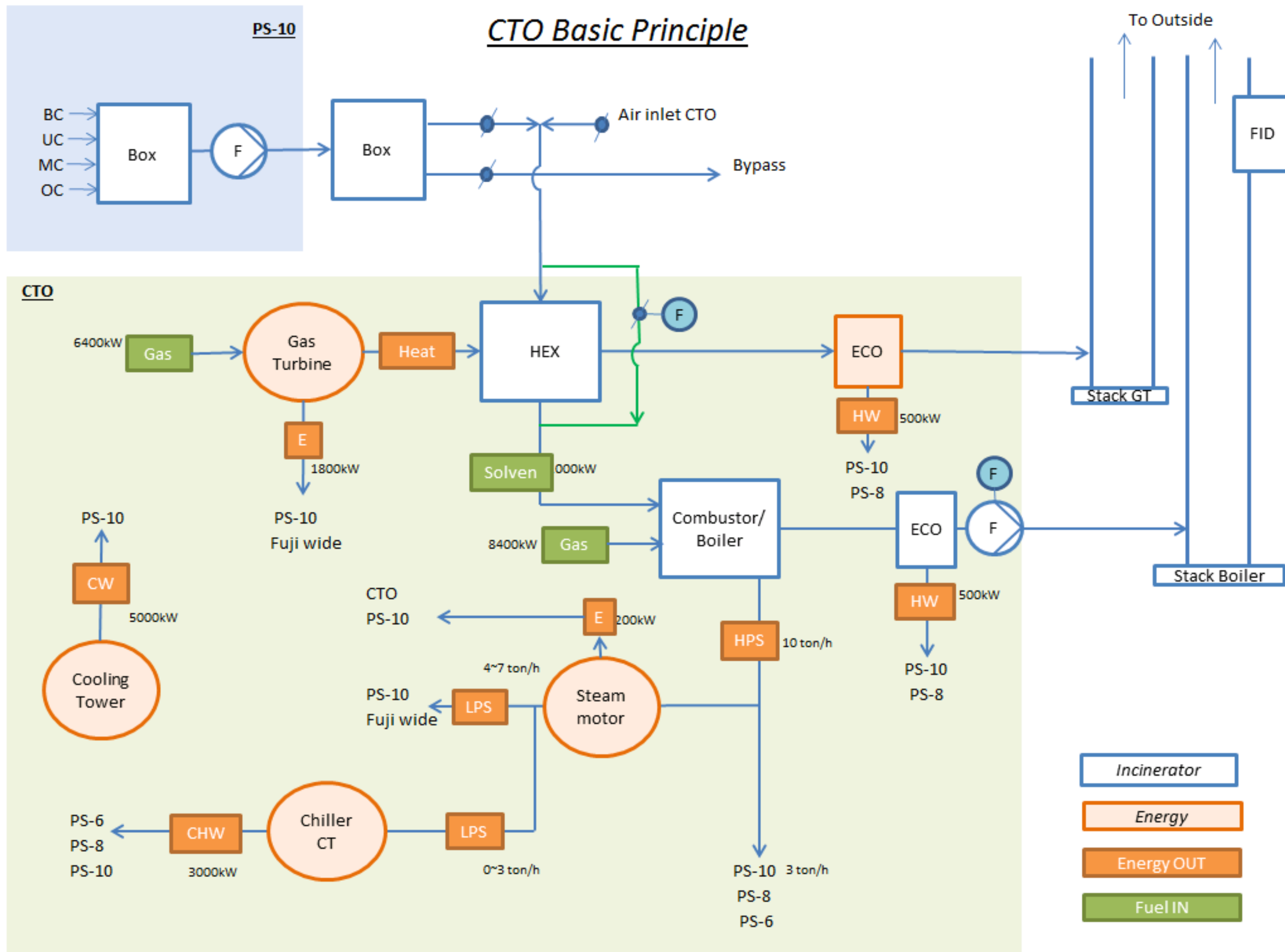


## Sustainable production of offset plates at Fujifilm in Tilburg

Fujifilm prides itself on its investment in sustainability, and the Tilburg manufacturing site is a prime example. The ability to manufacture offset plates locally in itself helps to reduce the carbon footprint of offset plate production, as it reduces energy consumed in the transportation process. This is one of the reasons why Fujifilm has invested heavily in expansion of the Tilburg production site. The site itself achieved ISO 14001 certification in 1997, and has been implementing sustainable improvements every year. The ultimate aim of the site is to be 100% CO<sub>2</sub> neutral in everything it does, and this objective has resulted in a number of significant recent investments of which the Cogenerative Thermal Oxidiser (CTO) is one.

# FUJIFILM

## Value from Innovation



### CTO principle

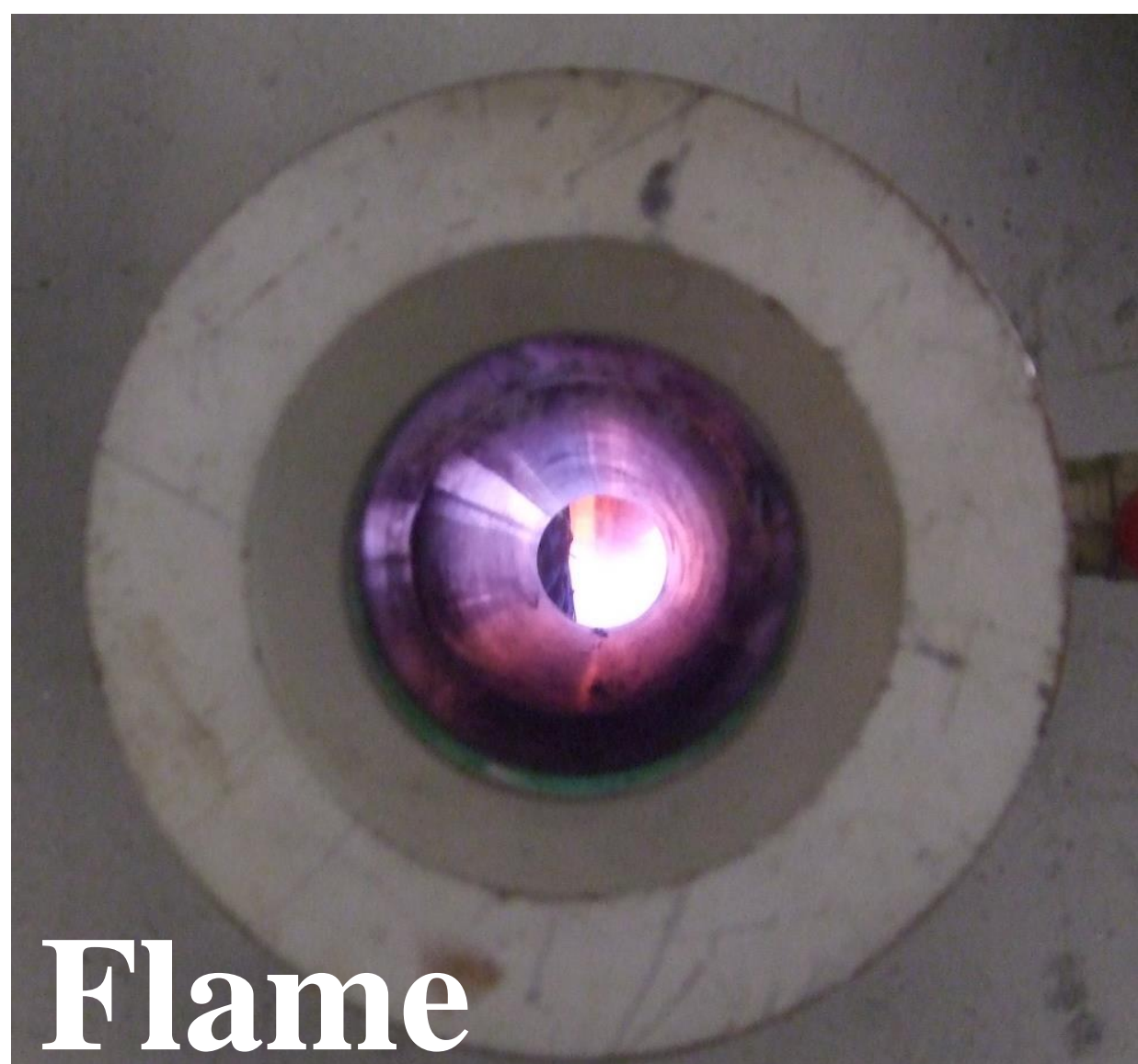
Waste gas that contains organic solvents is coming from the PS-10 offset plate production facility. This waste stream is lead into CTO where the total waste stream is combusted at a temperature of around 900°C in order to eliminate the solvents.

After combustion, the hot air stream is lead into a waste gas boiler in order to make steam.



### Improvement of CTO

CTO is developed by Fujifilm, together with two other companies, in 2009. The system became operational at the end of 2011. Since that time Fujifilm put a lot of effort in optimising this new CTO process and at this moment we have stabilised the main process. During stabilisation questions were raised about the reliability and robustness of the CTO. We are investigating the effect of the current way of operation on wear, lifetime and rigidity. Further at this moment we have no clear view of the combustion process itself; we have insufficient knowledge of this process and the impact of combustion on the wear, lifetime and rigidity.



### Assignment

Fujifilm wants to get a clear view of the combustion process with emphasis on the heat transfer and flow pattern of the combustion process in close relation to the chemical oxidation process. The assignment starts with a literature study and investigation of the processes itself. The results of the study and investigations have to be analysed and will be the basis for a CFD that's part of this assignment.

### What Fujifilm has to offer ?

- A challenging assignment.
- Working in an innovative and sustainable environment.
- Working with enthusiastic people "Come join us".
- Payment for your effort (appropriate graduation fee).



**Want to work with the number one thermotechnology company in Europe?**

Invented for life



**BOSCH**



### General information

The Bosch Group is a leading global supplier of technology and services. In 2016, 390,000 associates generated sales of 73 billion euros in sales. Bosch Thermotechnology is a division of the business sector Energy and Building Technology and has 14,300 associates, generating 3.3 billion euros sales revenue with an R&D budget of 163 million euros. Bosch Thermotechnology in Deventer focuses on energy systems for household applications, specifically wall mounted boilers. We are looking for a motivated student for a master project.

### MSc Project description

One of the methods to reduce CO<sub>2</sub> emissions is by replacing carbon-containing fuels with hydrogen. In the project 'Combustion Strategies for Next Generation Fuel-Flexible Burners', TU/e is investigating laminar premixed combustion of methane and methane/hydrogen mixtures. New design strategies for fuel-flexible burners for domestic appliances will be developed based on fundamental knowledge of flame stabilization mechanisms in hydrogen-enriched gas. At Bosch TT Deventer you will work on the development of next generation burners, adjusted for novel 'greened' fuel gases.

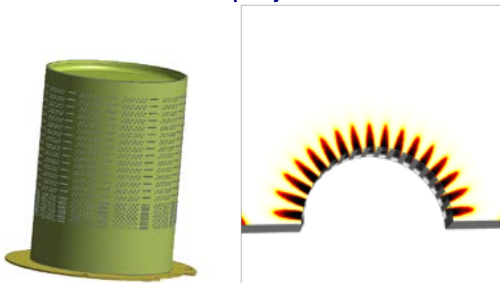


fig. 1: Classic cylindrical burner (l) and flame simulation on a curved burner plate (r).

### Project outline:

- Investigating the fundamental and practical differences between methane and hydrogen combustion in cooperation with the fuel-flexible-burner project team
- Literature and Feasibility study on hydrogen-fueled domestic boilers
- Combustion modeling of burner stabilized flames
- Development of new concept burner with improved burner combustion performance when used with novel fuel gas mixtures with variable properties.

### Student profile:

- MSc. student in mechanical engineering, physics or comparable study
- Interested in fluid dynamics, CFD simulations and combustion

For more information contact:

Dr. Ir. Rob Bastiaans (TU/e), Dr. Ir Nijso Beishuizen (Bosch TT)

## Next-Generation Heat Recovery

“State-of-the-art solving for two-phase dynamic simulation”



### Introduction

Renewable sources like wind and solar are quickly becoming more abundant in electric power production. 2015 has been a milestone in the global transitions to renewables, more renewable capacity has been installed than non-renewable capacity. These renewable sources are however inherently fluctuating, increasing the demand for flexibility in the remainder of the network. For NEM, this implies that our next-generation heat recovery steam generators (HRSG's) need to compensate by starting and stopping faster and faster.

HRSG's are an essential part of many power plants. A HRSG converts exhaust heat from a gas-turbine to steam, which is then used for electricity production. With a HRSG power plants can increase their overall efficiency from 40% to 60%. In order to design the next-generation fast starting HRSG's we are investing in dynamic modeling.

We are offering an opportunity to work with our R&D department on our newest multi-phase dynamical models.

