacing more diesel with H_2
- Analyzing the data, writing a report and presenting the results

STUDENT PROFILE

- Affinity with combustion engines
- Knowledge on the working principles of ICEs
- MATLAB programming and post-processing skills
- Followed the course Clean engines and future fuels

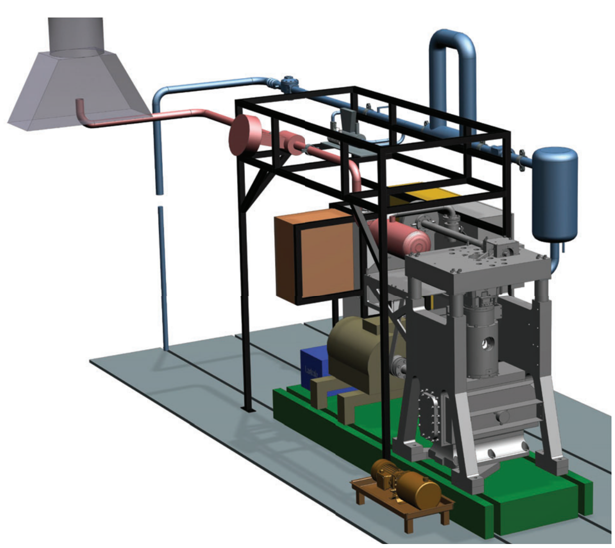


Figure 2: CAD render of the optical H_2 engine setup, currently being built in ZEL

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.

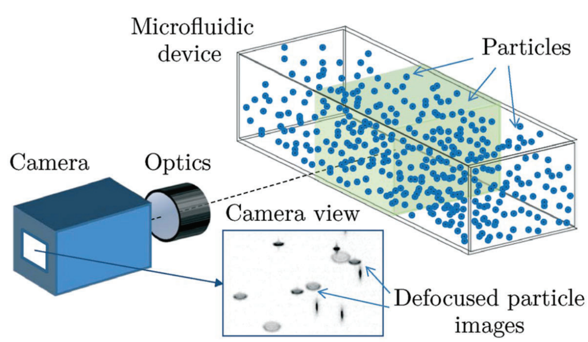


Figure 1: Schematic of the defocused tracking setup showing the camera view capturing defocused particle images within the microfluidic device. [3]

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

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

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Mini-Hydrocyclone for Microplastic Filtration

Youri van den Brink*, Nico Dam

***E-mail: y.v.d.brink@tue.nl**

INTRODUCTION

The release of microplastics, particularly synthetic fibers from washing machines, is a major contributor to aquatic pollution. Conventional filtration methods for capturing these sub-millimeter particles often rely on mesh filters that can clog, require frequent replacement, and may not be effective for the smallest particles. Hydrocyclones offer a promising alternative, using centrifugal force to separate particles from a fluid stream without any filter media or consumables [1, 2]. This allows for continuous operation and a robust, low-maintenance design.

While the principle of hydrocyclone separation is well-established, a compact system optimized for this specific application is not yet available. Understanding how performance is affected by the irregular, non-spherical shapes of microplastics (e.g., fibers) is critical for designing an effective filtration system.

This project will characterize the performance of a prototype hydrocyclone system designed for microplastic capture. The system will be built, tested, and potentially optimized using CFD to provide a benchmark for comparison against other mesh-free technologies, such as acoustofluidic filters.

TASKS & GOALS

Design, build, and characterize a hydrocyclone filtration system to benchmark its performance against other separation methods.

Research & Conceptualize: Investigate and propose a suitable hydrocyclone design for microplastic filtration.

Design & Build: Fabricate the hydrocyclone (e.g., (metal) 3D printing/CNC) and assemble the experimental setup.

Integrate & Test: Integrate the hydrocyclone into a test setup and validate its functionality.

Measure & Analyze: Evaluate separation efficiency under various conditions and analyze data (e.g., MATLAB/ Python).

STUDENT PROFILE

- Enjoys hands-on design and the process of building experimental setups.
- Interested in fluid mechanics and particle dynamics.
- An interest in analyzing experimental data to understand and improve system performance.

BENEFITS

- Gain practical experience in designing and fabricating a complete particle separation system.
- Develop skills in experimental planning, data acquisition, and performance characterization.
- Learn about hydrocyclone principles and their practical application in environmental technology.

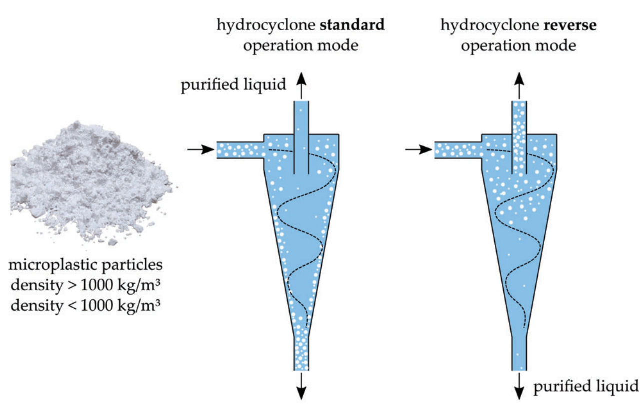


Figure 1: Schematic of hydrocyclone operation modes. In standard mode (left), particles denser than the fluid are separated via the underflow. In reverse mode (right), particles less dense than the fluid are separated via the overflow. [3]

REFERENCE

[1] Liu, L. et al., (2022). Science of the Total Environment, 840. DOI: 10.1016/j.scitotenv.2022.156697

[2] He, L. et al., (2022). Particuology, 71. DOI: 10.1016/j.partic.2022.01.011

[3] Senfter, T. et al., (2024). Microplastics, 3. DOI: 10.3390/microplastics3010002

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

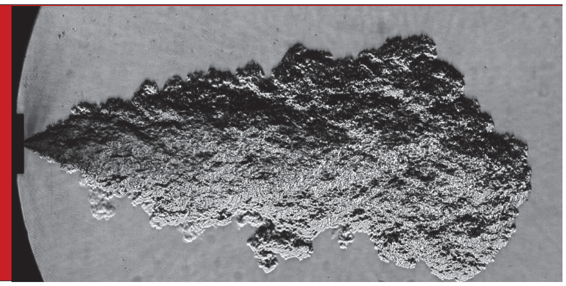
Available for ME, AT, SET

EINDHOVEN UNIVERSITY OF TECHNOLOGY

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.

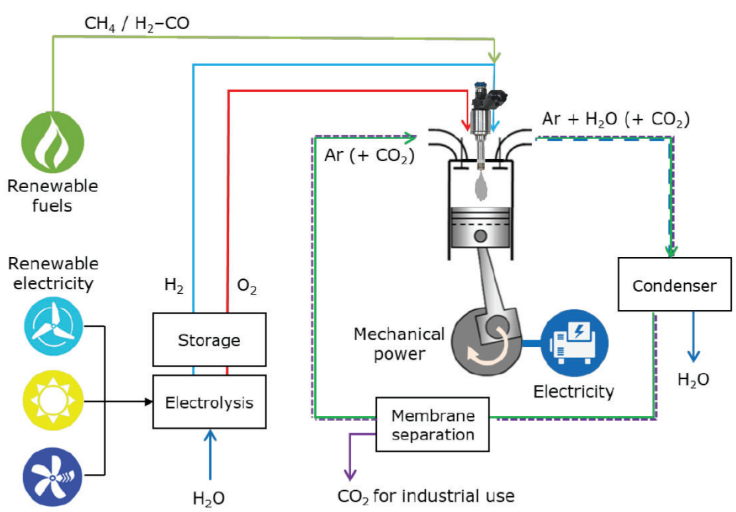


Figure 1: Schematic layout of the Argon Power Cycle.

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.

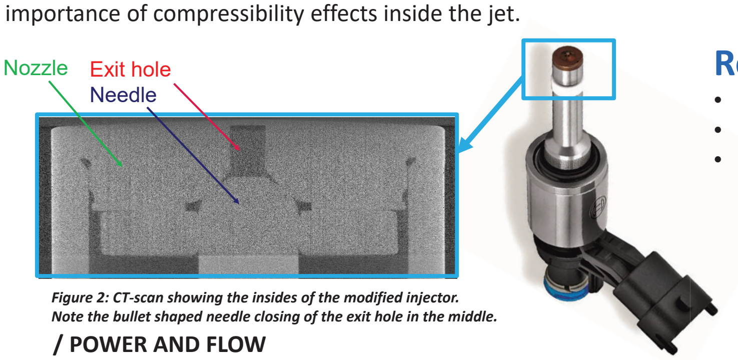


Figure 2: CT-scan showing the insides of the modified injector. Note the bullet shaped needle closing of the exit hole in the middle.

/ 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.

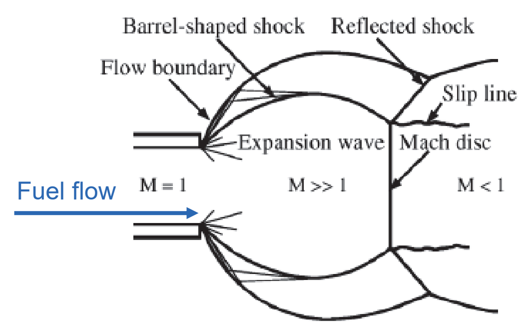


Figure 3: Classical model by Ewan and Moodie[1] on the injection of a compressible fluid.

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]

Supervisors	Xiaoxing Li, Prof. Hans Kuerten
Daily supervisor	Xiaoxing Li
Company	Canon Printing Production
Starting date	Any time
Exp./Num./Design	Numerical

Power &Flow

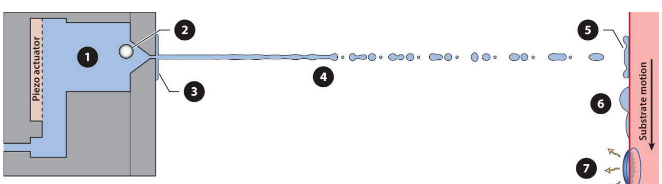
TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Absorption and Evaporation of Ink in Paper Sheets

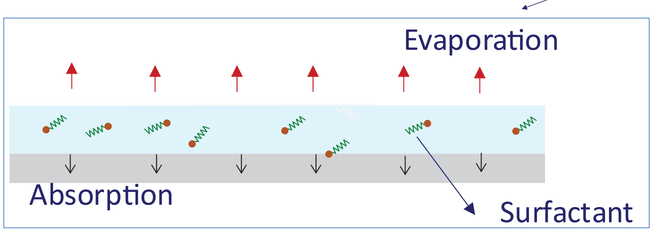
Xiaoxing Li, Hans Kuerten
x.li5@tue.nl

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.

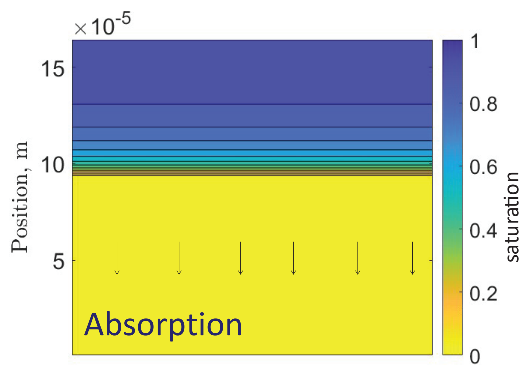


GOALS

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

TASKS

- Summarize the evaporation model in porous media in the literature.
- 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 Python, 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.