### R&D Department

The company NEM consists of 600 people of which 15 form the **R&D department**. To design next-gen HRSG's we are active in the fields: performance calculations, dynamic simulations, CFD flow studies, FEM stress analysis, lifetime assessment and techno-economic studies.

### Current dynamical model

Effort in dynamic modelling has led to simulation code that allows 1 two-phase fluid (e.g. water). A 1D model is chosen because HRSG's consist of long, small diameter tubes. Tube flow can be described well by the axial component only. The physical model is described by: mass-balances, momentum-balances and energy-balances. These balances are 1<sup>st</sup> order discretized in time and space. An implicit form of the numerical model is solved using Newton-Raphson iteration. Fluid state is described by pressure and specific energy and it is assumed that liquid- and gas-phase move at equal velocity, this is called a HEM<sup>1</sup>.

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<sup>1</sup> Homogeneous Equilibrium Model

The limitation of the current model is that we cannot simulate a number of critical use-cases of our product. When our product is started after a short period of standstill, the water in the system will be separated in phase. High energy gas is found in the higher part of the system and low energy liquid is found in the lower part of the system. Interactions between the two fractions during startup is causing large disturbances in the system, these are currently too large to be effectively handled by our solving method. Increasing the robustness of the system solver will allow us to cover these critical use-cases and give us much better confidence in our designs.

### Assignment

Goal:

- Investigate and implement solving methods to increase robustness.
  - *Optionally: Investigate alternative physical descriptions.*

Tasks:

- Study literature on alternative solving variants.
- Formulate selection criteria for model variants in cooperation with NEM.
- Implement most suited model variants.

Benefits:

- This assignment will allow you to tackle a challenging problem in multi-phase flow.
  - The modelling of multi-phase flow is by far not fully developed and the necessary physics and mathematics are of much wider use than steam generators.
- Your focus can be largely on mathematical models, programming effort will be limited as the model is only 1 dimensional.
- You will receive an appropriate financial compensation.

### Contact

If you are interested, please send us an e-mail:

David van der Lijn ([dvdlijn@nem.nl](mailto:dvdlijn@nem.nl))

NEM Energy B.V.

Stadhouderslaan 900

2382 BL Zoeterwoude

Information: Hans Kuerten, Gem Z 2.147

## Next-Generation Heat Recovery

### “Non-condensable gas in two-phase dynamic simulation”



#### Introduction

Renewable sources like wind and solar are quickly becoming more abundant in electric power production. 2015 has been a milestone in the global transitions to renewables, more renewable capacity has been installed than non-renewable capacity. These renewable sources are however inherently fluctuating, increasing the demand for flexibility in the remainder of the network. For NEM, this implies that our next-generation heat recovery steam generators (HRSG's) need to compensate by starting and stopping faster and faster.

HRSG's are an essential part of many power plants. A HRSG converts exhaust heat from a gas-turbine to steam, which is then used for electricity production. With a HRSG power plants can increase their overall efficiency from 40% to 60%. In order to design the next-generation fast starting HRSG's we are investing in dynamic modeling.

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#### Current dynamical model

Effort in dynamic modelling has led to simulation code that allows 1 two-phase fluid (e.g. water). A 1D model is chosen because HRSG's consist of long, small diameter tubes. Tube flow can be described well by the axial component only. The physical model is described by: mass-balances, momentum-balances and energy-balances. These balances are 1<sup>st</sup> order discretized in time and space. An implicit form of the numerical model is solved using Newton-Raphson iteration. Fluid state is described by pressure and specific energy and it is assumed that liquid- and gas-phase move at equal velocity, this is called a HEM<sup>1</sup>.

The limitation of the current model is that we cannot simulate a number of critical use-cases of our product. When our product is started after a longer period of standstill, air may be present in the system along with water. Having air in the system during startup

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<sup>1</sup> Homogeneous Equilibrium Model

significantly changes the dynamics of the system; air exists instead of boiling or condensing water. Air cannot be modeled with the current system. Including air in the simulation will allow us to cover these critical use-cases and give us much better confidence in our designs.

### Assignment

Goal:

- Investigate and implement the physics of a non-condensable gas (air) within our current model.
  - *Adding the physics of non-condensable gas (air) introduces inequality constraints that represent appearing and disappearing gas.*

Tasks:

- Study literature
  - On physical models with non-condensable gas.
  - On numerical handling of these models.
- Formulate selection criteria for model variants in cooperation with NEM.
- Implement most suited model variants.

Benefits:

- This assignment will allow you to tackle a challenging problem in multi-phase flow.
  - The modelling of multi-phase flow is by far not fully developed and the necessary physics and mathematics are of much wider use than steam generators.
- Your focus can be largely on mathematical models, programming effort will be limited as the model is only 1 dimensional.
- You will receive an appropriate financial compensation.

### Contact

If you are interested, please send us an e-mail:

David van der Lijn ([dvdlijn@nem.nl](mailto:dvdlijn@nem.nl))

NEM Energy B.V.

Stadhouderslaan 900

2382 BL Zoeterwoude

Information: Hans Kuerten, Gem Z 2.147



## MSc Project

### Burner optimization in an industrial oven



#### Introduction

Dijko Ovens BV is a Dutch company, located in Tilburg, that is well known for its industrial bakery equipment. Currently, over 90% of their equipment is exported throughout the world.

Dijko Ovens supplies a total solution for proofing/baking/(vacuum)cooling/freezing of a wide range of products, using a completely modular system.

At the heart of their product range is the oven module. In each of these modules, a modulating burner (maximum power around 200 kW) creates the perfect baking conditions.

In the oven, a premix gas-air mixture (natural gas or propane) is burned on a knitted fabric burner deck, that is located in the top of the oven. By means of a fan located directly above the burner deck, a forced airflow in the oven is realized for convection baking. The amount of recirculation of the exhaust gases inside the baking chamber can be set using a damper valve.

Dijko Ovens is looking for ways to optimize their burner design to achieve the best possible performance, from both an emission standpoint (low CO emissions are a key factor) as well as from an efficiency standpoint.

### **Assignment**

Indicate important design aspects regarding premix burner design in general, and, in a 2<sup>nd</sup> stage, specifically with regards to the existing burner system of the oven (or of closely related burner systems).

Measure the existing performance of the ovens, and, using the results of the literature review, identify possible points that can be improved upon.

If points of the burner system have been identified that can be improved upon, develop a proposed change to the burner system and analyze the effect of the change with additional measurements.

Provide further recommendations for future work.

### **Dijko offers**

- A very open and friendly working environment, with around 15 colleagues;
- Your own workstation with, when required, dedicated software;
- Full freedom to develop improvements to the existing burner system, with assistance from our engineering department;
- A market-oriented internship allowance

### **Contact**

dr. ir. Jeroen van Oijen, GEM-N1.48, 040-247 3133, [j.a.v.oijen@tue.nl](mailto:j.a.v.oijen@tue.nl)



### **Graduate Proposal: Combustion process instability (measurement techniques)**

The Dutch Association for Flame Research (NVV) is an association of companies and institutions in the Netherlands and Belgium, with a common interest in industrial research and education in the field of combustion and gasification. The background and industrial applications for these members are very diverse; from domestic boilers to Heat Recovery Steam Generation (HRSG) and from CFD simulations to the production of high quality lamps or steels.

To achieve low emissions and high efficiency, combustion systems are moving towards high modularity and high air-to-fuel ratios. These modifications can result in an unstable combustion process hydrodynamically, thermally or acoustically. To maintain optimum combustion during such instabilities is a continuous challenge for our members. There are various measurement and control systems that can help sustain the stability during modulation, however, most of them are known to be unsuitable for the application of our members' products. This difficulty of measurement can be due to the design of application or harsh operating conditions. The NVV is therefore looking for a graduate student to analyze and compare various measurement techniques for studying combustion instabilities that can be used by its members.

The graduate student will interview the participating companies to get an overview of the different requirements necessary according to these partners. A literature study for existing measurement techniques with relation to the instabilities will follow, paying attention to already suitable and commercially available technologies. The literature and company study combined will determine which techniques will best contain the wishes of the NVV partners. The most promising option will be developed in a detailed study towards robustness and long operating lifetime. This can be done on a theoretical, numerical and/or experimental basis. This study will be divided into different phases and every phase will be reported to the NVV user committee. The NVV has a placement fee available to support the graduate student.

The NVV user committee for this research will consist following NVV partners: TU-Eindhoven, Bekaert Combustion Technology, TU-Delft, University of Twente

The research work will be carried out at Bekaert Combustion Technology, Assen.

For more information please see the NVV website: <http://www.vlamvereniging.nl/nl> or contact:

Jeroen van Oijen, tel 040-2473133, [j.a.v.oijen@tue.nl](mailto:j.a.v.oijen@tue.nl)

Harshit Gupta, Development Engineer, Tel: +31 592 345 145 (608), [harshit.gupta@bekaert.com](mailto:harshit.gupta@bekaert.com)

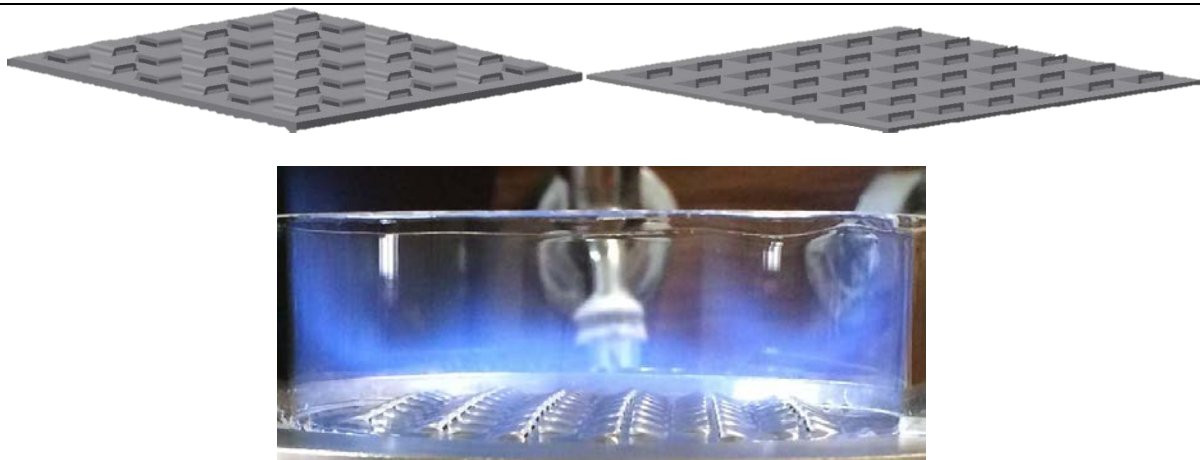
Joan Teerling, Technology Manager, Tel: +31 646 374 478, [OmkeJan.Teerling@bekaert.com](mailto:OmkeJan.Teerling@bekaert.com)

# **MSc Project: “Development of new generation of burners with 3D-deck pattern for application in domestic boilers”**

## **Introduction / the project context**

Currently in small scale combustion appliances e.g. in domestic boilers, flames of premixed gases are anchored on a flat (perforated or porous) surface of the burner deck. The deck patterns are optimized to resist to flash-back, maximize the boiler operation range (ratio of max to min power), minimize pressure losses, emissions (NO<sub>x</sub> and CO), production costs. To improve further these working characteristics of the burners dedicated for next generation of boilers an innovative idea is required. One of possible direction for R&D is to make a step beyond the limitations of 2-D deck patterns.

Recently at TU/e we have proposed and tested several designs of burners where the flow of combustible mixture is arranged in such a way that it provide formation of compact combustion zone on top of the deck with 3-D features.



Examples of 3D features of a burner pattern and flame anchored on the deck.

---

## **Assignment, the project goal**

The ultimate practical goal of the project is to develop an approach to design new generation of burners for premixed gaseous combustion. The generic goal is to gain fundamental understanding of features of combustion realized on this burners.

## **Your challenge/tasks**

To reach the goals the following steps/tasks to perform are foreseen:

- Develop an experimental setup, testing methods and data analysis techniques to compare different burners in respect to the practically relevant parameters.
- On the base of previously gained knowledge and some new ideas to design, produce and perform parametric study of range of experimental burner decks.
- Select the most promising burners configuration taking into account practical limitations and compromises of different requirements.
- Design, manufacture and test a complete burner which may retrofit existing one in real boiler. Test the burner on a real boiler(s). This step, as well as the whole project, will be performed in cooperation with TU/e partner, company POLIDORO (Italy).

## **Contact**

The daily supervision will be done by Viktor Kornilov ([v.kornilov@tue.nl](mailto:v.kornilov@tue.nl))

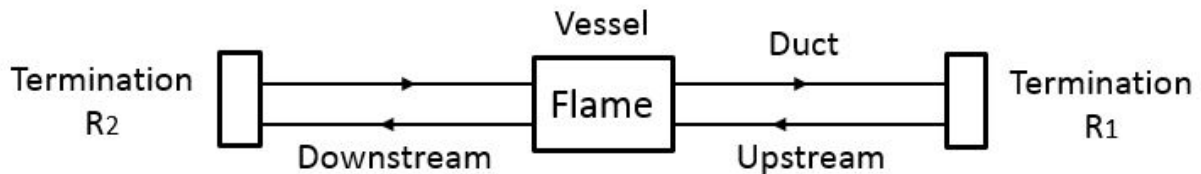
Promoting professor is Philip de Goey ([L.P.H.d.Goey@tue.nl](mailto:L.P.H.d.Goey@tue.nl))



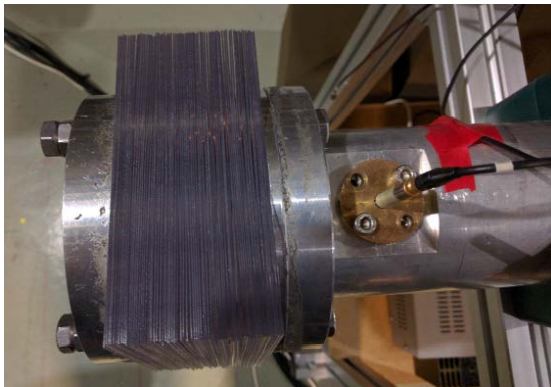
# **MSc Project: “Development of passive measure to eliminate thermo-acoustic instability in domestic boilers”**

## **Introduction / the project context**

Thermo-acoustic instability of combustion is a phenomenon of self-sustainable generation of (usually tonal) noise in systems where flame (burner) interacts with the acoustic waves propagating in the ducts and vessels of the combustor. One of possible methods to eliminate the origin of the instability is to brake the feed-back loop of acoustic energy production by the flame and its return (propagation and reflection) back to the burner via / from the acoustics of the appliance.



Recently at TU/e we have proposed and tested a compact, cheap and efficient device which can provide semi-anechoic acoustic termination of a duct. Logical next step is to implement this device in combustion appliance (boiler) aiming to brake the unstable acoustic feed-back loop and in this way to prevent the acoustic instability.



Experimental anechoic termination device installed at the impedance tube measurement setup.

## **Assignment, the project goal**

The ultimate goal of the project is to develop the add-on device for the domestic boiler which will function as a wide operation range stabilizer of the thermo-acoustic instability of combustion.

## **Your challenge/tasks**

To reach the goal the following steps/task to perform are foreseen:

- On the base of previously gained knowledge about the performance of the anechoic terminator we have to design, manufacture and test the range of prototypes which will satisfy to a set of the boiler working requirements.
- Test the prototypes using acoustic impedance tube and pressure loss measurement setups. Iterate the design-test steps till the promising configuration will be elaborated.
- Test the add-on stabilizer on a real boiler(s). This step will be performed in cooperation with TU/e partner, company POLIDORO (Italy).

## **Contact**

The daily supervision will be done by Viktor Kornilov ([v.kornilov@tue.nl](mailto:v.kornilov@tue.nl))  
Promoting professor is Philip de Goey ([L.P.H.d.Goey@tue.nl](mailto:L.P.H.d.Goey@tue.nl))

## **MSc project: New flame stabilization principles for fuel-flexible burners.**

**Motivation:** Reliable flame stabilization is one of the key issues in many practical applications of combustion for (combined) heat and power generation systems, such as gas turbines, industrial and household boilers.

Increasing diversification of fuel gas compositions is expected in near future, in particular, because of the injection of hydrogen produced from renewable energy sources into gas pipe systems. Therefore, new burners have to be designed to adjust combustion devices to variable fuel gases.

**Background:** Recent studies in the Combustion Technology group has demonstrated that even small additions of hydrogen to natural gas can lead to very large changes in the flame stabilization behavior. In particular, vital parameters for practical combustion systems, such as

- flame stabilization limits,
- locations of the flame anchoring points, or
- heat transfer from the flame to the flame holder,

are strongly affected. The observed effects are attributed to the very high diffusivity of hydrogen, which leads to non-uniform fuel gas redistribution along the flame front.

**Project goal:** This MSc graduation project is aimed at extending our current understanding of the flame stabilization principles obtained earlier for simple laboratory flames, to more complicated flames stabilizing on 3-D structured burners. This new knowledge obtained in this project will pave the way for future practical designs of fuel-flexible burners for household and industrial appliances.

**Project content:** The work is experimental. An existing experimental setup, built in a preceding project, will be used for measurements with some modifications. Stabilization and blow-off limits and mechanisms shall be studied for flames stabilizing on burner decks that are perforated and corrugated plates.

It is hypothesized that new flame stabilization principles, different from the ones that are traditionally used in household appliances, can be discovered with such burner decks. These new flame stabilization mechanisms are expected to minimize the effects of variation of the fuel gas composition on the burner performance and to extend the burner power modulation range.

To verify this hypothesis and to optimize the burner deck design, flames stabilized on burner decks will be characterized experimentally with some parameters.

Flame stabilization limits shall be tested for different gas mixture compositions, flame shapes and sizes characterized by using video recording. Burner deck temperatures shall be measured with an IR pyrometer/thermal imaging camera. Mixture temperature will be measured with thermocouples, and flame noise levels will be characterized.

More advanced laser diagnostics, e.g. Rayleigh scattering or Particle Image Velocimetry are available in the lab and can optionally be used upon willingness of the applicant. Numerical simulations of selected experimental flames are planned in a parallel separate ongoing project. Useful experience about complementary experimental and numerical study, which is a common approach in modern industrial research centers, can be acquired during this project.

Contact: [y.s.shoshin@tue.nl](mailto:y.s.shoshin@tue.nl)



# High-speed soot diagnostics using laser techniques

R.C. Willems, P.C. Bakker, N.J. Dam

Studying soot  
can be an  
ear-opener

## Research

Formation and oxidation of soot particles remains a hot topic in combustion research, as both mechanisms are still poorly understood. Several (laser-based) techniques exist to study soot, of which laser-induced incandescence (LII) is the most widely applied. Imaging of soot, however, poses several difficulties originating from the intricate nature of thermal radiation. Alternatively, one can **listen** to laser-heated soot using a sensitive microphone. This photo-acoustic (PA) technique is believed to be more accurate and sensitive than LII.

In this research project we aim to increase the understanding of the LII and PA techniques, both of which can be used to determine local soot volume fractions. Comparing the two signals might provide particle size information as well, since each signal responds slightly different to changing particle diameters. Eventually, the two techniques might be used to chart the soot volume fraction and particle size history in this particular flame! Measurements will be performed on a stable co-flow diffusion flame burner.

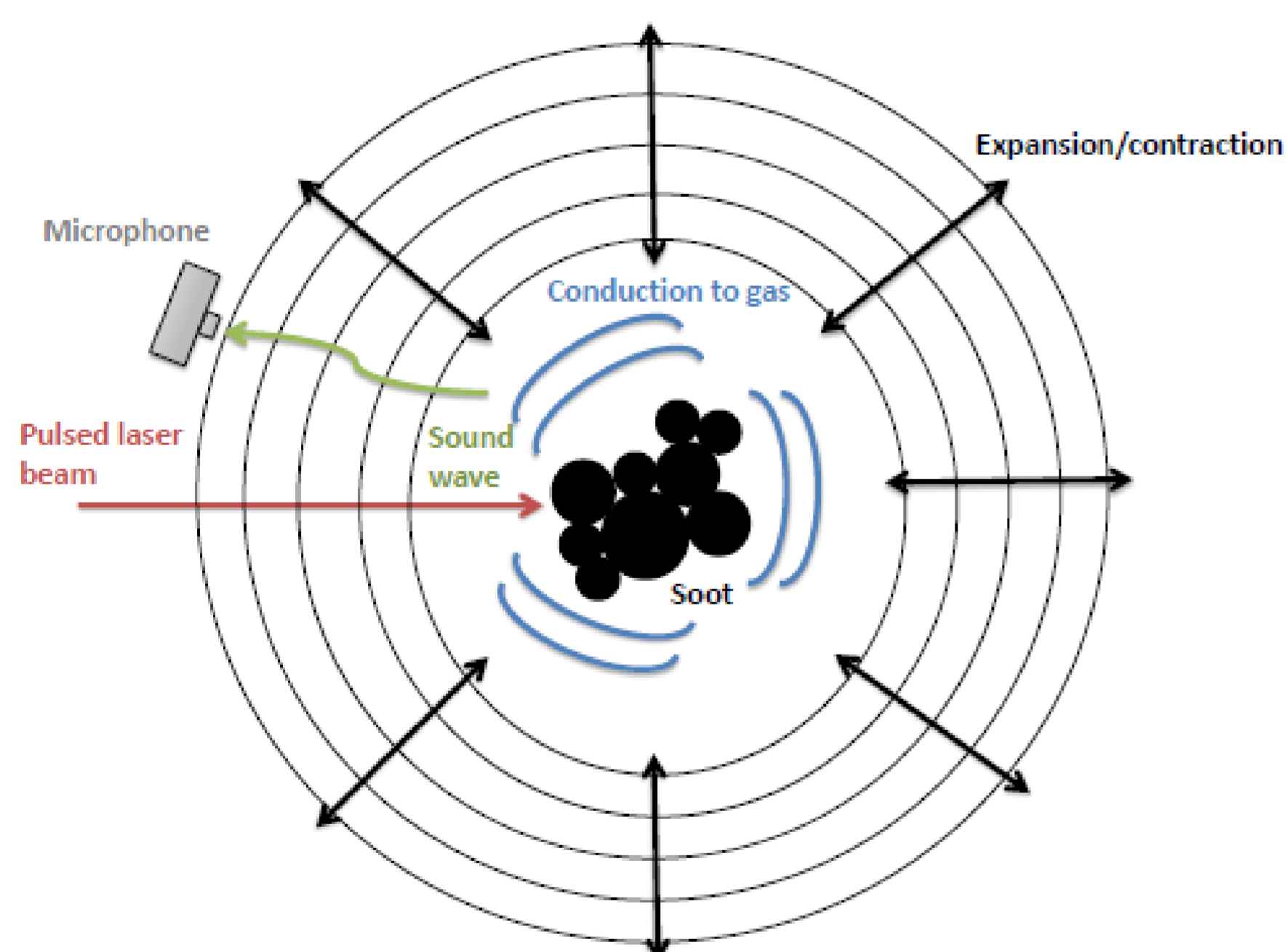


Figure 1: Visualization of the photo-acoustic principle.

## Contact information

Robbert Willems

[r.c.willems@tue.nl](mailto:r.c.willems@tue.nl)

Gem-N1.20

Tel: 2877

## Student responsibilities

### Tasks

- Explore the fundamentals of the photo-acoustic and laser-induced incandescence signals
- Investigate the capabilities of the experimental equipment
- Prepare and perform laser experiments
- Create post-processing routines and analyze experimental results in detail

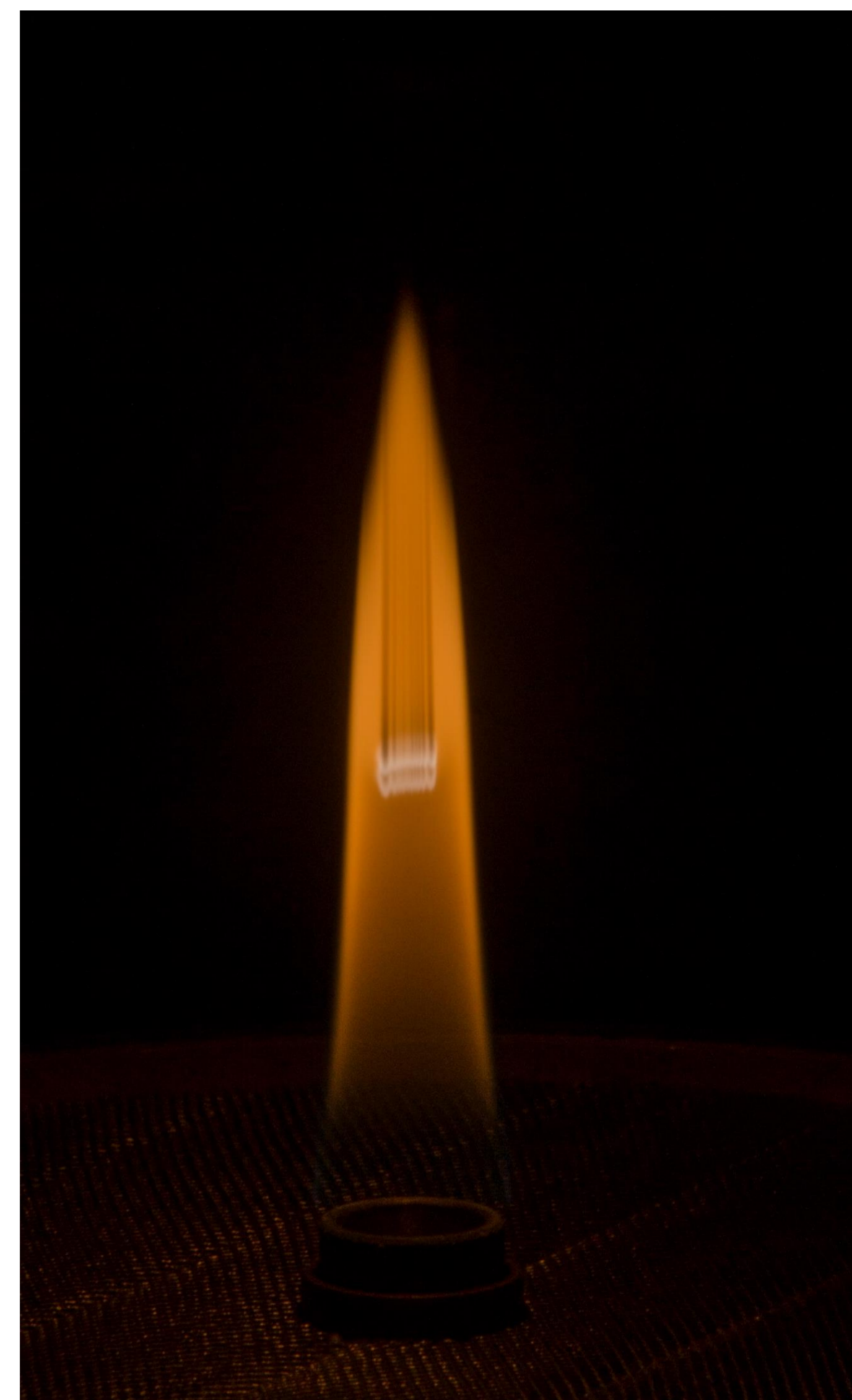


Figure 2: Co-flow diffusion flame with laser-heated soot.