General Information	
Supervisor	Noud Maes
Mentor	Ralph Maas
Internal/External	Internal
Exp./Num./Design	Numerical / Design

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Numerical investigation of a side-mounted prechamber for hydrogen engines

Ralph Maas*, Noud Maes
*E-mail: j.f.p.w.maas@tue.nl

INTRODUCTION

Hydrogen internal combustion engines (H_2-ICEs) offer a promising path to decarbonizing transportation but face key challenges such as NO_x emissions, combustion stability, and knock. One approach to address these issues is the use of prechamber ignition systems.

The concept involves the use of a small pre-chamber, separate from the main combustion chamber, where a rich air-fuel mixture is ignited. This ignition generates high-energy turbulent jets of hot combustion products that are forcefully expelled into the main chamber through small orifices.

A previous CFD study using CONVERGE, has investigated a centrally mounted passive prechamber. The results were promising, and the research is continued experimentally. Planned research will be conducted using an optically accessible engine at the Zero Emissions Lab. Due to design constraints of this engine, the prechamber must be located on the side of the cylinder, introducing new complexities.

In this master thesis project, CFD software will be used to gain insights into this novel configuration. The outcomes aim to advance the understanding and feasibility of prechamber-based hydrogen combustion systems.

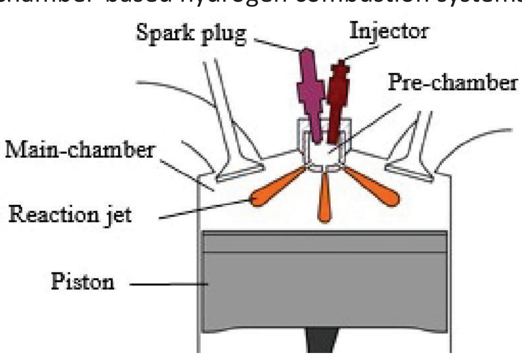


Figure 1: Schematic image of a centrally mounted active prechamber

OBJECTIVE

Improve the understanding of a side-mounted active prechamber on the combustion process inside the engine. This understanding is to be used to optimize the design of the prechamber.

APPROACH

- Short literature study on hydrogen combustion engines and turbulent jet ignitions systems
- Review of existing model [1], and adaptation to include the side-mounted prechamber
- Study the combustion process with the side mounted prechamber and optimize prechamber configuration
- Writing report, presenting result and give advice on the design of the prechamber

STUDENT PROFILE

- Affinity with internal combustion engines
- Good understanding of thermodynamics

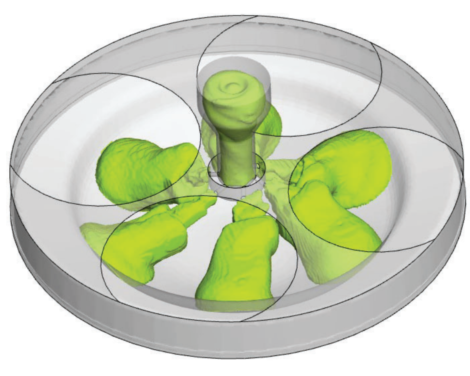


Figure 2: Result from the simulations performed with a centrally mounted passive prechamber [1]

REFERENCE

[1] *Maas, R., Bekdemir, C., and Somers, B., "Numerical Study on the Design of a Passive Pre-Chamber for a Heavy-Duty Hydrogen Combustion Engine," SAE Technical Paper 2024-01-2112, 2024, https://doi.org/10.4271/2024-01-2112.*

Supervisor	Jeroen van Oijen
2nd supervisor	Boyan Xu, R.J.M.Bastiaans, Hesheng Bao
Company	N.A.
Starting date	Anytime
Exp./Num./Design	Numerical

Modelling bluff-body stabilized flame with FGM model

Jeroen van Oijen, Boyan Xu, R.J.M.Bastiaans, Hesheng Bao
J.A.v.Oijen@tue.nl
b.xu1@tue.nl

Keywords: Turbulent combustion, FGM

INTRODUCTION

- Current simulation [1][2] for bluff body stabilized premixed $NH_3/H_2/N_2$ flame shows good agreement with experiment but needs long simulation time.
- Flamelet-Generated Manifolds (FGM) model can reduce computational time (order-of-magnitude speedups).
- Turbulent-FGM modelling framework has been well established[3] .

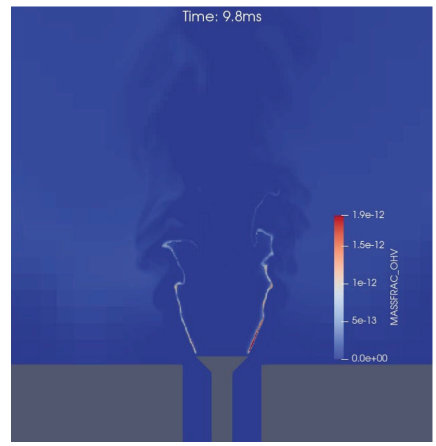


Figure 1. Bluff-body stabilized flame.

TASKS

- Follow the assignment in course “Modelling combustion”, build FGM table for premixed $NH_3/H_2/N_2/O_2$ flame using CANTERA /CHEM1D.
- Build the geometry and mesh in ANSYS Workbench (same step as the course assignment) and implement FGM for simulation in OpenFOAM (well established in-house modelling framework).
- Compare the result (flow field & flame position) with previous simulation/experiment.
- Predict the blow-off behavior (analyze the NOx emission).

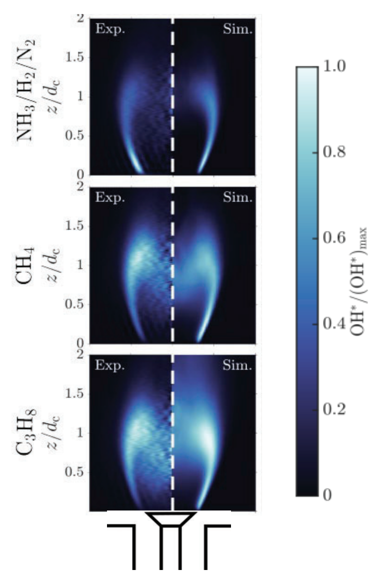


Figure 2. Time-averaged comparison: LES/experiment [1].

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] Su, T., Xu, B., Bastiaans, R. J., & Worth, N. A. (2024). The behaviour of NH3/H2/N2, CH4 and C3H8 turbulent premixed bluff-body stabilized flames near lean blow-off. Proceedings of the Combustion Institute, 40(1-4), 105739.

[3]Hesheng B, Hayri Y, Dirk R, Bart S, The inclusion of scalar dissipation rate in modeling of an n-dodecane spray flame using flamelet generated manifold, Combustion and Flame,Volume 249, 2023

Supervisor	Dr. Stein Stoter
2^{nd} supervisor	N.A.
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

High-performance finite element-based Navier-Stokes solver

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

Keywords: *CFD, Finite element method, high-performance*

INTRODUCTION

Various advances within the field of computational mechanics have opened the door to the development of highly efficient and scalable Navier-Stokes flow solvers. This project will give you the opportunity to build such a solver (nearly) from scratch. You will use the python finite element library FEniCS (written in C++ and fully supportive of parallel processing), enabling rapid development (python) while being able to use highly optimized finite element routines and linear solvers.

FEM for flow

This project revolves around the use of the finite element method for the flow solver. Most commercial CFD solvers are finite volume based. When tailored correctly, the finite element method can yield pointwise mass conserved flow approximations, a very powerful concept. Additionally, FEM can achieve arbitrary order of spatial convergence on unstructured grids. Both of these concepts will play a role in your project.

Advanced computational methods

Achieving this ambitious goal requieres combining various advanced numerical solution techniques:

- Higher-order mixed implicit/explicity time stepping, to separate non-linear from linear effects.
- Higher-order specialized finite element pairs to achieve exactly divergence-free approximations.
- Hybridization and static condensation of degrees of freedom to reduce the size of the matrix solve.
- Dedicated preconditioning for using efficient iterative solving algorithms.

Your project will either zoom into one of the above points or combine multiple, depending on your interests, goals and progress.

STUDENT PROFILE

- Affinity towards (advanced) numerical solution methods,
- Strong interest in programming and eager to improve upon their existing programming skills (e.g., Python).
- Having taken the course Advanced Discretization will enable you to make a flying start.

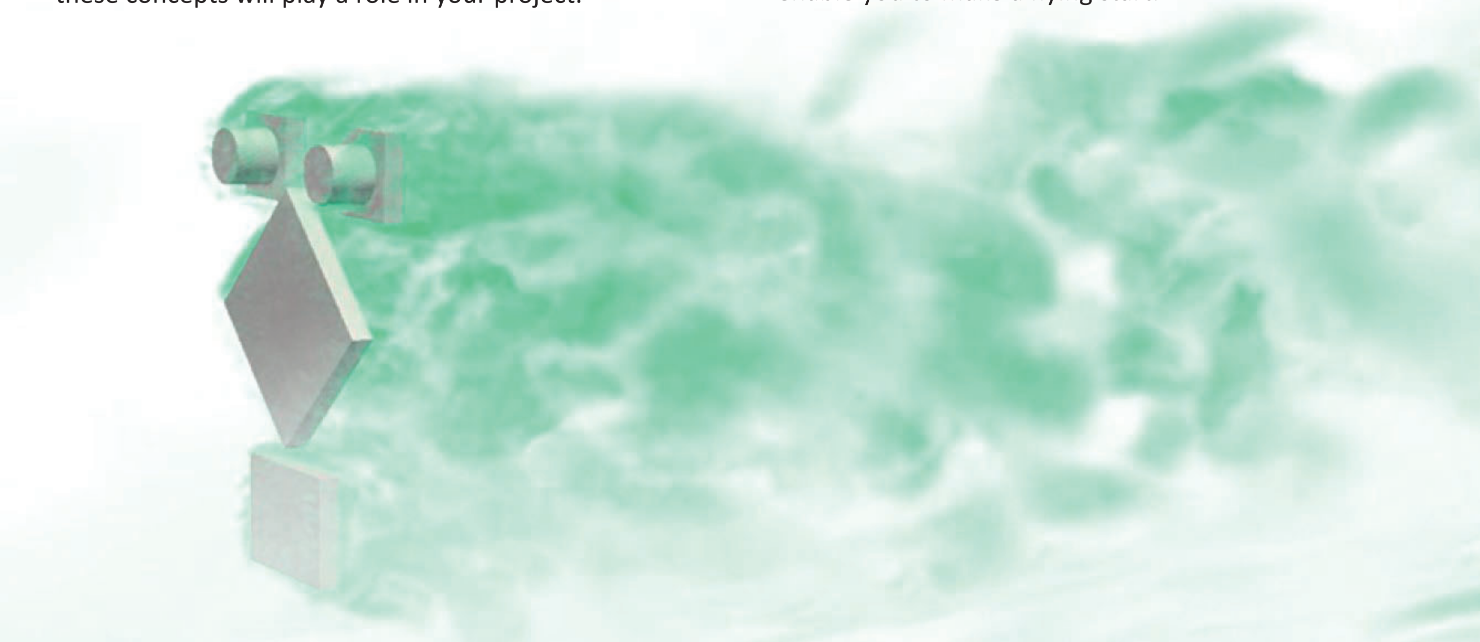


Fig 1: High-performance FEM-based CFD solve.