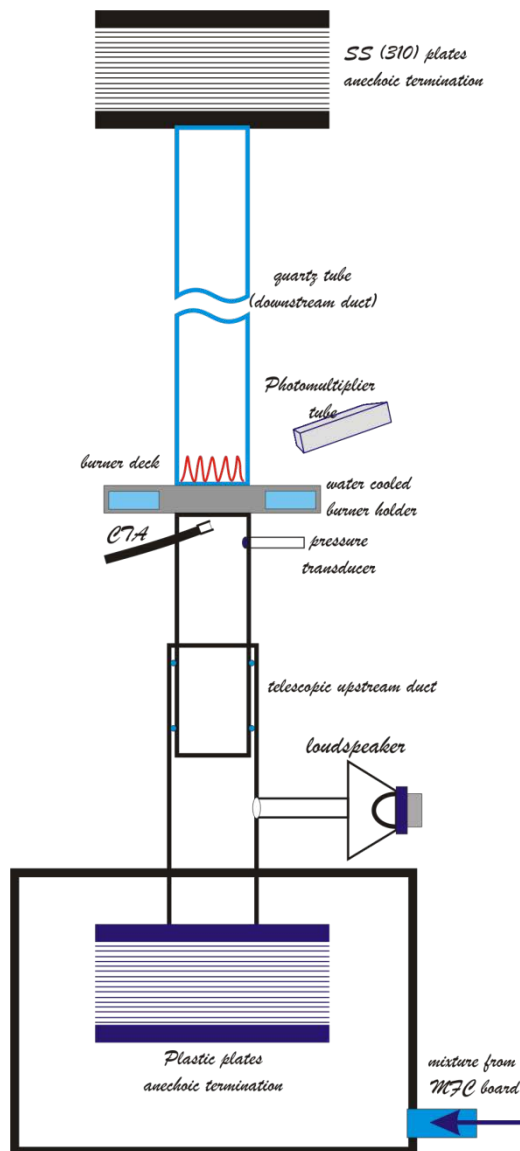
## Requirements

- Affinity with complex experimental work
- Successful completion of course 4BM40 is a plus

# MSc Project: “Experimental investigation of intrinsic thermo-acoustic combustion instability mode”

## Introduction / the project context

Thermo-acoustic instability of combustion is an effect of autonomous generation of (usually tonal) noise in systems where flame (burner) interacts with the acoustic waves propagating in the ducts and vessels of the combustor. Recently at TU/e a new class of acoustic instability called intrinsic acoustic mode was discovered. The unique feature of this mode is that it can exist even when the acoustic feedback (reflection of waves back to the burner) is completely suppressed. The phenomenon was found first theoretically and next it was confirmed by several research groups in the world via dedicated numerical (DNS) experiments. Some experimental evidences of the intrinsic acoustic instability of combustion were already obtained, however the direct and unambiguous experimental proof of the effect as well as experimental investigation of it is still pending.



## Assignment, the project goal

The ultimate goal of the project is to demonstrate an existence and reveal specific properties of the intrinsically unstable mode of combustion.

## Your challenge/tasks

The main challenge on the way to this goal is to create such a conditions for a burner/flame that the acoustic waves doesn't return back from the up and downstream directions looking from the place of the burner.

To reach the goal the following steps/task to perform are foreseen:

- To design and construct a test setup (combustor) where the acoustic reflections from the ducting up- and downstream of the burner are suppressed. For this purpose the newly developed at TU/e – anechoic terminations unit can be adapted.
- Test the effect of intrinsic acoustic instability for several flames (burner decks). Reveal specific features predicted theoretically for this instability mode.
- Investigate the phenomenon. Search for new, unknown effects and properties of this specific instability mode.

## Contact

The daily supervision will be done by Viktor Kornilov ([v.kornilov@tue.nl](mailto:v.kornilov@tue.nl))  
Promoting professor is Philip de Goey ([L.P.H.d.Goey@tue.nl](mailto:L.P.H.d.Goey@tue.nl))



# MSc Project

## Title

Metal Fuels as clean energy source: which oxidation method of Zinc is the best ?

## Introduction

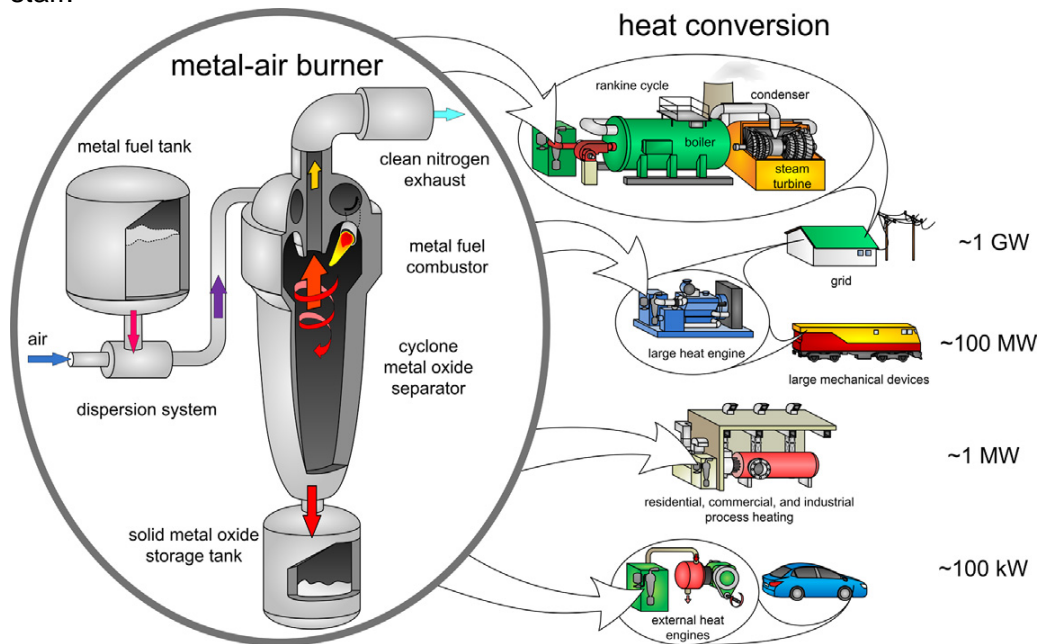
Hydrocarbon fuels, from fossil sources, currently dominate global energy trade and are used in nearly all applications where high power density [kW/L], is required, such as large scale power generation, high-power vehicles and machinery. However, it is widely recognized that our world-economy should transition away from energy sources based on fossil fuels to clean and, preferably, renewable low-carbon energy sources.

A key challenge in this quest is the development of renewable energy commodities, so-called energy carriers. Metal fuels seem to be a very promising option in many regards. Nyrstar, a zinc-producing company near Eindhoven is also interested to investigate the possibilities for metal fuels, especially zinc powder as a recyclable alternative fuel.

## Assignment

In order for metal powder to be such a promising alternative fuel, the metal particles have to be burnt generating useful energy and power. There are several ways to oxidize (or hydroxide) these metal particles, each with their own (dis)advantages.

In this assignment you will join us in this new research area by comparing several existing oxidation/hydroxation methods and doing some experiments, in close cooperation with our staff.



(Fig taken from J.M. Bergthorson et al., Applied Energy 160 (2015) 368-382)

## Contact

More information: Philip de Goey, Gem Z 2.143, 040-2473268/2140, l.p.h.d.goey@tue.nl

# MSc Project

## Title

Metal Fuels as clean energy source: which regeneration method of Zinc-oxide is the best ?

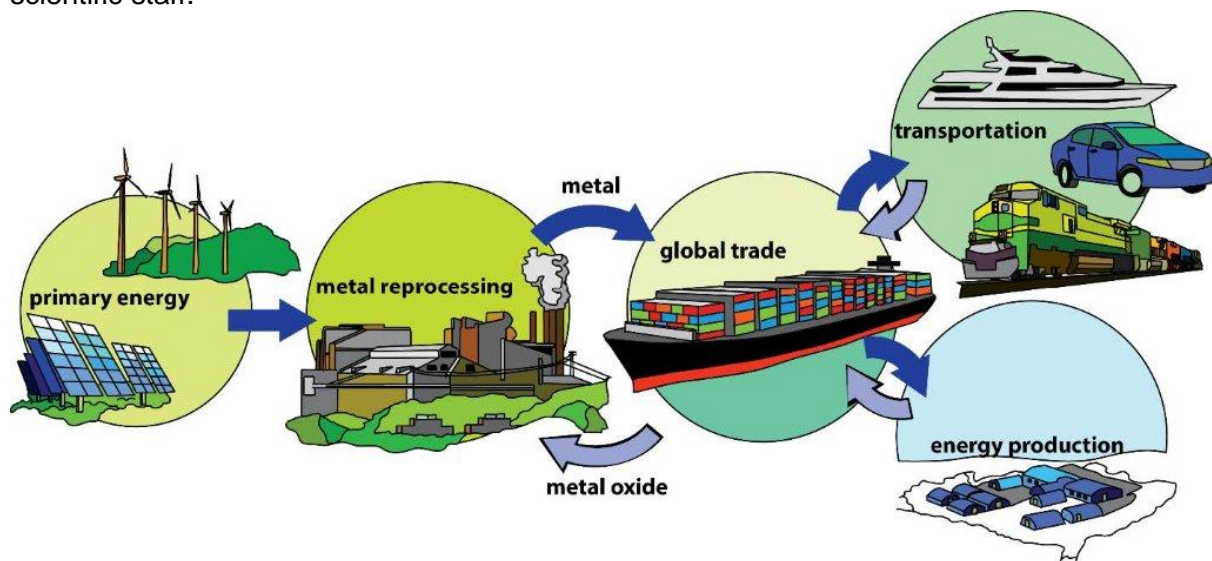
## Introduction

Hydrocarbon fuels, from fossil sources, currently dominate global energy trade and are used in nearly all applications where high power density [kW/L], is required, such as large scale power generation, high-power vehicles and machinery. However, it is widely recognized that our world-economy should transition away from energy sources based on fossil fuels to clean and, preferably, renewable low-carbon energy sources.

A key challenge in this quest is the development of renewable energy commodities, so-called energy carriers. Metal fuels seem to be a very promising option in many regards. Nyrstar, a zinc-producing company near Eindhoven is also interested to investigate the possibilities for metal fuels, especially zinc powder as a recyclable alternative fuel.

## Assignment

In order for metal powder to be such a promising alternative fuel, the burnt metal oxide particles have to be regenerated to metal particles again, in a clean, economical and energetic attractive way. We know that several methods exist to regenerate zinc from zinc oxide. In this assignment you will join us in this new research area by comparing several existing regeneration methods and doing some experiments, in close cooperation with our scientific staff.



(Fig. taken from J.M. Bergthorson et al., Applied Energy 160 (2015) 368 – 382)

## Your challenge

<project goal, tasks/work/steps involved, decisions to be made, intended results>

.....