Supervisor	MSc. Aramesh Mirsaeidi
2nd supervisor	Dr. Stein Stoter
Mentor	
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

Aramesh Mirsaeidi, Stein Stoter

E-mail: k.f.s.stoter@tue.nl

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.

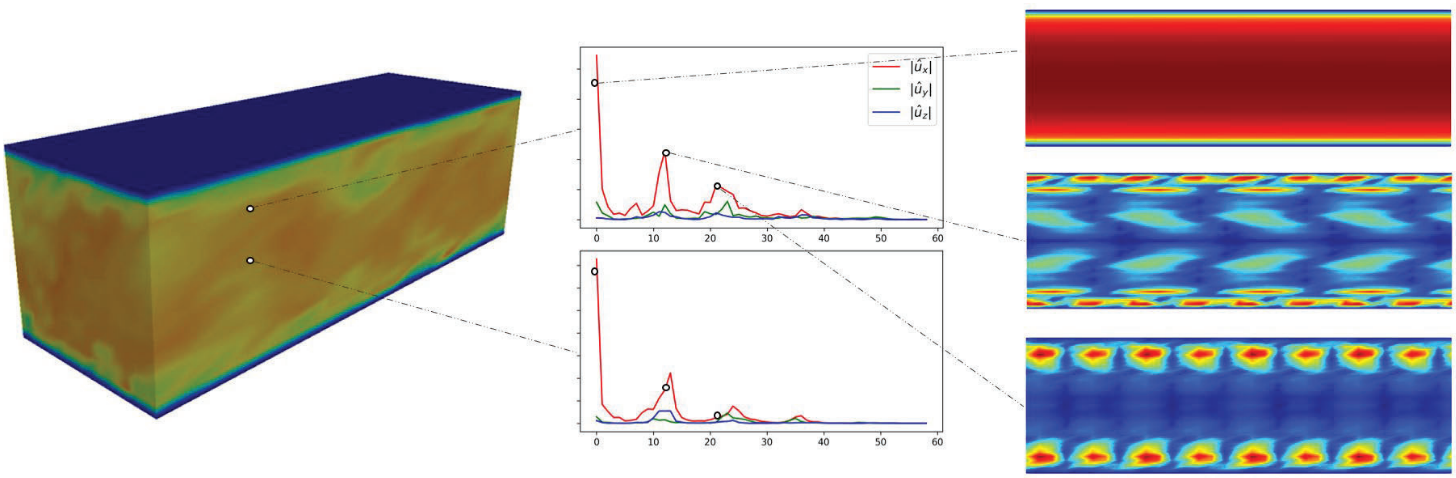


Fig 1: Turbulent flow decomposed into its dominant mode shapes.

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*

Master Thesis Project Proposals
Q2 2025-2026

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

Preface

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

Please select 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	Dr. Clemens Verhoosel
2nd supervisor	
Mentor	
Company	TouchWind BV.
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Experimental

Available for ME

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number:

Validation study on the wake behavior of wind farms with tilted turbines

Clemens Verhoosel

*E-mail:

Keywords: *Validation, CFD, Rotor tilt, Wake steering*

INTRODUCTION

Climate change is a big problem facing us today. There is a strong need for renewable energy sources and it is increasing each year. TouchWind is developing a floating offshore wind turbine. As a startup, it is hard to compete with the already existing turbine manufacturers. However, with the design of a tilting one-piece rotor, TouchWind believes that the cost per kWh can decrease. Furthermore, TouchWind estimates that tilted turbines can be placed closer to each other and thus occupying less space.

Figure 1: TouchWind rotor during normal operating conditions.

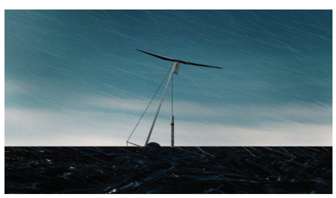


Figure 2: TouchWind rotor during storm conditions.

Both beliefs arise from the so-called 'Park effect' of the TouchWind turbines. The TouchWind rotors can tilt. This means that the rotor will be, as visible in Figure 1 and 2 , positioned at an angle relative to the wind. This has a lot of benefits for one turbine itself, but with multiple turbines placed in a row, more benefits can arise. The benefits that arise by placing multiple turbines is called the TouchWind park effects.

Wind turbines form wakes downwind of the turbines. Wakes are the more turbulent and less energy rich flow that form due to the energy extraction of wind turbines. By applying tilt to a rotor the wake gets redirected downwards creating a new fresh stream of energy for the downwind placed turbines. This phenomena is visualized in Figure 3. Research has shown that with a wind gradient present, even higher energy outputs can be reached for a wind farm with tilted turbines then for a conventional wind farm.

However, tilted rotors are not commonly used and so only a little information is known about the airflow/wake behavior of these turbines. With the use of CFD simulation, TouchWind has gained better insight in the wake behavior. To ensure that LES simulations accurately reflect real-world behavior, validation with experimental data is essential. The goal of this assignment is to contribute to the development of a validated CFD model for a tilted wind turbine.

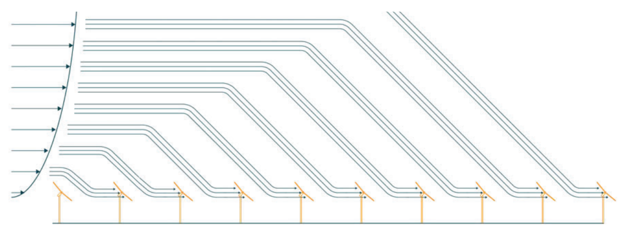


Figure 3: TouchWind rotor during storm conditions.

TASKS

- Conduct research into how LES simulations can best be validated using experimental data.
- Develop an experimental plan focused on tilted turbines, aligned with the required validation insights.
- Support or conduct experiments and compare the measured data with LES simulation results.

STUDENT PROFILE

We are looking for a MSc student who:

- Is eager to contribute to the validation of aerodynamic models for wind energy applications.
- Has interest in working in a start-up. This involves working in a small team, but also work independent.
- Has interest in working in the sustainable energy market contributing to creative energy solutions.

TouchWind
Pulling Forward

Supervisor	Arjan Frijns
Daily supervisor	Bas Gieling
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Numerical

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Extending the DSMC method for Polyatomic Gas Mixtures in Rarefied Flow Regimes

Arjan Frijns*, Bas Gieling, Michael Abdelmalik
*E-mail: a.j.h.frijns@tue.nl

Introduction

When Size Shrinks or Pressure Drops

As pressures decrease or system sizes shrink, traditional fluid behavior changes dramatically. Molecular interactions become important, and rarefaction effects dominate the flow.

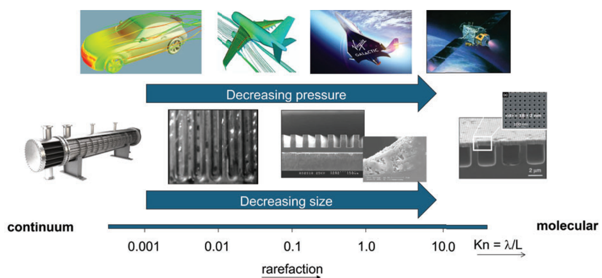


Figure 1: Rarefaction effects occur when a system's pressure or size decreases.

Where This Matters in Industry

Some examples:

- Semiconductor Lithography
  Micro-scale vacuum chambers
- Spacecraft Re-entry
  Low-pressure atmospheric conditions
- Carbon Capture Technologies
  Gas transport in micro-porous materials

Why Traditional Models Fail

In these transition and free-molecular flow regimes, the Knudsen number is high, meaning the assumptions behind continuum models like the Navier-Stokes or Euler equations no longer hold.

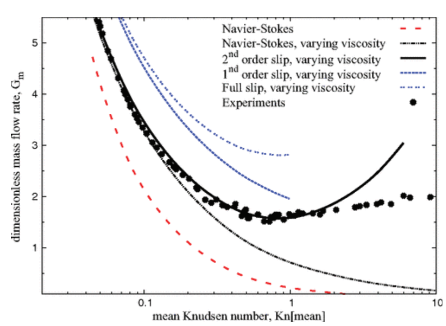


Figure 2: The mass-flow rate through a micro-channel attains a minimum in the transition regime, which continuum models cannot predict. *Figure from Kokou Dadzie, S. and Brenner, H. (2012). DOI: 10.1103/PhysRevE.86.03631*

Project

Aim

To design and optimize systems in rarefied flow regimes, industry requires accurate physical models that go beyond classical fluid dynamics.

This project focuses on:

- Extending the Direct Simulation Monte Carlo (DSMC) method from monatomic to polyatomic molecules.
- Developing a structure-preserving Machine Learning model to infer the collision operator from particle-based simulations.
- Implementing this model within DSMC and comparing results with a Boltzmann solver.

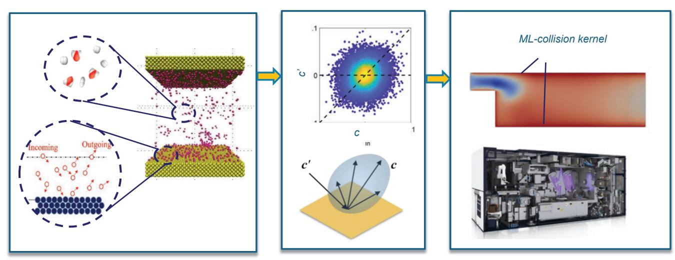


Figure 3: The multiscale approach: Molecular dynamics → ML-based stochastic kernels → DSMC

Project Tasks

As a student researcher, you will:

- Conduct a literature review on rarefied flows, collision operators for polyatomic mixtures, and particle-based methods.
- Implement the new numerical model within our existing framework.
- Assess results both qualitatively and quantitatively.
- Conclude and provide recommendations on modeling and numerical implementation.

Student Profile

We are looking for a Master's student who:

- Has a strong interest in advanced numerical methods.
- Enjoys programming and is eager to enhance his/her skills (e.g., in Python).
- Is curious, analytical, and motivated to contribute to cutting-edge research.

Supervisor	Camilo Rindt
2nd supervisor	Michel Speetjens
Daily supervisor	Nikolaos Georgousis
Company	VITO
Starting date	As soon as possible
Exp./Num./Design	Experimental

ETFD

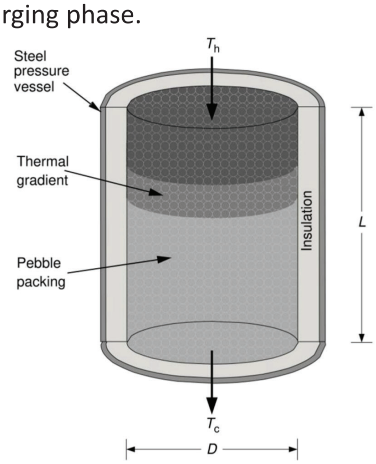
TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

EXPERIMENTAL INVESTIGATION OF FULL CYCLE PACKED-BED THERMAL STORAGE OPERATION

Camilo Rindt: c.c.m.rindt@tue.nl

INTRODUCTION

Packed-bed thermal storage (PBTS) systems are thermal energy storage (TES) devices and they typically constitute of a storage tank and a solid phase material, in the form of packing elements (PEs) for the storage of heat. Also, a heat transfer fluid (HTF), either liquid or gas, is used to exchange heat with the PEs[1]. Precise computation of the HTF and PEs temperature fields inside the storage tank are of great importance for the analysis and design of PBTS systems. The numerical analysis of the PBTS systems is commonly done through a volume-averaging technique for the porous media structure solid and the HTF phases (2 phases). In literature a common numerical model used is the 2 phase – 1 dimensional (2P-1D)[2] model which can calculate the HTF and PEs temperature distribution in the axial direction of the PBTS. However, in literature there is a lack of experimental studies validating the 2P-1D numerical model under full cycle operating conditions. A full cycle consists of a charging, stand-by and discharging phase.

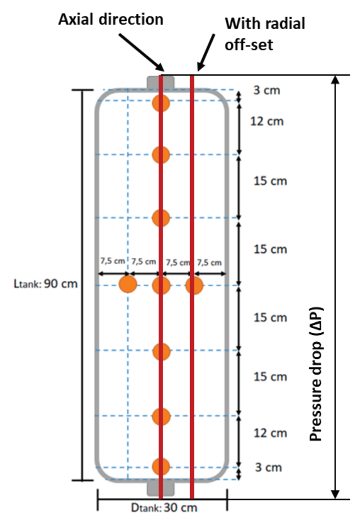


Keywords: *PBTS systems, experimental validation, full cycle operation, characteristic dimensionless numbers*

TASKS

The main expectations of this MSc project are:

- Construction of a vertically oriented PBTS system with a cylindrical storage tank (HTF: preferably air, PEs: spheres or rocks).
- Conducting full cycle experiments and measuring at least the HTF (or PEs) temperature at various axial and radial positions and the pressure drop across the PBTS height.
- Conducting experiments under conditions similar to those in a real PBTS system by using a set of characteristic dimensionless numbers, defined for PBTS systems.



GOALS

- Designing a PBTS setup that allows accurate measurements under various experimental conditions.
- Conduct a thorough experimental validation of the commonly used 2P-1D numerical model.

STUDENT PROFILE

We are looking for a highly motivated MSc student with interests in energy technology and experimental investigations for this quite unexplored scientific field. Any experience with the design of an experimental set up is appreciated. (A 2P-1D numerical model, coded in Python, can be provided for the numerical validation of the experimental temperature and/or pressure drop measurements.)

REFERENCES

[1] McTigue JD *et al.* (2018), Performance of packed-bed thermal storage to cycle duration perturbations, Journal of Energy Storage, (19) 379-392.

[2] Kocak B & Paksoy H (2019), Performance of laboratory scale packed-bed thermal energy storage using new demolition waste based sensible heat materials for industrial solar applications, Solar Energy, (211) 1335-1346.

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

ETFD

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.

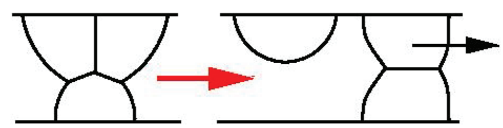


Figure 1: A bubble train that breaks up

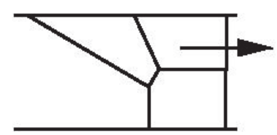


Figure 2. A flat film state that does not break

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

EINDHOVEN UNIVERSITY OF TECHNOLOGY

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.

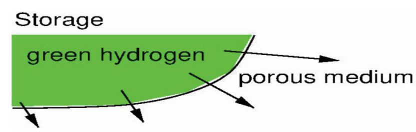


Figure 1: Seasonal storage of green hydrogen

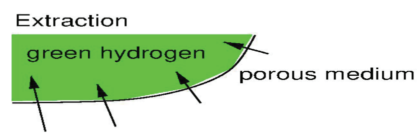


Figure 2. Seasonal extraction of green hydrogen

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	See below
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*

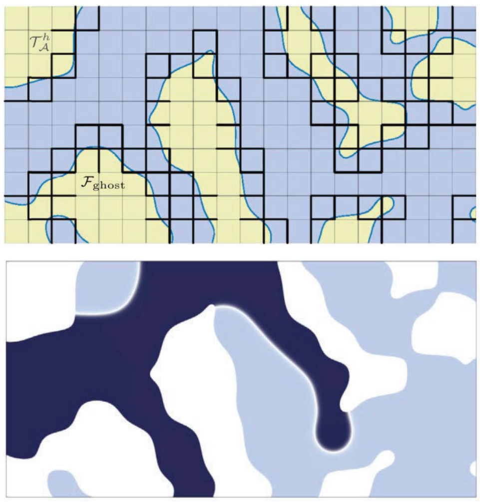


Fig 1: Multi-phase flow through porous material

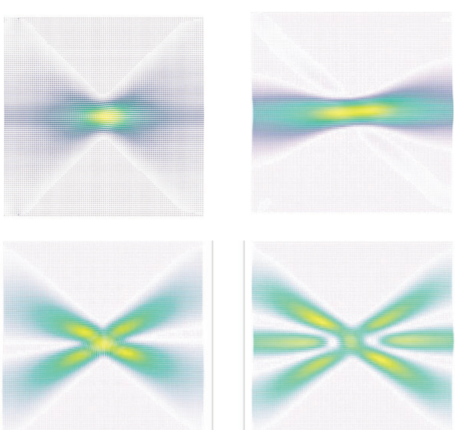


Fig 2: Model order reduction

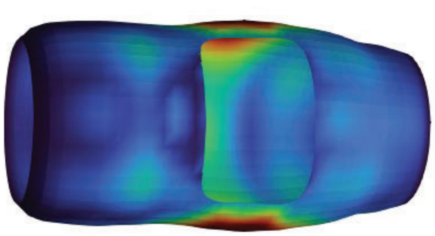


Fig 3: Explicit analysis of a shell-structure

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	Rick de Lange
2nd supervisor	-
Company supervisor	David van Venrooij
Company	Weheat
Starting date	-
Exp./Num./Design	Exp/Design

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Smart EXV superheat control in residential heat pumps

Rick de Lange
H.C.d.Lange@tue.nl

Introduction

Weheat develops state-of-the-art heat pumps for central heating systems. Reliability and performance are large contributors to Weheat's success. Superheat is a critical component in the efficiency and safety of our heat pump operations. It ensures the refrigerant fully transitions into vapor before compression, crucial for both the system's efficiency and safety. Your graduation assignment will involve developing and optimizing control strategies for this intricate and captivating process.

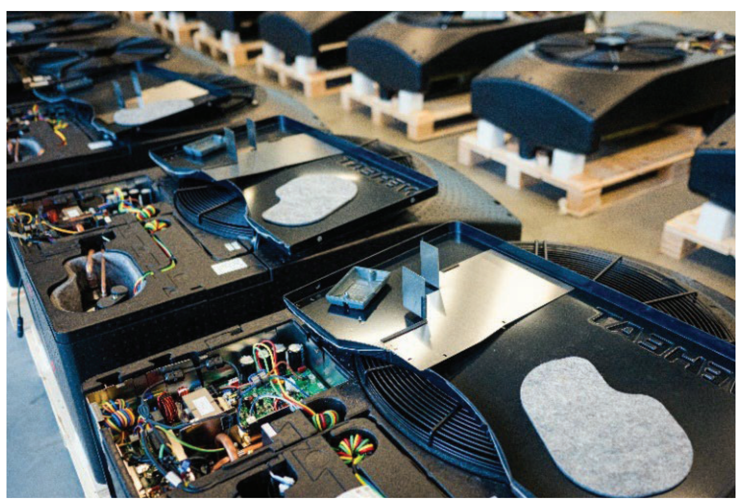
Objective

The goal of this thesis is to develop and implement a robust control method for the electronic expansion valve (EXV) in our heat pumps, ensuring precise superheat control while adapting to dynamic operating conditions. The control algorithm, implemented in C or Python, must effectively handle a wide range of air and water temperatures, adapt to varying load conditions, compensate for sensor inaccuracies and phase shifts, and be transferable across our entire heat pump catalog.

Goals

- **Develop a control method** for the expansion valve which can handle a varyity of load conditions
- **Validate its performance** and robustness, extensive testing will be conducted in the in-house climate chamber, which allows for simulations across the full operating range. The control method will be evaluated under extreme conditions, such as sudden changes in temperature and flow, rainfall on the evaporator, and evaporator freezing.

This thesis presents a challenging theoretical basis of control theory and thermodynamic behavior while providing extensive hands-on opportunities to test and refine hypotheses in a controlled test environment.



Supervisor	Ir. Ronald Lamers
2nd supervisor	Dr. Michel Speetjens
Mentor	
Company	Thermo Fisher Scientific
Internal / External	External
Starting date	Any time
Exp./Num./Design	Num./Exp.

Available for ME-SET

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number:

MODEL-BASED THERMAL DRIFT COMPENSATION FOR ELECTRON MICROSCOPES

ThermoFisher SCIENTIFIC
The world leader in serving science

Ronald Lamers, Michel Speetjens*
*E-mail: m.f.m.speetjens@tue.nl

INTRODUCTION

Thermo Fisher Scientific develops electron microscopes capable of visualizing individual atoms. A common problem for these devices is so-called “thermal drift”, i.e. positioning inaccuracies of O(nm/min) due to thermal expansion, which can already be caused by heat loads of O(mW). Thermal drift can often be mitigated by a microscope design that is less sensitive to thermal deformation and/or by reducing the drift (heat) sources. However, if insufficient, then a further option is active adjustment of the position of the stage holding the sample to counteract the thermal drift. Essential for such methods for “thermal drift compensation” is to understand the thermo-mechanics behind the drift and translate this in predictive models for practical use.

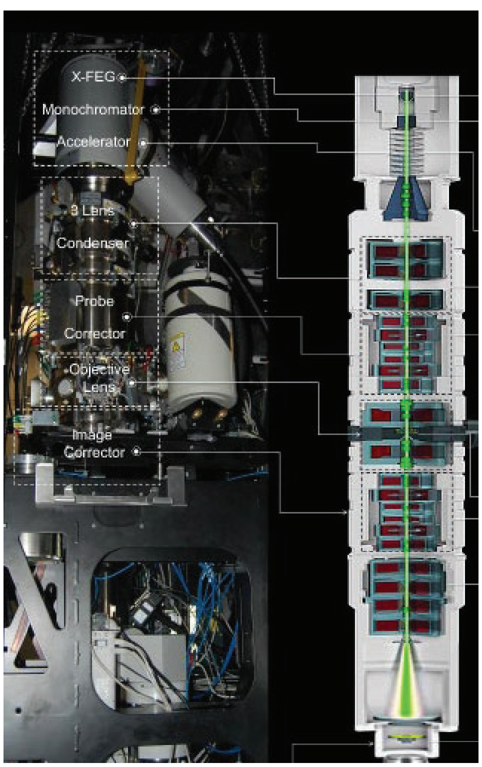


Fig. 1. Typical electron-microscope system.