## Contact

More information: Philip de Goey, Gem Z 2.143, 040-2473268/2140, l.p.h.d.goey@tue.nl

## Master thesis proposal

# CFD to aid development of highly efficient and clean RCCI engines

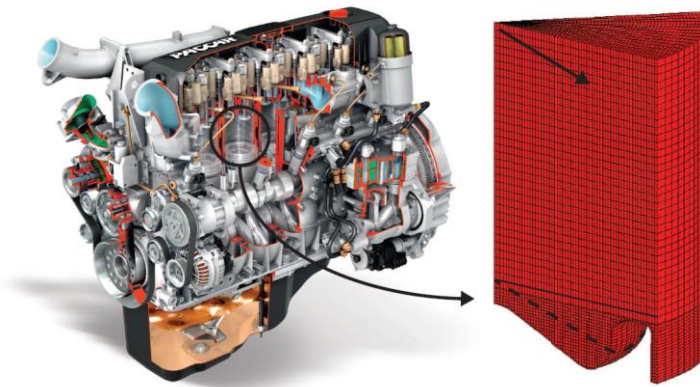
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### Background

The Powertrains group of TNO Automotive focuses on reducing CO<sub>2</sub> emission (fuel consumption) of diesel powered vehicles while meeting emission legislation on particulate matter (PM) and nitrogen oxides (NO<sub>x</sub>). To achieve this, the powertrains group develops model-based diesel engine and aftertreatment control strategies.

The latest combustion technology under investigation is the so-called **RCCI** (Reactivity Controlled Compression Ignition) engine which makes use of 2 different fuels at the same time. RCCI has a large potential compared to other concepts regarding efficiency and emissions. However, the application of RCCI on a multi-cylinder engine is still very challenging.

Some of the most important research questions are fuel-air mixing related. Modern Computational Fluid Dynamics (**CFD**) simulations can give insight and understanding to **help develop highly efficient and clean RCCI engines**.



### Objective

Creation of CFD setup to study in-cylinder mixing processes using OpenFOAM, and apply it to answer engine design related questions.

### Activities

In this project, the following activities are foreseen:

- Realization of CFD simulation setup for a reference engine
- Validation of the CFD model with existing experimental data
- Parameter variation study to understand effect on fuel-air mixing
- Determine injection strategy for optimal mixing
- Report writing and presentation of results at TNO and TU/e

### Timeframe and placement fee

Planned to **start February 1st** for the duration of 9 months. You will work at TNO which is located at the Automotive Campus in Helmond and you will be eligible for TNO's standard placement fee. Dr. ir. Bart Somers (TU/e) and Dr. ir. Cemil Bekdemir (TNO) will supervise you during this period.

### Contact information

Dr. ir. Bart Somers, MRF – WTB, GEM-Z 2.139, Tel: +31 40 247 2107, Email: [L.M.T.Somers@tue.nl](mailto:L.M.T.Somers@tue.nl)  
Dr. ir. Cemil Bekdemir, TNO Powertrains, Tel: +31 8886 63975, Email: [cemil.bekdemir@tno.nl](mailto:cemil.bekdemir@tno.nl)



## Master thesis proposal

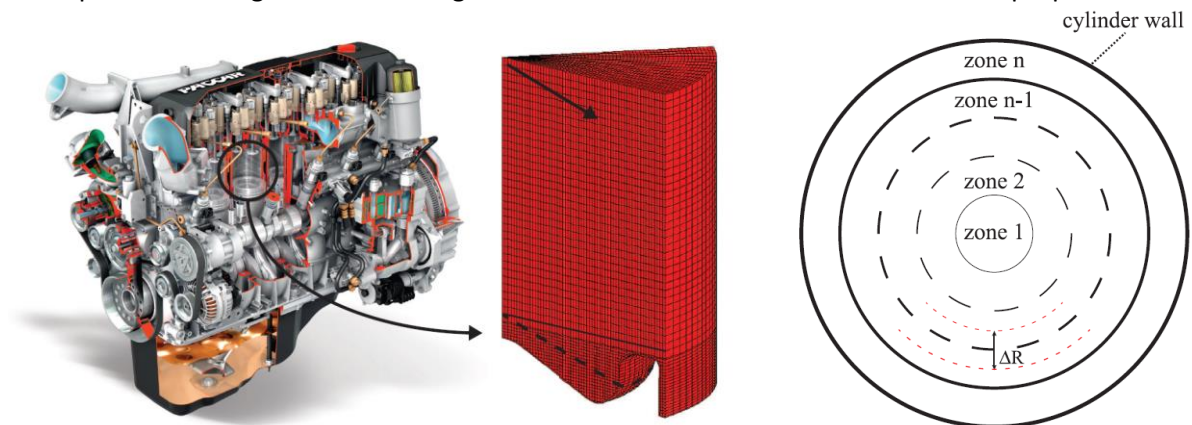
# Establishing new model to handle advanced and conventional dual-fuel

## Background

The Powertrains group of TNO Automotive focuses on reducing CO<sub>2</sub> emission (fuel consumption) of diesel powered vehicles while meeting emission legislation on particulate matter (PM) and nitrogen oxides (NO<sub>x</sub>). To achieve this, the powertrains group develops model-based diesel engine and aftertreatment control strategies.

Lately, dual-fuel combustion technologies attract a lot of attention from research communities and the industry. Dual-fuel concepts make use of 2 fuels with different reactivity at the same time. These concepts have the potential to **significantly reduce CO<sub>2</sub> emissions** by making use of **biofuels and natural gas**, and by operating at **higher thermal efficiency**. However, the application of dual-fuel on a multi-cylinder engine is still very challenging.

**Control-oriented combustion models** are vital for the successful implementation of the dual-fuel concept on a real engine. The challenge is to have **fast and accurate models** for this purpose.



## Objective

Creation of conventional and advanced dual-fuel combustion model using Matlab/Cantera.

## Activities

In this project, the following activities are foreseen:

- Literature study on dual-fuel and premixed combustion models for engines
- Realization of a dual-fuel combustion model
- Validation of the model with existing experimental data
- Report writing and presentation of results at TNO and TU/e

## Timeframe and placement fee

Planned to **start February 1st** for the duration of 9 months. You will work at TNO which is located at the Automotive Campus in Helmond and you will be eligible for TNO's standard placement fee.

Dr. ir. Bart Somers (TU/e) and Dr. ir. Cemil Bekdemir (TNO) will supervise you during this period.

## Contact information

Dr. ir. Bart Somers, MRF – WTB, GEM-Z 2.139, Tel: +31 40 247 2107, Email: [L.M.T.Somers@tue.nl](mailto:L.M.T.Somers@tue.nl)

Dr. ir. Cemil Bekdemir, TNO Powertrains, Tel: +31 8886 63975, Email: [cemil.bekdemir@tno.nl](mailto:cemil.bekdemir@tno.nl)

## MSc Project Multiphase and Reactive Flows

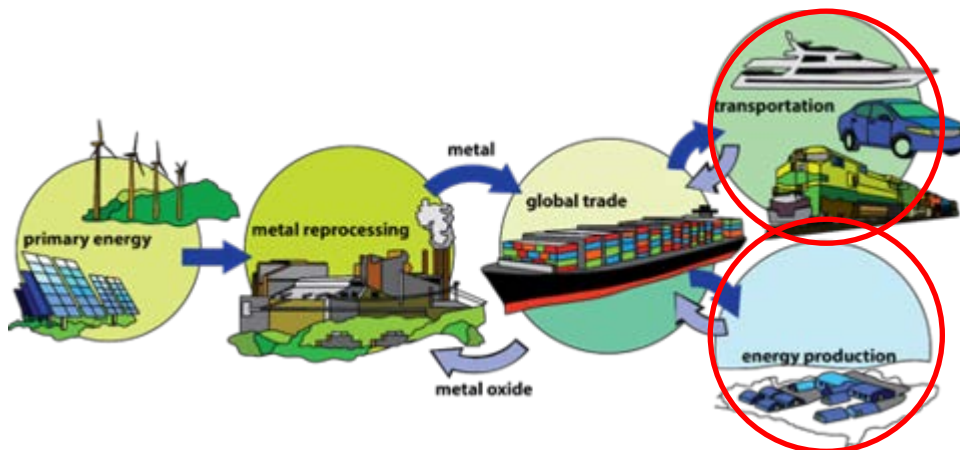
### Title

MF higher temperature wet cycles

**Technology area:** Energy transition, combustion, alternative power sources.

### Industrial scenario:

The energy transition away from hydrocarbons is oriented to solar and wind generated electricity. Nonetheless new dense energy carriers are required given the foreseeable restrictions on battery storage potential. One option is to combine solar and wind with metal powder fuels. Metal powder can generate in-situ hydrogen for combustion at power stations. The solid metal oxide waste is shipped for regeneration to metal powder at central solar and wind powered facilities.



*Schematic cycle for the use of metal fuels as a carbon free high density energy carrier. The red circle shows the part of the cycle with which your project is concerned.*

### Assignment

- Mass balances for hydrogen generation: comparison for power generation from hydrogen at 100, 500, 1000 and 1500 MWth.
- Wet-cycles: Generation rates of H<sub>2</sub> higher temperature operation.
- Identify limiting step inhibiting performance above 200°C – is it thermodynamic or kinetic?.
- in-situ hydrogen generation in mobile sources

### Contact

More information: Prof. Niels Deen, Gem Z 2.133, 040-2473681, n.g.deen@tue.nl

## MSc Project Multiphase and Reactive Flows

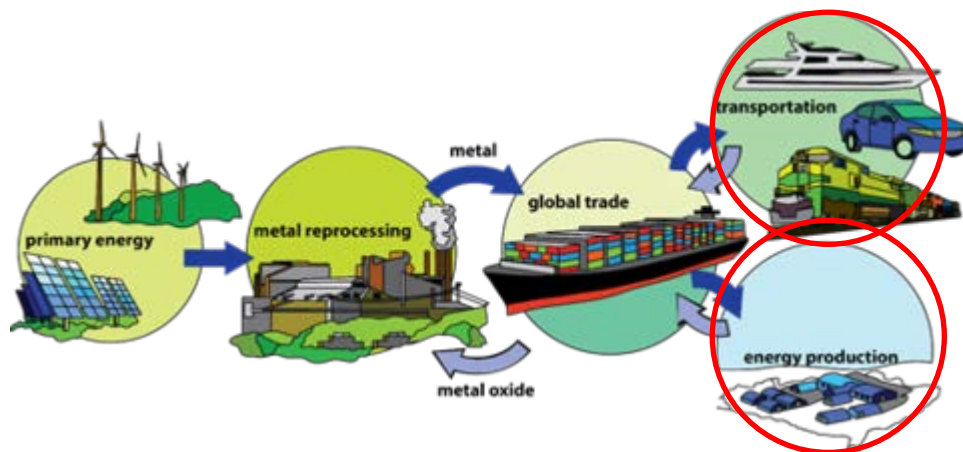
### Title

**Metal fuels – small is more**

**Technology area:** Energy transition, combustion, alternative power sources.

### Industrial scenario:

The energy transition away from hydrocarbons is oriented to solar and wind generated electricity. Nonetheless new dense energy carriers are required given the foreseeable restrictions on battery storage potential. One option is to combine solar and wind with metal powder fuels. Metal powder can generate in-situ hydrogen for combustion at power stations. It can also be used directly as a fuel and burned without generating CO<sub>2</sub>. The solid metal oxide waste is shipped for regeneration to metal powder at central solar and wind powered facilities.



*Schematic cycle for the use of metal fuels as a carbon free high density energy carrier. The red circle shows the part of the cycle with which your project is concerned.*

### Assignment

- Effect of powder particle size distribution on burning velocity and resulting power density
- Energy balance of grinding costs compared to incremental energy generation
- Consequence for aerosol/slag partitioning balance (see other project)
- Evaluation for 3 systems Si/Al/Fe.

### Contact

More information: Prof. Niels Deen, Gem Z 2.133, 040-2473681, n.g.deen@tue.nl



## MSc Project

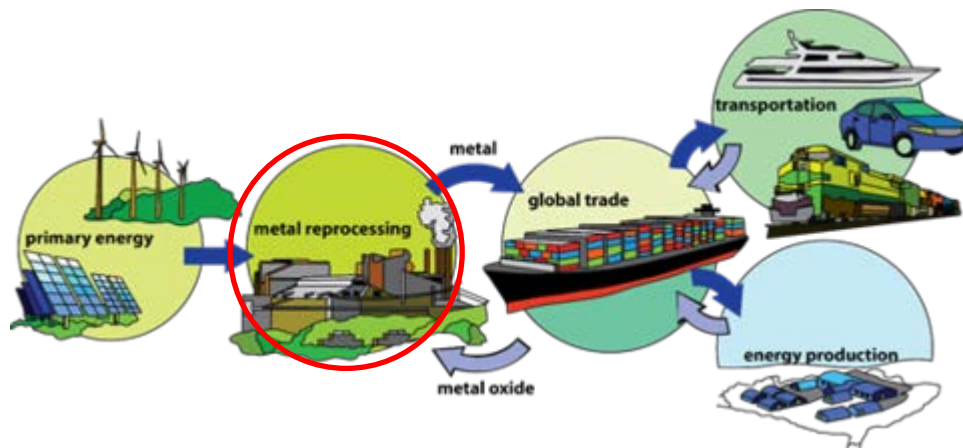
### Title

Hydrogen reduction of metal oxides

**Technology area:** Energy transition, combustion, alternative power sources.

### Industrial scenario:

The energy transition away from hydrocarbons is oriented to solar and wind generated electricity. Nonetheless new dense energy carriers are required given the foreseeable restrictions on battery storage potential. One option is to combine solar and wind with metal powder fuels. Metal powder can either generate in-situ hydrogen for combustion at power stations or indeed be used for combustion itself. The solid metal oxide waste is shipped for regeneration to metal powder at central solar and wind powered facilities.