MODELLING ISSUES

Modelling techniques for predicting thermal drift exist yet their application to realistic systems has proven challenging in previous studies done at Thermo Fisher Scientific. This stems primarily from fundamental assumptions in the early modelling stages. However, the impact of such assumptions on the prediction accuracy and how to improve current models while maintaining practical usability remains an open question.

PROJECT

The main project goal is the ***development of new models for thermal drift compensation*** in electron microscopes. This will be done via a modular test set-up at Thermo Fisher based on an actual microscope and involves the following steps and subgoals:

- Literature study on the impact of thermo-mechanical effects on positioning accuracies in complex industrial precision systems and ways to model and tackle this.
- Identify assumptions and factors causing mismatches between current models and test set-up such as e.g. convective/radiative boundary conditions, simplified geometries, contact resistances, uncertain material properties, impact of vacuum, measurement errors.
- Use insights from the above literature study and analysis of the test set-up versus current models to develop new models for thermal drift compensation.
- Develop an experimental strategy that enables systematic validation and testing of the new models using the test set-up and its instrumentation.
- Further develop and fine-tune the new models using insights gained from the experimental study.

Supervisor	Dr. Michel Speetjens
2nd supervisor	Ir. Benno van der Werff (IF Technology)
Mentor	
Company	IF Technology
Internal / External	External
Starting date	Any time
Exp./Num./Design	Num./Exp./Design

Available for ME-SET

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number:

SUSTAINABLE HEATING FOR THE BUILT ENVIRONMENT

Michel Speetjens*, Benno van der Werff

***E-mail: m.f.m.speetjens@tue.nl**

INTRODUCTION

The engineering & consultancy company **IF Technology** (https://iftechnology.nl) specializes in development of sustainable energy systems. One area of application concerns *sustainable heating & cooling of the built environment* using technologies such as e.g. geothermal or aqua-thermal systems and heat pumps.

RESEARCH TOPICS

1. Performance of thermal-energy storage systems

Two promising forms of thermal energy for heating & cooling of the built environment are:

- Aqua-thermal energy (Fig. 1);
- Acquifier Thermal Energy Storage (ATES).

Both systems rely on the seasonal availability of energy, which results in "charging" and "discharging" of a reservoir (i.e. a body of water or a subsurface porous rock layer) either directly by exchange of water or indirectly via a heat pump. Efficient design and operation is essential for an optimal and sustainable performance of such systems.

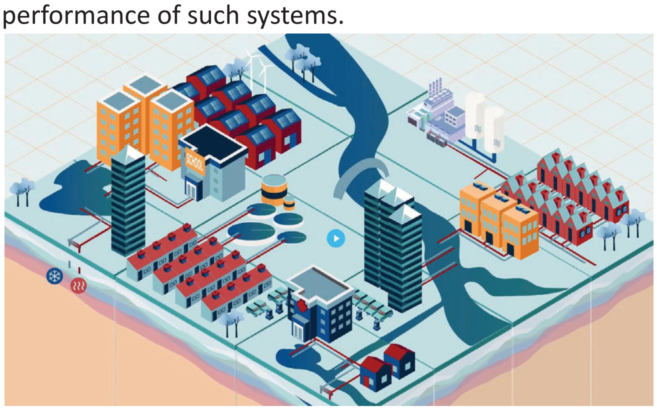


Fig. 1. Heating & cooling of the built environment by aqua-thermal energy (from IF Technology).

Challenges within this scope include:

- Thermal and hydraulic modelling of the seasonal heat exchange of the thermal-energy reservoirs.
- Optimization of the seasonal (dis)charging for both technical and economic performance.
- The impact of variable operating temperatures on the COP of the heat pump and the overall efficiency.

2. Integration of power-to-heat (P2H) systems

Intermittency and fluctation due to weather is a major challenge for sustainable electricity generation by e.g. solar panels and wind turbines. Electricity storage in e.g. Li-ion batteries can mitigate this yet is a costly option. The fact that a substantial part of the generated electricity is eventually used for heating naturally advances storage of electricity in the form of thermal energy via heat pumps (so-called "power-to-heat" or P2H) as a promising alternative. Challenges include:

- Integration of the P2H concept in existing thermal-energy systems & energy networks.
- Techno-economic optimization of such integrated energy systems for certain ranges of energy prices.
- Techno-economic feasibility of heat pumps for P2H applications: dynamic response to electricity variations; economic viability of P2H units; optimal P2H operation on basis of predicted heat demands.

MSc PROJECTS

MSc projects can be defined for both research topics (or closely related topics) and tailored to personal interests and preferences. We invite students with an interest in these topics to contact us (via m.f.m.speetjens@tue.nl) to discuss opportunities for MSc projects.

Supervisor	Ir. Wouter Kuyper, Dr. Theo Ruijl
2nd supervisor	Dr. Michel Speetjens
Mentor	
Company	VDL ETG and MI Partners
Internal / External	External
Starting date	Any time
Exp./Num./Design	Num./Exp.

Available for ME-SET

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number:

MODELING THERMAL CONTACT CONDUCTANCE IN MECHATRONIC SYSTEMS

VDL ETG

MI PARTNERS
PARTNERS IN MECHATRONIC INNOVATION

Wouter Kuyper (VDL), Theo Ruijl (MI), Michel Speetjens*
***E-mail: m.f.m.speetjens@tue.nl**

INTRODUCTION

Thermal effects are often important error sources in high-end mechatronic systems (e.g. high-precision production equipment, instruments) in that sub-Kelvin temperature changes can easily cause micro-meter deformations. Many applications operate under near-vacuum conditions and thermal contact conductance at mechanical interfaces then often dominates thermal system behaviour. However, models for predicting such behaviour remain very inaccurate due to the still limited understanding of thermal contact conductance. Existing methods mostly employ a statistical approach to model the interaction between roughness asperities. Their distribution determines a critical model parameter: the interfacial contact area. The thermal contact resistance namely ensues from the contraction of the heat-flux lines from the bulk to the contact areas (see figure). Determining the interfacial contact area is therefore extremely important to accurately model the thermal contact conductance and predict the system behaviour

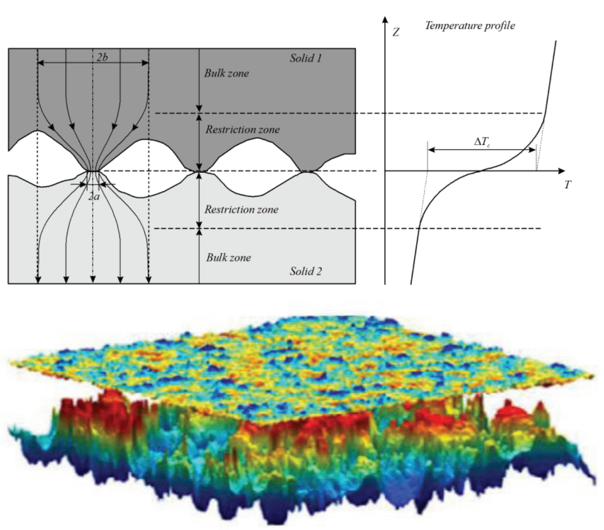


Fig. 1. Top: thermal contact resistance (in terms of temperature drop ΔT_c) due to contraction of heat-flux lines from bulk to contact areas (width 2a). Bottom: contact pressure (blue/red=low/high) between 2 rough surfaces

PROJECT

The main project goal is the ***development of a model for the accurate prediction of thermal contact conductance*** between real engineering surfaces. Key to this end is the ability to predict the real contact area as a function of applied compression pressure and relevant roughness parameters. This involves the following steps:

- Literature study on (i) classical contact mechanics, (ii) contact mechanics at real roughness asperities and ways to model this (iii) models for thermal contact conductance as a function of the contact mechanics.
- Specification of rough surfaces with well-defined characteristics (e.g. non-flatness and waviness) that are representative of real engineering surfaces.
- Development of analytical/numerical models for contact mechanics for these representative surfaces.
- Development of numerical models for simulation of temperature distributions and heat transfer within/between these representative surfaces.
- Development of predictive (analytical/numerical) models for thermal contact conductance for these representative rough surfaces from the simulated temperature distributions and heat transfer.
- Experimental validation of thermal conductance models on real problems (time permitting).

ABOUT VDL AND MI-PARTNERS

MI-Partners is specialized in the development of high-end mechatronic systems for e.g. production processes and measurement devices. **VDL Enabling Technology Group** (ETG) works on innovating state-of-the-art industrial systems with a (growing) focus on solutions for thermal effects in precision engineering.

Supervisor	Dr. Michel Speetjens
2nd supervisor	Dr. Erik Steur (Dynamic & Control)
Mentor	
Company	N.A.
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Num./Exp.

Available for ME-SET

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Project number:

OPTIMAL HEAT TRANSFER BY SMART FLOW CONTROL

Michel Speetjens*, Erik Steur
*E-mail: m.f.m.speetjens@tue.nl

INTRODUCTION

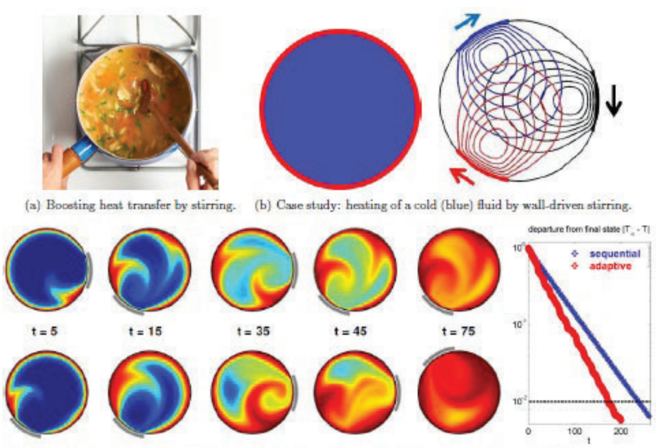
Thermal transport phenomena in flows is relevant to many (industrial) applications:

- heating and cooling in the processing industry;
- thermal management of power electronics;
- thermal conditioning of high-precision systems.

The common goal in such applications essentially is accomplishment of maximum heat transfer between an object and a flow via active manipulation of the flow.

CASE STUDY

Boosting of heat transfer by stirring of the fluid (Fig. 1a) is adopted as a case study. An industrial implementation of this principle exists in the heating of an initially cold fluid inside a circular container via the hot boundary (Fig. 1b, left) [1]. Stirring occurs via switching between the three flows that each are driven by a sliding wall (arrows) along apertures (heavy arcs) in the boundary (Fig. 1b, right). **The key question is: *"<u>How</u> to stir?"***



(a) Boosting heat transfer by stirring. (b) Case study: heating of a cold (blue) fluid by wall-driven stirring.

(c) Flow-enhanced heating driven by sequential (top) vs. adaptive (bottom) wall actuation. (d) Heating rate.

Figure 1: Accomplishing optimal heat transfer in fluid flows by "smart" flow control.

Stirring by <u>sequential</u> actuation of the sliding walls is commonly regarded the best way to boost heat transfer (Fig. 1c, top). However, this approach is sub-optimal [1].