*Schematic cycle for the use of metal fuels as a carbon free high density energy carrier.*

***The red circle shows the part of the cycle with which your project is concerned.***

### Assignment

- (Wind/solar electrolytically produced) H<sub>2</sub> reduction of FeO/SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> \$ per J; m<sup>3</sup> and kg comparisons – cost comparison on energy utilised for reduction vs. energy generated during wet or dry cycles
- Mass balance based on 1000 MWth plant
- Study options for methane reduction of metal oxides
- Presentation form of metal oxide for optimal reduction i.e. particle size distribution, possible fluidization in reducing gas etc.
- Separation schemes for M and MO.

### Contact

More information: Prof. Niels Deen, Gem Z 2.133, 040-2473681, n.g.deen@tue.nl

## MSc Project

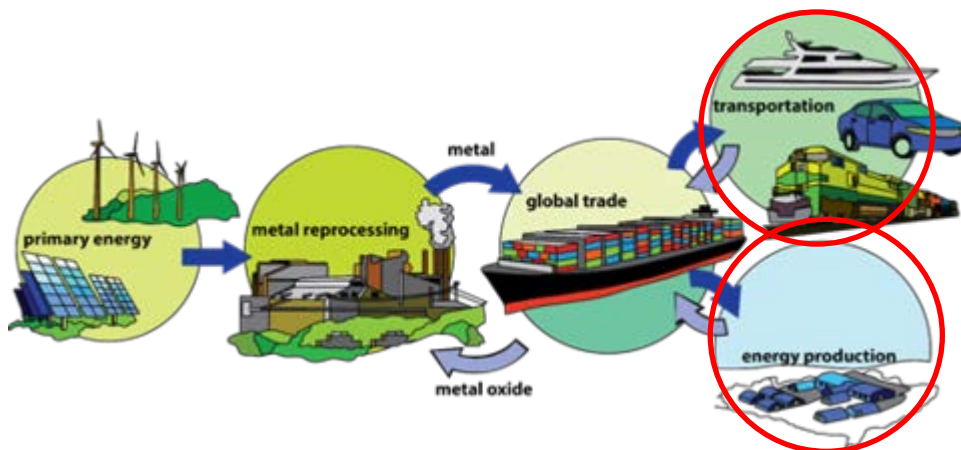
### Title

Gravity settling vs. aerosol formation in MF combustion

**Technology area:** Energy transition, combustion, alternative power sources.

### Industrial scenario:

The energy transition away from hydrocarbons is oriented to solar and wind generated electricity. Nonetheless new dense energy carriers are required given the foreseeable restrictions on battery storage potential. One option is to combine solar, wind and hydrogen with metal powder fuels. These provide higher power than traditional combustion flames and do not emit any CO<sub>2</sub>. Rather solid metal oxide is shipped for regeneration to metal powder at central solar and wind powered facilities.



*Schematic cycle for the use of metal fuels as a carbon free high density energy carrier. The red circle shows the part of the cycle with which your project is concerned.*

### Assignment

- Fluidisation of metal powders and effect on particle size distribution
- Particle size distribution of resulting metal oxide products
- Estimate partitioning between gravity settled and aerosol gas bound product components
- MF powder size distribution and burning rates

### Contact

More information: Prof. Niels Deen, Gem Z 2.133, 040-2473681, n.g.deen@tue.nl

## MSc Project

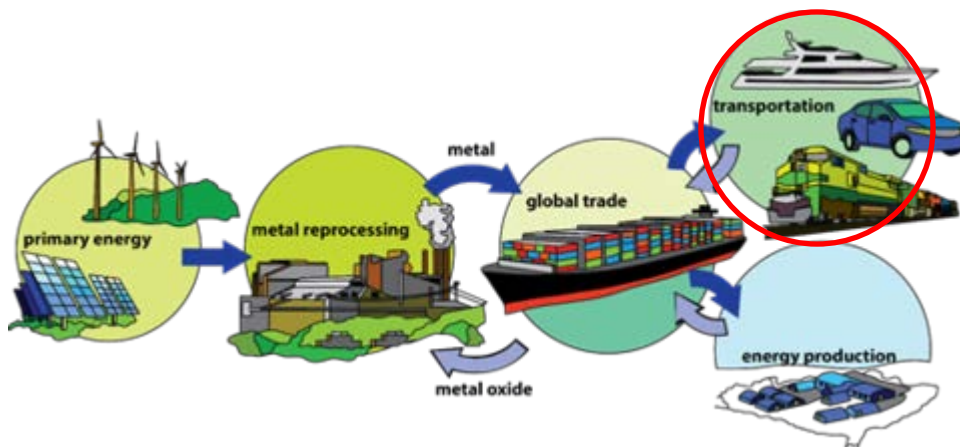
### Title

MF Internal combustion engine

**Technology area:** Energy transition, combustion.

### Industrial scenario:

The energy transition away from hydrocarbons is oriented to solar and wind generated electricity. Nonetheless new dense energy carriers are required given the foreseeable restrictions on battery storage potential. One option is to combine solar, wind and hydrogen with metal powder fuels. These provide higher power than traditional combustion flames and do not emit any CO<sub>2</sub>. Rather solid metal oxide is shipped for regeneration to metal powder at central solar and wind powered facilities.



*Schematic cycle for the use of metal fuels as a carbon free high density energy carrier. The red circle shows the part of the cycle with which your project is concerned.*

### Assignment

- Review state of art of solid fuels for mobile combustion (including coal driven trucks – see WW2)
- What is better for metal fuel powders: Spark or compression ignition?
- Concept engineering of technical modifications for IC engines based on metal fuels – this will mainly be concerned
- Use FCC (fluid catalytic combustion) and pulverised coal combustor concepts to address slag residue collection and removal from chamber

### Contact

More information: Prof. Niels Deen, Gem Z 2.133, 040-2473681, n.g.deen@tue.nl



# MSc Project

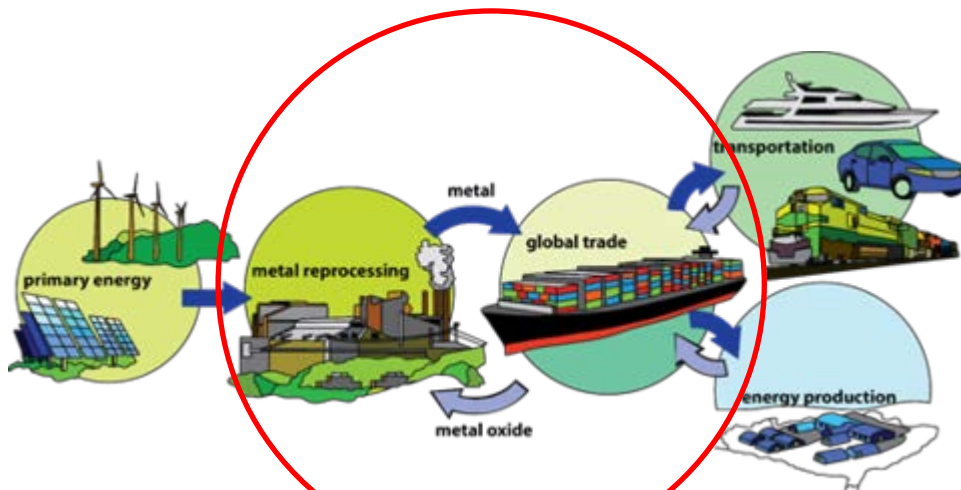
## Title

### Metal fuels – life cycle analysis

**Technology area:** Metals processing; Energy transition, Combustion, Alternative power sources; transportation models.

#### Industrial scenario:

The energy transition away from hydrocarbons is oriented to solar and wind generated electricity. Nonetheless new dense energy carriers are required given the foreseeable restrictions on battery storage potential. One option is to combine solar, wind and hydrogen with metal powder fuels. These provide higher power than traditional combustion flames and do not emit any CO<sub>2</sub>. Rather solid metal oxide is shipped for regeneration to metal powder at central solar and wind powered facilities.



*Schematic cycle for the use of metal fuels as a carbon free high density energy carrier. The red circle shows the part of the cycle with which your project is concerned.*

#### Assignment

- Cycle based on 1000MW<sub>th</sub> power station
- Mass balances for Si/Al/Fe transport for dry cycle power generation – metal combustion cycle.
- Mass balances for Si/Al/Fe transport for wet cycle power generation
- Include option for powering ship from transported “heel” of metal with on-board H<sub>2</sub> generation for power
- Estimate of transportation costs as part of cycle for a short and long distance scenario

#### Contact

More information: Prof. Niels Deen, Gem Z 2.133, 040-2473681, n.g.deen@tue.nl

## MSc Project

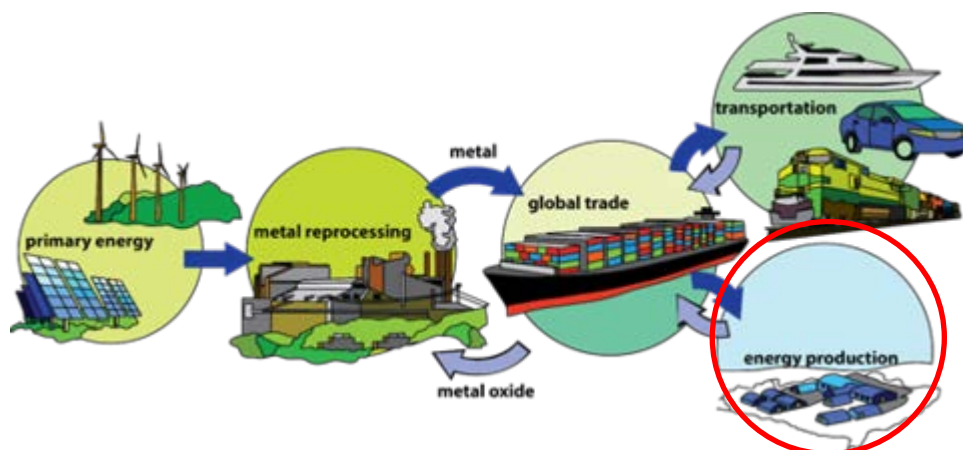
### Title

Metal powders in subcritical water

**Technology area:** Energy transition, combustion, alternative power sources.

### Industrial scenario:

The energy transition away from hydrocarbons is oriented to solar and wind generated electricity. Nonetheless new dense energy carriers are required given the foreseeable restrictions on battery storage potential. One option is to combine solar and wind with metal powder fuels. Metal powder can generate in-situ hydrogen for combustion at power stations. The solid metal oxide waste is shipped for regeneration to metal powder at central solar and wind powered facilities.



*Schematic cycle for the use of metal fuels as a carbon free high density energy carrier. The red circle shows the part of the cycle with which your project is concerned.*

### Assignment

- Literature review of subcritical water and enhanced electrochemical properties for solubilising and reacting metal powder
- Tests of Si/Al/Fe powders in subcritical water reactor – bomb calorimetric ranking for different rates of H<sub>2</sub> generation
- Effects of powder SMD size and distribution spread on H<sub>2</sub> generation and heat.

### Contact

More information: Prof. Niels Deen, Gem Z 2.133, 040-2473681, n.g.deen@tue.nl

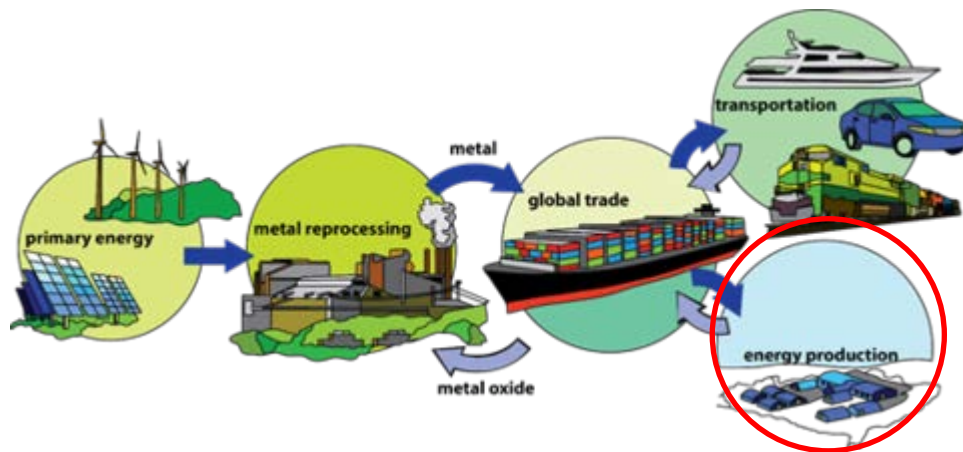
# MSc Project

Title: Metal powder combustion boilers

Technology area: Energy transition, combustion, alternative power sources.

## Industrial scenario:

The energy transition away from hydrocarbons is oriented to solar and wind generated electricity. Nonetheless new dense energy carriers are required given the foreseeable restrictions on battery storage potential. One option is to combine solar, wind and hydrogen with metal powder fuels. These provide higher power than traditional combustion flames and do not emit any CO<sub>2</sub>. Rather solid metal oxide is shipped for regeneration to metal powder at central solar and wind powered facilities.



*Schematic cycle for the use of metal fuels as a carbon free high density energy carrier. The red circle shows the part of the cycle with which your project is concerned.*

## Assignment

- Review of 1000 MW<sub>th</sub> coal fired boiler system including aerosols removal.
- Comparison with state of art metal powder combustion systems including scale up estimations from current systems
- Identify solid waste throughput balance and estimate annual metal (Al/Si/Fe) oxide transportation for regeneration costs
- Mass flow estimates for 100, 500, 1000 and 1500 MW<sub>th</sub>
- Concept engineering for major required changes to a large coal boiler for metals operation – possible critical comparison of Al/Si/Fe oxide waste collection

## Contact

More information: Prof. Niels Deen, Gem Z 2.133, 040-2473681, n.g.deen@tue.nl



# MSc Project

## Title

Optical void probe for objective flow pattern mapping

## Introduction

Flow regimes or flow patterns depend on the channel geometry, pressure, mass flow and heat flux but also on orientation of the channel. In order to properly design an evaporator tube, it is desirable to know the flow pattern and thus fluid spatial and temporal distributions of the vapor and liquid phases as these have large influence on the heat transfer and friction, i.e. the pressure drop. Examples of flow patterns occurring in a vertical, upward flow are illustrated in figure 1. Measuring the local void fraction enables us to derive flow pattern maps.

## Assignment

This assignment concerns construction of optical, local, void probes and perform experiments with these probes to gain more knowledge on their performance.

## Illustration

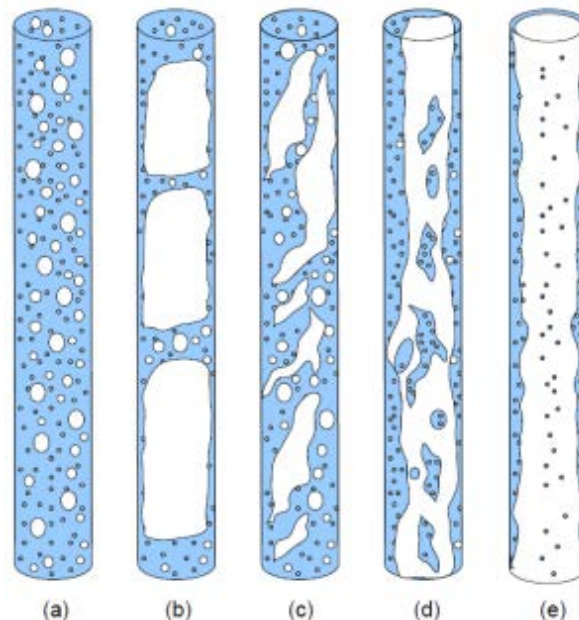


Figure 1: Flow patterns for vertical, upward flow

## Your challenge

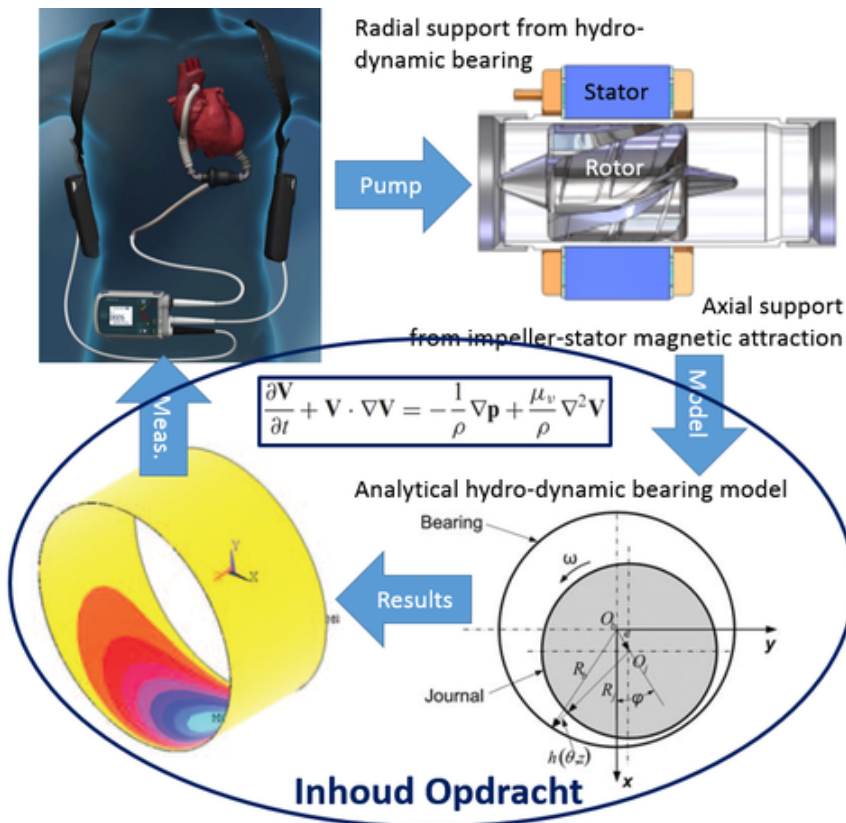
A novel optical void probe has been designed to accurately measure the local void fraction and the local velocity of the interface passing the probe. In this assignment an improvement of the construction method is asked for. You will need to build the probe and use it in an experimental setup to validate its functioning using multiple high speed cameras. You will analyse the results and improve the probe to the optimum. Experience in the lab is preferred.

## Contact

More information: Giel Priems, Gem N 1.42, 040 247 2573, [g.j.m.priems@tue.nl](mailto:g.j.m.priems@tue.nl)

## MSc project "Analytical Modelling of a Hydro-magnetic bearing"

A hydro-magnetic journal bearing is a new and innovative type of bearing, where especially minimization of shear stress on the fluid is important in medical applications. Impeller levitation is achieved by combining a magnetic coupling (passive by using permanent magnets) and a hydro-dynamic bearing (fluid forces). This combines the advantages of both types of bearings to give rise to new possibilities for instability control, increased load-carrying capacity, diagnostics of the rotor system, etc. This hydro-magnetic journal bearing should operate as either a passive or active journal bearing.



The hydro-dynamic journal bearing is designed with the appropriate clearance, where the suitable operational regions need to be modelled in an analytical manner, which could then be used to find the optimum ratio between airgap and clearance. For this, an analytical model is required to calculate the hydro-dynamic pressure field within the airgap between stator and rotor. The journal bearing dynamic characteristics, in terms of the stiffness and damping coefficients versus the Sommerfeld number, need to be analyzed analytically. Verification of the results is done using a 3D finite element method (ANSYS). Dedicated experiments are carried out to validate the model.

Type of project : external, at a Dutch company  
Location : region Den Bosch, the Netherlands  
Start : as soon as possible

Information : dr. [Bart van Esch](#)

<https://www.tue.nl/universiteit/faculteiten/werktuigbouwkunde/de-faculteit/medewerkers/detail/ep/e/d/ep-uid/19970626/>, GEM-Z 2.138,  
[b.p.m.v.esch@tue.nl](mailto:b.p.m.v.esch@tue.nl)

# Assignment for master graduation project

Group of Multiphase and Reactive Flows (Combustion Technology), TU/e in cooperation with Elco B.V., Kerkrade, the Netherlands

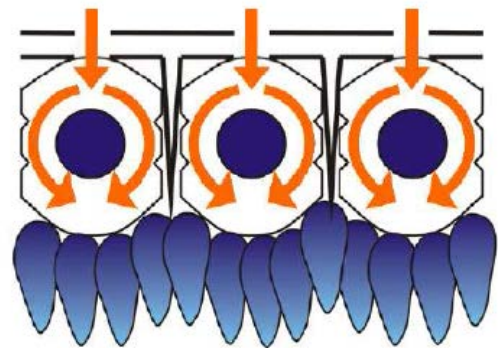
Principal supervisor: prof. dr. L.P.H. de Goey (Philip)

Daily supervision: V.N. Kornilov (Viktor) (v.kornilov@tue.nl)

## Problem of thermo-acoustic stability of combustion in Rendamax central-heating boilers

The ultimate goal of the research is to develop the systematic methodology to solve and/or predict the thermo-acoustic instability of combustion in particular type of boilers (namely "Rendamax") equipped with water-cooled premixed gaseous burners. The particular targets of the present R&D phase are:

- to develop or to adapt the existing measurement technique to characterize the Rendamax burner in respect to its thermo-acoustic properties;
- To perform systematic parametric research of the burner acoustic properties (Transfer Functions) within the relevant working range of the burner.
- To develop an approach to combine relevant acoustic properties of elements of the boiler/burner and predict with reasonable level of certainty the thermo-acoustic behaviour of the complete boiler.



The transfer of corresponding knowledge from TU/e to Elco B.V. and gain of relevant experience is the main expected deliverable of this phase.

### Approach of the problem

The work includes the measurement of the thermo-acoustic characteristic of the Rendamax burner. This will require design and manufacturing of special adaptation to incorporate the sample of Rendamax burner into TU/e measurement setup. Modifications of the measurement technique will be also required. The concept of the flame/burner Transfer Function (TF) will be used to characterize the thermo-acoustic property of the burner.

The measurements should be done for typical range of the fuel-air composition (equivalence ratio /  $\text{CO}_2$  in exhausted gas) and surface power density (flow rate/speed). The results of the measurements will provide information about possible physical mechanisms of the flame-acoustics interaction and suggest the methods to improve the burner in its thermo-acoustic aspect.

Next step is the incorporation of the measured burner/flame as the constitutive part of the boiler model. The aim is to provide a certain level of ability to predict the instability of complete boiler on the design stage and foresee measures to prevent it. Consequently, the description of acoustics of Rendamax boilers within acoustic network modelling will be developed.

Finally the effectiveness of application of different passive methods (for instance, an additional damping device or certain geometrical changes) can be assessed using the developed model.



# ***Internship and/or Graduation Project***

## **Feasibility Study into an EN228 compliant 'Zero Oil' fuel**

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GUTTS (<https://gutts.nl/>) has an established track record in motorsports and has developed and sold over 200.000L of Renewable Performance Fuel, together with key industry partners in both OEM, Science and Renewable Fuel Industry, celebrated over 500 wins, won three tender contracts and reduced approximately 300.000kg of CO<sub>2</sub>. GUTTS will lead the effort to bring this experience in renewable performance fuels to the everyday driver, by working with our partners, using our creativity to introduce the first renewable, EN228 drop-in fuel in the Netherlands.



Our aim is to design, develop and deliver a 'Zero Oil', 'Drop-in' fuel on the market with the working title: LCGR Fuel (Low Carbon Gasoline Replacement Fuel). LCGR Fuel will be a blend of 10-15 renewable components, EN228 compliant, low carbon (<50% CO<sub>2</sub> WtW), have low soot and NO<sub>x</sub> emissions, be technically equivalent to current market offerings, and be ISCC certified.

It will be a serious technical challenge to define a LCGR FUEL that performs on par at a technical, chemical (compliance), sustainable and economical level with current fossil offerings. The main scientific challenges to be addressed by the student in this project are:

1. Development and validation of a model that can predict critical blend parameters:
  - a. Miscibility
  - b. Octane rating
  - c. Flash point
  - d. Heating value
  - e. Heat of vaporization
  - f. ...
2. Aided by the validated model, prepare 2-3 blends that adhere to all the requirements and assess the performance (e.g., fuel economy, emissions) of which means of a series of engine tests
3. Finally, be creative and actively participate in team discussions that might generate new intellectual property

Please respond with a motivational letter and CV to Michael Boot ([M.D.Boot@tue.nl](mailto:M.D.Boot@tue.nl))

# Hydrodynamics of Gas Fluidization of Wet Particles Using Discrete Particle Method Simulations

Y. Tang<sup>1</sup>, N.G. Deen<sup>2</sup>, J.A.M. Kuipers

*The assignment is done in close collaboration between the departments Mechanical Engineering and Chemical Engineering and Chemistry. Please contact:*

1. Yali Tang, STW 0.49, E-mail: [Y.Tang2@tue.nl](mailto:Y.Tang2@tue.nl)

2. Niels Deen, GEM-Z 2.133, E-mail: [N.G.Deen@tue.nl](mailto:N.G.Deen@tue.nl)

## Introduction

Gas-fluidization involving liquid injection is widely applied in a variety of industrial processes. Despite wide applications, such processes are not yet understood. One of the most important mechanisms in those processes is particle collisions. It is known that the collisional behaviour of wet particles are fundamentally different from dry particles, which results in completely different macro-flow characteristics. Figure 1 shows an experimental demonstration of the significant influence of moisture content on the bed dynamics, as a result of different collision behaviour of wet particles. In this project, we aim to model this influence of wet collisions on the macro bed dynamics using the Discrete Particle Method (DPM).