<u>Adaptive</u> stirring by a controller that step-wise actuates the sliding walls on the basis of the most effective temperature evolution (Fig. 1c, bottom) can namely significantly accelerate the heating rate (Fig. 1d) [1].

RESEARCH TOPICS

The above findings demonstrate the potential of dedicated flow control for heat-transfer enhancement and its further exploration (by the case study of Fig. 1) is the principal goal of this research line. Specific research topics within this scope include (but are not limited to):

- Further development of the control strategy of [1] for achieving maximum heat transfer.
- Development of control strategies for other control targets (e.g. establishment of thermal fronts).
- Data-based modelling of the temperature evolution using (nonlinear) system identification.
- Development of an observer that enables state estimation from discrete sensor data.
- Experimental investigation & validation of adaptive flow control using the laboratory set-up of [2].

A multi-disciplinary approach involving expertise on heat & flow versus dynamics & control is essential to address these topics and therefore research is performed as a collaboration between research groups *Energy Technology & Fluid Dynamics* and *Dynamics & Control*.

MSc projects can be defined around any of the above topics and tailored to personal interests and preferences. We therefore invite students with an interest in these (and related) multi-disciplinary topics to contact us to discuss opportunities for MSc projects.

REFERENCES

[1] R. Lensvelt, M.F.M. Speetjens, H.Nijmeijer, Fast fluid heating by adaptive flow reorientation, Int. J. Therm. Sci. **180**, 107720 (2022).

[2] O. Baskan, M. F. M. Speetjens, G. Metcalfe, H. J. H. Clercx, Experimental and computational study of scalar modes in a periodic laminar flow, Int. J. Therm. Sci. **96**, 120 (2015).

Supervisor (Suncom)	Frank Peters
Supervisor (TU/e)	David Smuelders and Arjan Frijns
Company	Suncom Energy
Internal / External	External at Suncom
Starting date	Q4 2025 (or Q1 2026)
Exp./Num./Design	Experimental, numerical and design

Available for ME-SET/PT/ET

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Optimization of a packed-bed thermocline thermal energy storage

Frank Peters

*E-mail: .F.Peters@suncom-energy.com, D.M.J.Smeulders@tue.nl

INTRODUCTION

Suncom is a Dutch start-up developing concentrated solar thermal (CST) systems that deliver industrial heat up to 425 ° C. To be able to balance supply and demand, Suncom is developing a thermal energy storage (TES) solution. More specific, this is a thermocline packed-bed thermal energy storage (PB-TES) system consisting of a storage vessel filled with granular (porous) storage media such as basalt, magnetite or steel slag.

To achieve an optimal storage utility, there is a need to manage a stable *thermocline*. This is a temperature gradient layer between the hot and the cold parts of the tank, that helps maintain thermal stratification. Proper stratification leads to improved storage efficiencies.

From a previous graduation project, a 1D CFD code (Python) was developed to model the thermocline performance. Additionally, an experimental setup (at TU/e, Gemini) was used to validate the models.

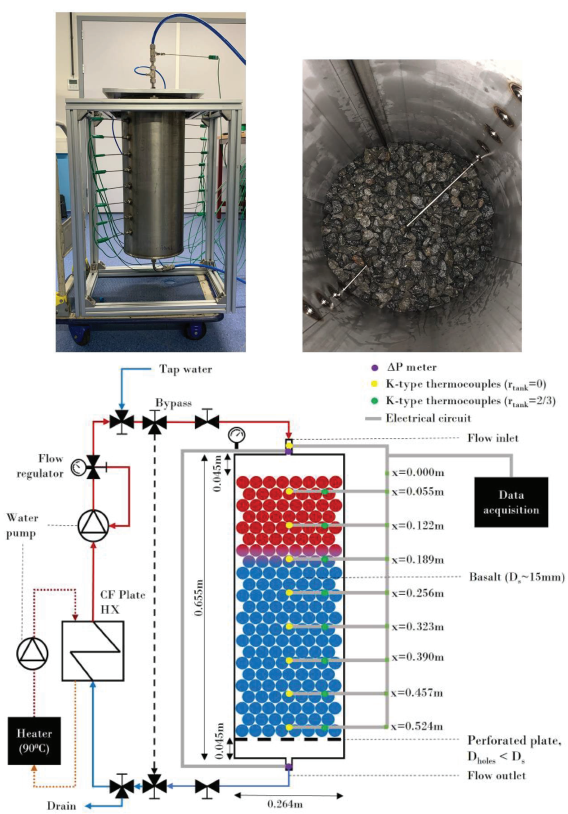


Figure 1: Experimental setup from thesis of MSc. Mark Willemsz (2023)

PROJECT GOALS

- Improve the 1D CFD code, for example by incorporating wall thermal effects (currently not considered, but likely not insignificant);
- Propose and implement other model improvements.
- Apply the model to perform an extensive parameter study, to optimize the TES solution:
  - Influence of particle size (distribution) and porosity;
  - Influence of material parameters;
  - Influence of process parameters such as (dis)charge flow speed and ΔT between supply and return
- Validate the model(s) using an experimental setup.
- Propose design improvements.

(Scope can be discussed to match academic and personal interest with company interests).

PROFILE

We are looking for an entrepreneurial and enthusiastic MSc student that is both strong in modelling of thermal systems (preferably in Python), as well as being interested in performing experiments to bridge the gap between theory and practice.

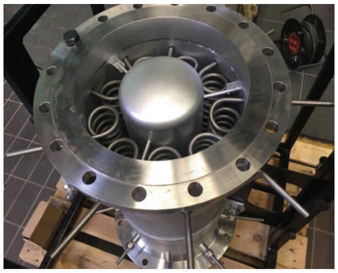
Figure 2: an operational TES built by Suncom for a project in Spain

BENEFITS

- Work in a mission-driven start-up which is decarbonizing the world's energy supply.
- Gain hands-on experience with multi-physics modelling and energy storage.
- Collaborate and learn from experienced engineers from Suncom, Fraunhofer, and Dehoust as part of a funded international research project.
- Internship compensation of €500 per month.
- Opportunity to join the team long-term after your internship, with the possibility to become co-owner

<u>**Master project**</u>**:**
Improvements & experiments with a metal fuel fired Rankine Compression Gasturbine (RCG) prototype

Background
Heat Power & TU/e developed a compact, fast responding and Steam and gas turbine: the Rankine Compression gas turbine (RCG). A 5kWe industrial prototype was realized in a wood milling factory in Schijndel (see figure to the right).
Heat Power & TU/e also developed the sub critical once through boiler: a fast responding steam generator that can start form cold within minutes. A metal fuel fired 80kW prototype was realized together with Metalot, team solid and the metal fuel partners (see figures below).



Currently, Engineering Design student teams are combining the components of the RCG prototype with the metal fuel fired once through boiler, thus creating a metal fuel fired RCG prototype. A preliminary model was made in Simulink to determine which layout and design choices would fit best for the prototype.

Goals
- Determine the expected performance of the RCG prototype and metal fuel fired boiler using & while improving the Simulink model
- Carry out remaining realisation & improvements of the RCG prototype
- Perform experiments with the metal fuel fired RCG prototype & compare results with the Simulink model

Assignment
Pursue goals as described in the above. Note that the scope is flexible and that there will be support of TU/e supervisor Rick de Lange and Heat Power staff. The supervisor and Master student together will assess which of the above goals are feasible within this assignment and where the focus of this assignment will be.

Contact: Henk Ouwerkerk (H.Ouwerkerk@tue.nl) & Rick de Lange (H.C.d.Lange@tue.nl)

Supervisor	Maja Rucker
Daily supervisor	G. Claudiu Savulescu
Starting date	Any time
Exp./Num./Design	Experimental

ETFD

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

The impact of structural evolution during crystallization on energy storage performance of phase change materials

George Claudiu Savulescu, Maja Rücker

Phase Change Materials (PCMs)

PCMs represent a promising alternative for energy storage, with a high impact on CO2 emission reduction. The latent heat of crystallization from PCMs could be used to store heat during the day, when solar energy triggers the solid-liquid transition and release heat during the night, when the lack of solar energy triggers the reverse transition. To improve the heat conductivity of PCMs, fillers such as graphite are added to the chemical composition, modifying the dynamics of crystallization, especially the moment of nucleation and the propagation of the crystallization front. The exact mechanism of interaction between fillers and PCMs during crystallization is not fully understood [1], especially in plant-based PCMs, which often come with large heterogeneities.

Novel experimental techniques

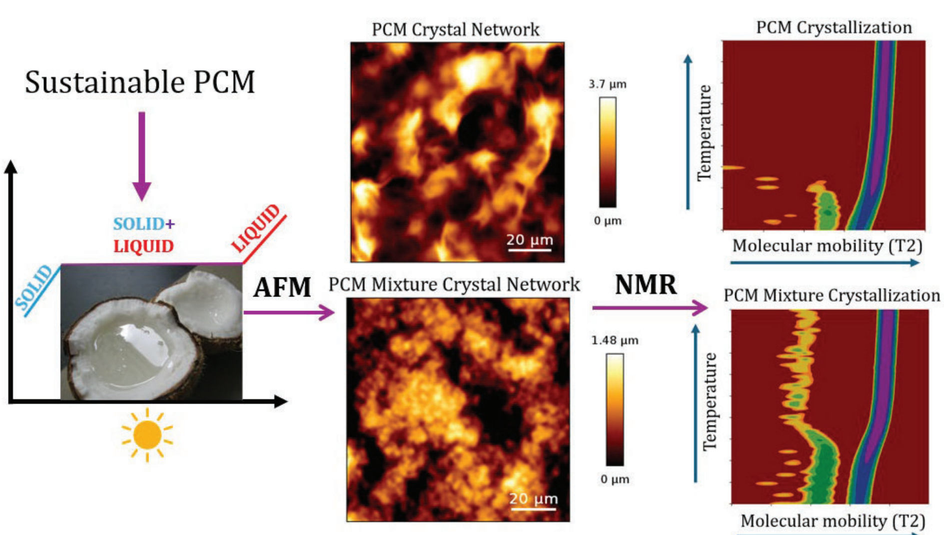
Atomic force microscopy (AFM) will be used to measure both nano-topographies and nano-stiffness of PCM surfaces during crystallization [2]. Nuclear magnetic resonance (NMR) will be used to quantify the presence of intermediate phases and their mobility at microscopic level. Classic thermodynamic methods (DSC, T-history) are used to quantify the heat stored and released and correlate with AFM/NMR findings

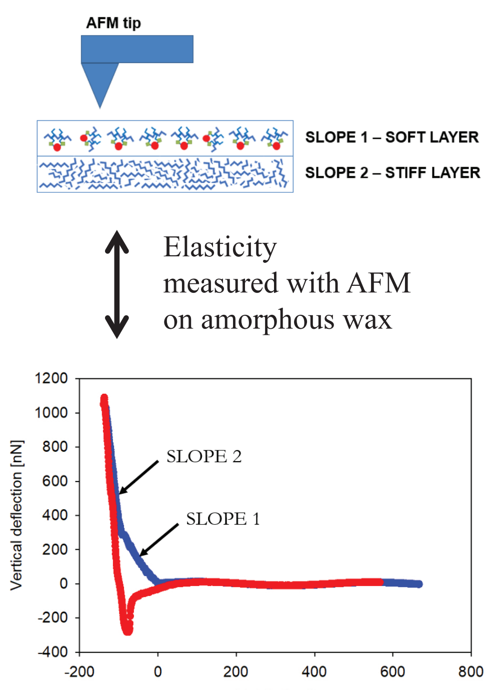
Benefits

- Improve your laboratory skills with AFM – a novel nanotechnology tool, NMR and DSC
- Expand your knowledge about sustainable energy storage technologies and phase change materials (PCMs)

Tasks

- Task 1: Review the literature for the use of AFM, NMR, thermodynamic methods on phase change materials
- Task 2: Perform dynamic experiments on multiple types of melting waxes and wax-filler mixtures.
- Task 3: Establish a relationship between structural evolution and the energy storage performance capacity of phase change materials.
- Task 4: Assess how the techniques could be used for material selection in system integration (heat pumps, solar panels, encapsulation in ceilings and walls)





References

[1] Mehrali et al, Shape-Stabilized Phase Change Materials with High Thermal Conductivity Based on Phase Change Materials with High Thermal Conductivity Based on Paraffin/Graphene Oxide Composite, Energy Convers. Manag. (2013)

[2] Savulescu et al, Alterations in Paraffin Wax Crystal Networks Induced by Asphaltenes and Pour Point Depressants, Investigated by Atomic Force Microscopy, Colloids Surf. A Physicochem. Eng. Asp. (2024)

Supervisor	Angele Reinders
2nd supervisor	to be decided
Starting date	Flexible
Exp./Num./Design	Num./Design

ETFD

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Life Cycle Analysis of Solar Powered Electric Vehicles

Angele Reinders
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INTRODUCTION

The road transport sector has commenced to reduce the carbon emissions of electric vehicles (EVs). However, the magnitude of the potential for carbon reduction depends on the electricity source. Efforts have been put into supplying this electricity demand from clean energy sources as much as possible. One of the solutions has been the use of stationary photovoltaic (PV) and battery storage systems [1]. Another proposal is to integrate PV modules into the vehicle to charge the battery directly. By means of life cycle analysis (LCA) [2] the environmental impact of such solutions can be quantified.

Figure 1: Nissan Leaf, front view with charging plug in (right), Lightyear with integrated PV technology in roof and hood (left)

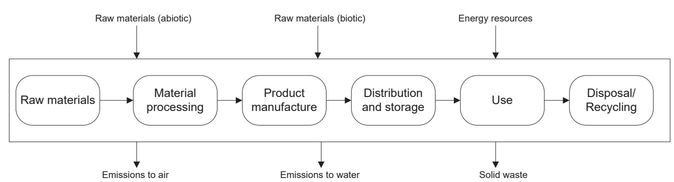

Figure 2. Life cycle system concept [2]

GOALS

The goal of this project is to quantify and optimize the environmental impact and CO_2 emissions of various EVs with integrated PV [3], taking into account the EV's size, weight and related energy consumption per km, the local irradiance, climate, and PV technologies. This will be done through an LCA.

BENEFITS

Better insight into the design of electric vehicles and their use in combination with solar charging will stimulate further adaptation to vehicle-integrated PV and, hence, decarbonize road transportation.
The project will be executed with the LCA software SimaPro, which forms the standard for LCA studies in industry. Learning how to work with it is beneficial for any student.

PROFILE

The project requires a student with an interest in simulations, environmental impact assessments, and vehicle design.

REFERENCES

[1] A. Sierra Rodriguez, T. Santana, I. MacGill, N. J. Ekins-Daukes, and A. Reinders, "A Feasibility Study of Solar PV-Powered Electric Cars Using an Interdisciplinary Modeling Approach for the Electricity Balance, CO2 Emissions, and Economic Aspects: The Cases of the Netherlands, Norway, Brazil, and Australia," Progress in Photovoltaics: Research and Applications 28, no. 6 (2020): 517–532, https://doi.org/10.1002/pip.3202.
[2] International Standardisation Organisation, 14040:2006, Environmental management — Life cycle assessment — Principles and framework, report, 2006
[3] C. Gercek, N. Nijenhuis, A. Sierra and A. Reinders, PV in Mobility – Report 2.2 Results of LCA study on PV powered EV systems, report, University of Twente, 2020

Supervisor	Angele Reinders
2nd supervisor	To be decided
Starting date	Flexible
Exp./Num./Design	Experimental/Num./Design

ETFD

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Advanced Luminescent Solar Concentrator Photovoltaic Devices with High Efficiency

Angele Reinders
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INTRODUCTION

A Luminescent Solar Concentrator Photovoltaic (LSC PV) device [1] 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 lightguide, see Fig. 1.

GOALS

The goal of this project is to optimize LSC PV technology with a seed laser, see Fig. 2, which can increase the emission of the luminescent dye towards solar PV cells. In this project, such an advanced LSC PV device will be modelled, prototyped and experimentally characterized.

BENEFITS

The typical material properties of LSC PVs—low cost, colorful, bendable, and transparency—offer a lot of design freedom [2] as compared to other PV technologies. They fit therefore very well in the built environment and building integrated PV [3]. It is assumed that the efficiency of an LSC PV device can be doubled to 20% by means of a seed laser. In this project it is evaluated how this high efficiency can be achieved in reality.

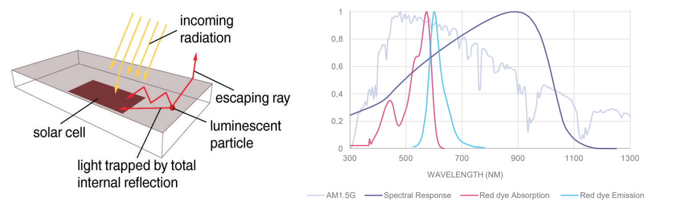

Figure 1: Left, Functional scheme of an LSC PV device, Right, Incoming irradiance spectrum, absorption and emission curves of a luminescent dye and spectral response of PV cell

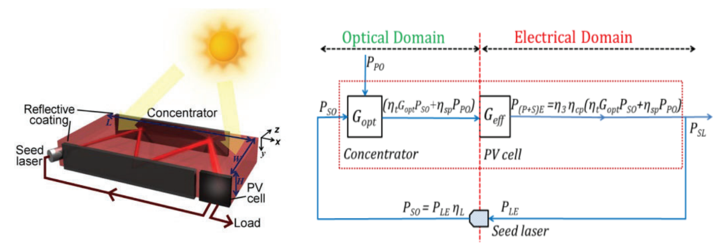

Figure 2. Left: an advanced LSC PV device with integrated laser. Right: a scheme representing the power balance of this device.

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	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

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Experimental study of borehole Stoneley waves in multi-fractured formation

David Smeulders and Yukai Liu
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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 creating potential leakage pathways. Stoneley waves, i.e., 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.

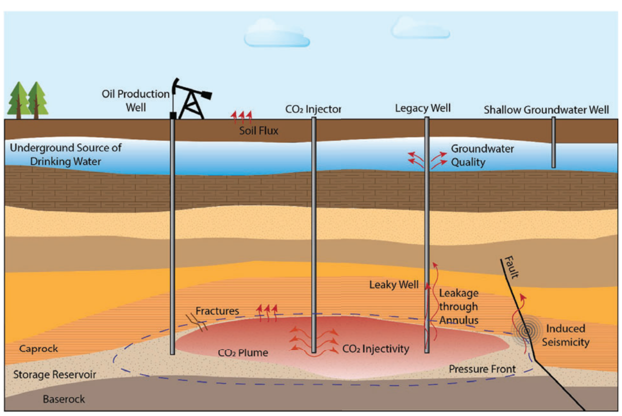

Fig. 1. Geological storage of CO_2 and Its potential leakage pathways (Xiao. T. et al.,2024)

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.

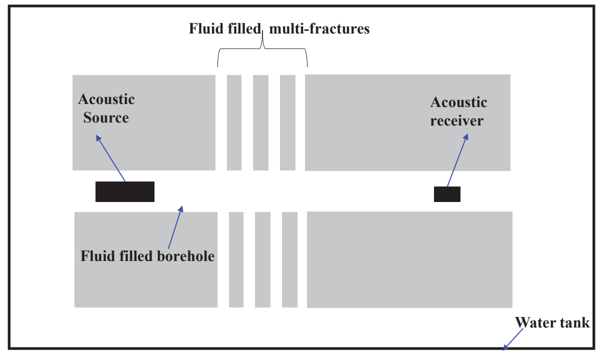

Fig. 2. Schematic diagram of Stoneley wave measurement in a multi-fractured formation.

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.

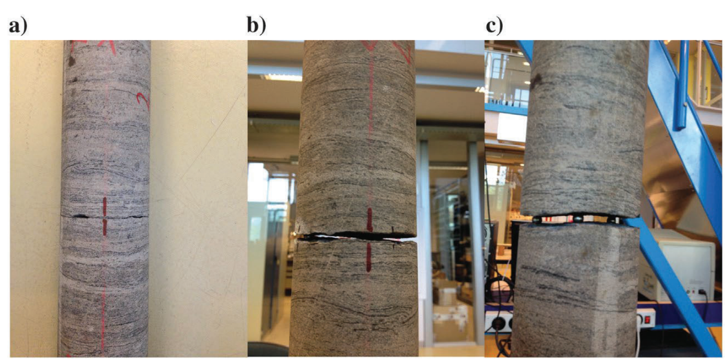

Fig. 3. Photo of three rock samples with varying fracture apertures. (a) Closed fracture, (b) 4 mm fracture, and (c) 6 mm fracture

STUDENT PROFILE

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

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

ETFD

4TU. Energy

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

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.

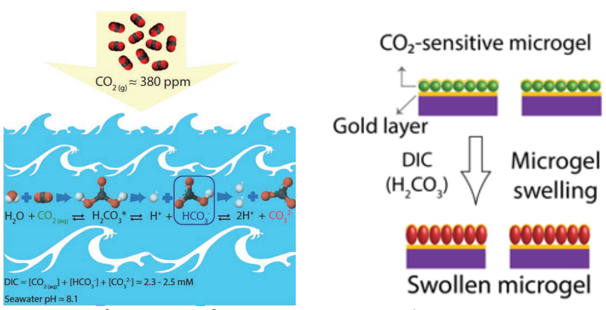

Figure 1. Left: Storage of CO_2 in oceanwater, right: CO_2 sensing concept

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 for different CO2 concentrations.
- 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.

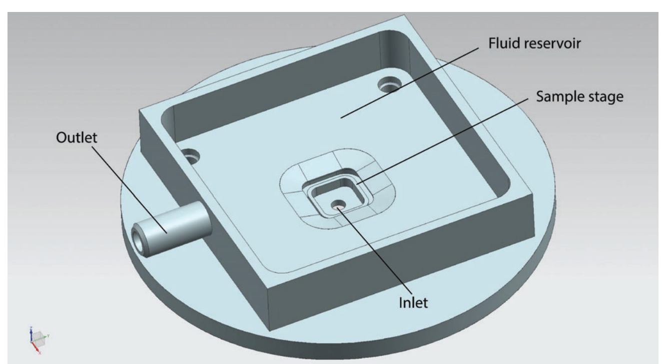

Figure 2: Schematic of AFM in-situ flow sample holder.

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	David Rieder
2nd supervisor	Maja Rücker
Company	Internal
Starting date	Any time
Exp./Num./Design	Experimental & Numerical

ETFD

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

From Micro to Nano

Shedding light on the nano-scale

David Rieder*, Maja Rücker
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INTRODUCTION

From heat storage to electrolysis to carbon capture- porous materials are at the heart of many cutting-edge energy technologies. Their internal structure plays a crucial role in the effective flow pattern and transport phenomena, directly impacting performance, efficiency and scalability [1].
Recent advances in X-ray imaging have enabled us to capture images of wet porous substrates with nanometer resolution at the Advanced Light Source of the Berkeley Labs and observe deposition phenomena throughout those substrates.
In a next step, we want to resolve the 3D structure of our samples and the internal processes by utilizing established 3D-reconstruction algorithms based on our sets of 2D images. However, at the nano-meter scale resolution, the image and reconstruction quality is strongly influenced by miniscule phenomena, i.e. manufacturing tolerances of the equipment, thermal expansion during the acquisition or simply air-flow by the ventilation.
Therefore, we require novel image correction algorithms which allow us to determine and mitigate the influence of such miniscule influences. Finally, the insights obtained from the improved dataset will enable us to investigate nano-scale multi-phase phenomena and their impact on system-scale energy applications, such as seasonal storage of hydrogen in depleted gas reservoirs.

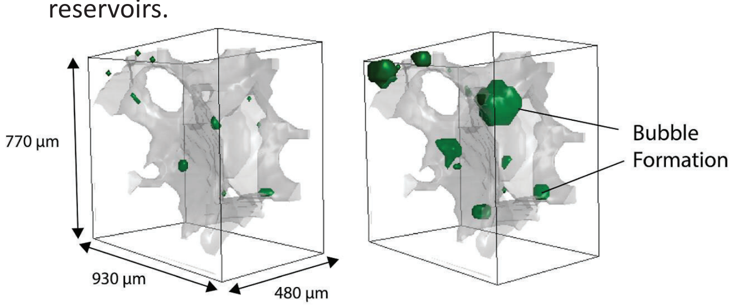


Figure 2: Delayed bubble formation due to sub-micrometer pores [1]

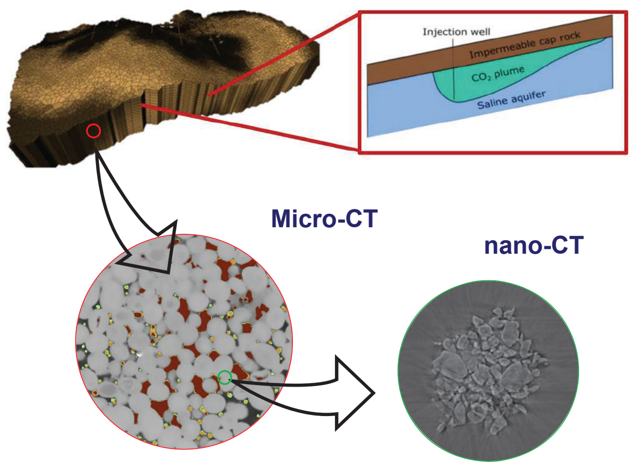


Figure 1: Multiscale nature of porous substrates in real-world application

GOALS

We ask you to design a digital equivalent of our porous substrates and subsequently simulate the image acquisition process under realistic conditions. Based on your insights you will then derive necessary image correction algorithms and apply them to our data set. Finally, we ask you to derive insights for real scale applications.

BENEFITS

- You will gain hands-on experience on advanced imaging technologies
- Get confident in the handling and processing of large data sets
- Work with high-performance computational equipment
- Advance our understanding of fluid dynamics in porous systems

REFERENCES

[1] Wensink et al., 2023. Spontaneous Imbibition and Evaporation in Rocks at the Nanometer Scale. Energy & Fuels, 37(23), doi:10.1021/acs.energyfuels.3c02456

Supervisor	Angèle Reinders
2nd/3rd supervisor	Conrad Hessels, Roy Hermanns
Company	N.A.
Internal / External	Internal
Starting date	Any time
Exp./Num./Design	Numerical/Design

Available for ME & SET

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Life-cycle assessment (LCA) of Iron Power

What is the impact of storing sustainable energy in iron?

ANGÈLE REINDERS, CONRAD HESSELS, ROY HERMANNS

EMAIL: A.H.M.E.REINDERS@TUE.NL

WHAT IS IT ABOUT

In the iron power cycle, we would like to harness the power of iron for sustainable energy storage and transport. By converting sustainable energy into hydrogen, we can convert (reduce) iron-oxide into iron, which can be used as a fuel for adapted coal fired power plants. That means that we can power our world by burning iron (see figure 1)!

While the concept sounds very promising and quite some (techno-economic) feasibility studies have been performed showing its competitiveness in comparison to other carriers like H_2, NH_3, LOHC (see e.g. 1-3), research is lacking on a full life-cycle assessment of the process, accounting for cradle-to-grave environmental impact. These results might influence the decision on which energy carrier aught to be used for specific use cases.

<u>Your tasks</u> will be to (1) Study the literature and get familiar with LCA and the concept of Iron Power (2) Setup an Iron Power framework using the SimaPro LCA software, (3) Define specific use cases for which Iron Power is a good candidate, (4) Compare the LCA of different energy carriers for this use case.

WHAT YOU WILL LEARN

- How the combustion/reduction of iron powder can be used to store sustainable energy.
- What a life-cycle assessments is and how important it is for comparing the environmental impact of new technologies

WHY SHOULD YOU CHOOSE THIS

- You are an enthusiastic student and interested in reducing societies environmental impact.
- You are interested in "bigger picture" research going on at TU/e

Iron Power Cycle

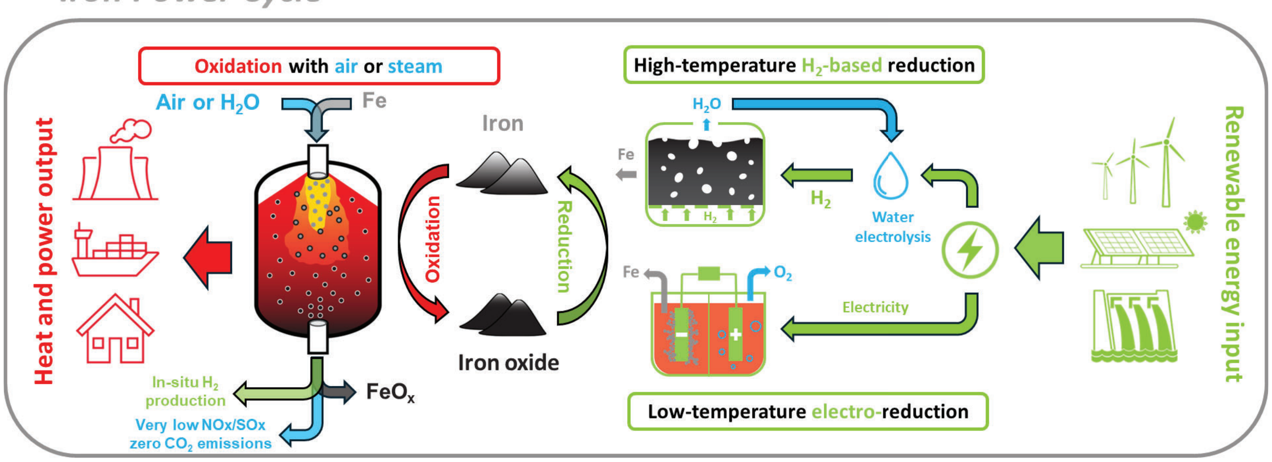


figure 1: The conceptual overview for the iron power cycle (courtesy of Xiaocheng Mi).

/ THERMO-FLUIDS ENGINEERING

[1] J. Neumann et al. Applications in Energy and Combustion Science 14 (2023) 100128
[2] Roland Berger. Iron power vision document. https://www.metalot.org
[3] J. Schuler et al. Energy Conversion and Management 342 (2025) 120125

Supervisors	**Max Beving, Arjan Frijns**
Starting date	**a.s.a.p.**
Exp./Num./Design	**Exp/Num**

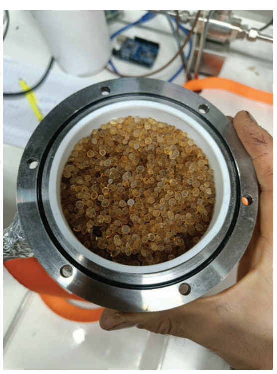
EINDHOVEN UNIVERSITY OF TECHNOLOGY

Material characterization for thermochemical heat storage

Max Beving, Arjan Frijns
Contact emails: m.a.j.m.beving@tue.nl, a.j.h.Frijns@tue.nl

INTRODUCTION

A heat battery is developed within the Energy Technology group. The core of the battery is a thermochemical material (TCM). This TCM can cyclic react with water.
One of the main challenges is selecting the right material based on properties like: power output, working temperatures, cost and environmental impact. Charging and discharging should be as fast as possible without damaging or cracking the particles.



TASKS

The student will mostly perform experimental work to characterize the TCM.

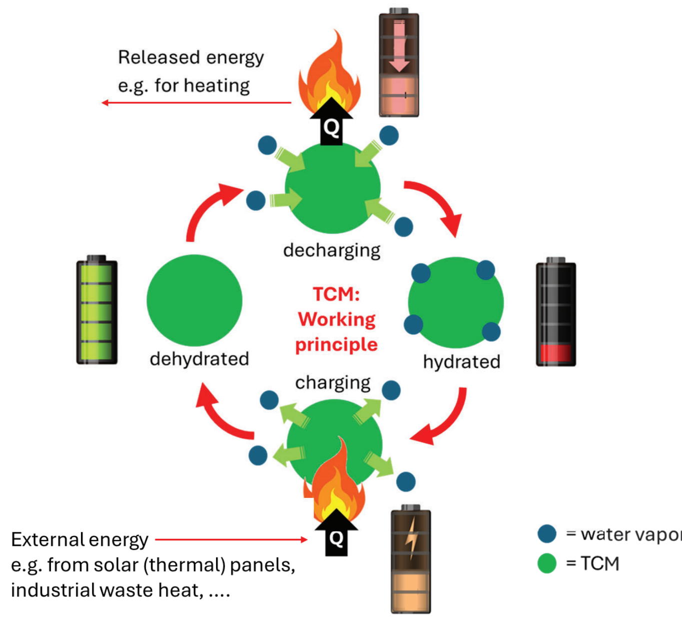
Experimental: Material characterization will be performed on different levels: grains (TGA/DSC), micro- and mini-bed reactors.

Modeling: In addition a 1D model will be developed to show the impact of the measured characteristics of the TCM.

GOALS

The ultimate goal is to find a characterize TCM materials for domestic applications.

To reach that, the first step is to select and characterize a TCM that ultimately can be charged with a heat pump.



STUDENT PROFILE

- Interested in the energy transition
- Likes to work in the lab
- Some basic programming skills in Matlab or Phyton
- Interest in numerical modelling