Particle collisions can be characterized by the restitution coefficient, which describes the total energy dissipation rate of this micro-process. In DPM simulations, the restitution coefficient is taken as a particle physical property and specified as an input parameter. A fundamental description of the restitution coefficient of wet particles depends on many parameters, such as the density, size of the particle, surface tension, viscosity of the liquid, impact velocity, etc. However, experiments under the same controlled conditions have always shown a scattered distribution of the measured restitution coefficient for non-ideal particles, which are characterized by an effective density, sphericity and diameter. Since particles in industrial applications are truly non-ideal, a single value of the restitution coefficient might not be sufficient to characterize their collision behaviour, which significantly influences on the accuracy of modelling such fluidization by DPM simulations. Instead, a distribution of the restitution coefficient might do a better job by considering the nature of real particles.

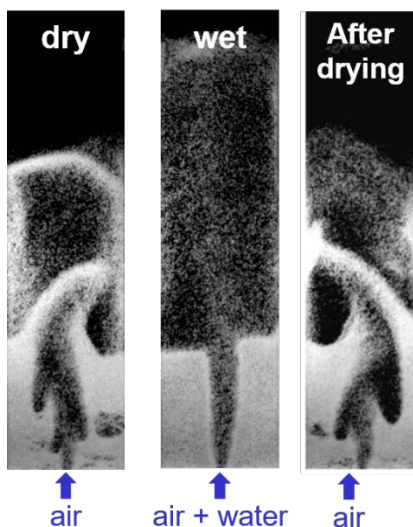


Figure 1. Particle velocimetry images of fluidization of glass particles.

## Objectives

1. To model the bed dynamics of gas fluidization of wet particles using DPM simulations.
2. To investigate the influence of the distribution of wet restitution coefficient, which considers the nature of non-ideal particles.

## Graduation projects

In our earlier work, a gamma function was proposed to describe the distribution of the wet restitution coefficient. In this project, we would like to apply this result in DPM simulations of gas fluidization of wet particles, and to investigate its influence on description of the bed behaviour comparing to the use of a single averaged restitution coefficient. Simulation results are compared with experimental data, in terms of the bed expansion, solids fraction distribution, solids volumetric flux profile

# Experiments of Gas Fluidization with Liquid Injection using Visual/Infrared Measurements

Y. Tang<sup>1</sup>, N.G. Deen<sup>2</sup>, J.A.M. Kuipers

*The assignment is done in close collaboration between the departments Mechanical Engineering and Chemical Engineering and Chemistry. Please contact:*

1. Yali Tang, STW 0.49, E-mail: [Y.Tang2@tue.nl](mailto:Y.Tang2@tue.nl)

2. Niels Deen, GEM-Z 2.133, E-mail: [N.G.Deen@tue.nl](mailto:N.G.Deen@tue.nl)

## Introduction

Gas-fluidization involving liquid injection is widely encountered in a variety of industrial processes. Many important applications can be found in the food, pharmaceuticals, fertilizer, detergent, granulation and coating industries etc. Despite wide applications, such processes are not yet understood. One of the most important mechanisms in those processes is particle collisions. It is known that the collisional behaviour of wet particles are fundamentally different from dry particles, which results in completely different macro-flow characteristics. Figure 1 shows an experimental demonstration of the significant influence of moisture content on the bed dynamics, as a result of different collision behaviour of wet particles. In this project, we aim to systematically study the characteristics of gas fluidization of wet particles using a combined IR (infrared)/PIV (particle image velocimetry) /DIA (digital image analysis) measuring technique.

## Objective

1. To investigate the influence of various operating parameters and physicochemical properties of solid materials on dynamics of the fluidized bed under dry and wet (with additional liquid injection) conditions.
2. To investigate the heat and mass transfer effects in the fluidized bed reactor under wet conditions.
3. To serve as validation reference for our in-house numerical simulations of the same flow problem.

## Graduation projects

Experimental setup is sketched in Figure 1. A high resolution IR camera and a high speed visual camera are combined together to get the visual image of particle positions and the temperature distribution simultaneously. PIV and DIA measure techniques will be applied to get quantitative information on the particle velocity, gas hold up, bubble size, etc. Graduation project will emphasize on comprehensive study the dynamics of a pseudo 2D fluidized bed under liquid injection.

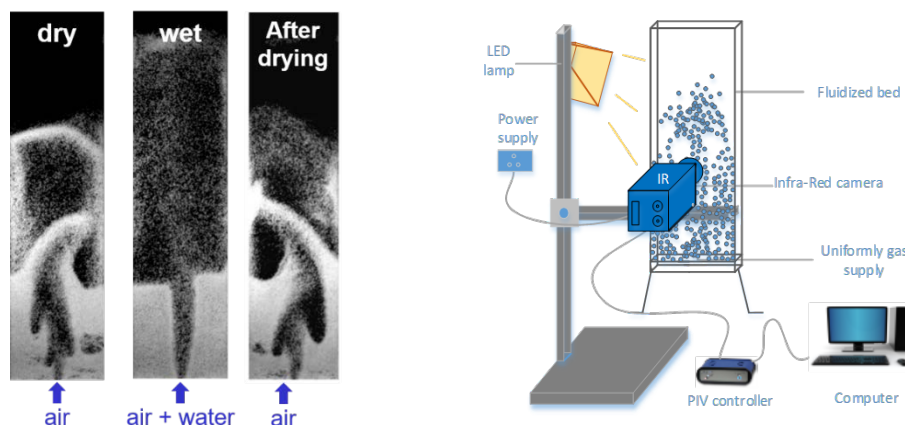


Figure 1. Particle velocimetry images of fluidization of glass particles (left) and the sketch of experimental setup (right).

# MSc Project

## Title

*Computational Fluid Dynamics simulation of electrochemical system*

## Location

Strategic Research Group Process Technology, AkzoNobel, Deventer

## Assignment

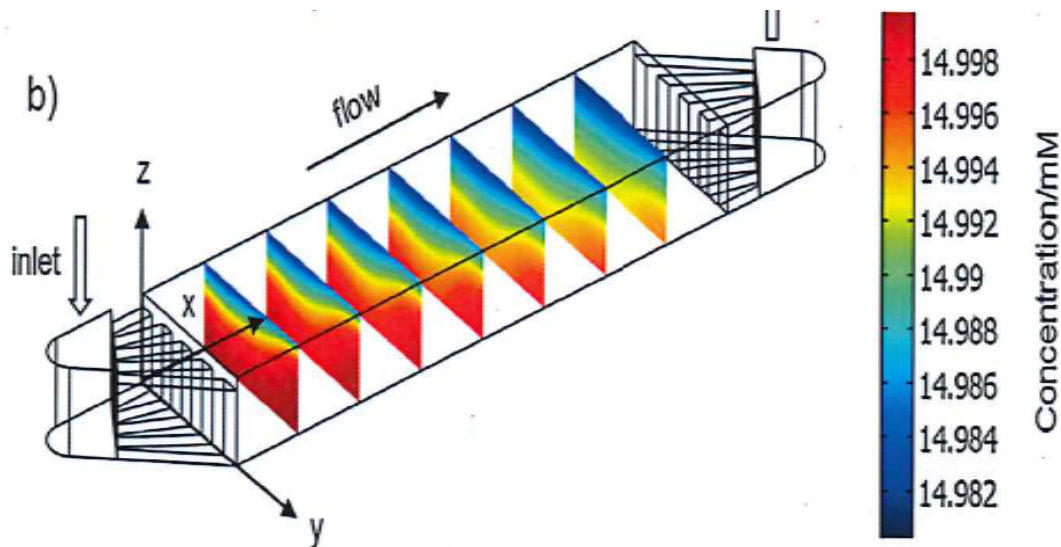
Use computational fluid dynamics (CFD) to predict mass transfer in a laboratory electrochemical cell and check whether the results are comparable to experimental observations.

## Details

- The governing equations for the electrolytic process have to be formulated (the system is single-phase, no gases): Navier-Stokes equations combined with equations for the transport and reaction of the species in the solution.
- A simulation approach has to be selected (DNS, LES or RANS).
- Simulations have to be performed (commercial CFD package (Ansys) is available).
- Results should be interpreted and compared to available experimental data.
- The outcome of a relation between Sherwood and Reynolds number for this system is desired.

## Illustration

(taken from F.F. Rivera et al., *Electrochimica Acta* 161 (2015), 436-452)



More information: Niels Deen, Gem Z 2.132 or Hans Kuerten, Gem Z 2.147.



## Numerical investigation of interaction between a bubble and a needle

Measurements of void fraction in multiphase flows are important for understanding these flows but not simple. In the Multiphase & Reactive Flows group at TU/e an experimental setup has been built that enables the determination of the void fraction by using a local void probe. The accuracy and quality of this method depend on how an approaching bubble is pierced by the probe.

In this project we will use a CFD tool (OpenFOAM) to investigate the behavior of the interface of a bubble when it approaches a void probe. The CFD tool is already equipped with an accurate method for simulating flows with bubbles. The main goals of the project are to create a geometry and a mesh corresponding with the experimental setup and to perform a numerical simulation of the interaction between a bubble and the probe. Results of the simulation will be compared with experimental results.

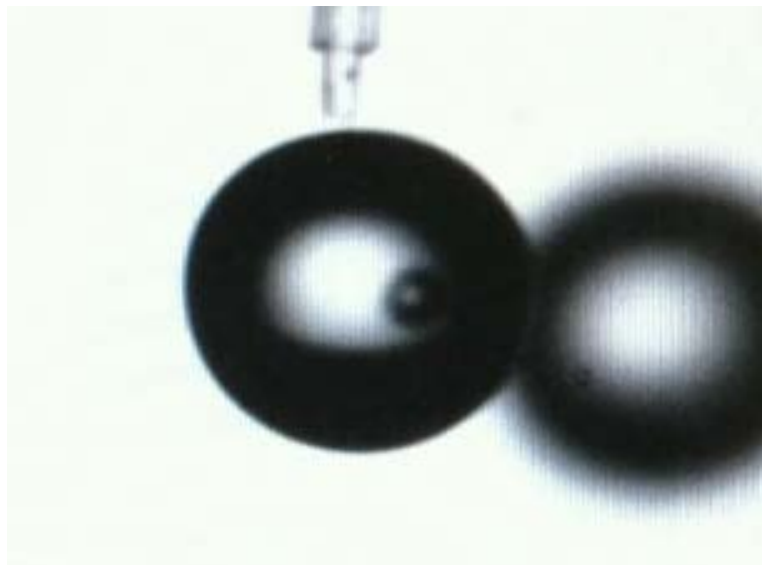


Fig. A rising bubble approaching a void fraction probe.

The project consists of the following steps:

- Familiarization with the software (OpenFOAM)
- Generation and validation of a mesh
- Numerical investigation of a flow with a bubble pinned by a probe
- Comparison with experimental results
- Writing report

Supervision: Wiktor Michalek (GEM-N 1.42) and Hans Kuerten (GEM-Z 2.147).

# Partially Premixed Combustion Laser Induced Fluorescence

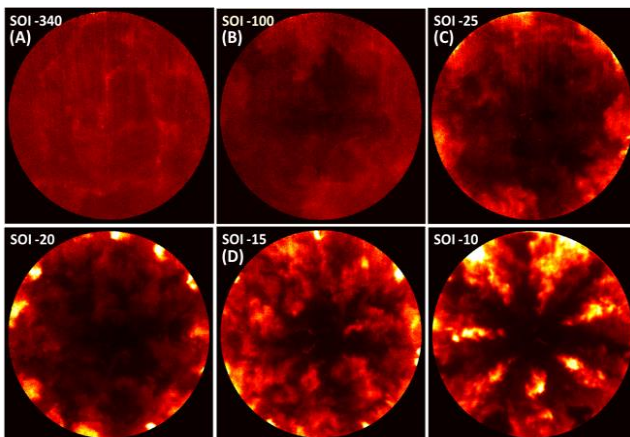
# ECCO-MATE

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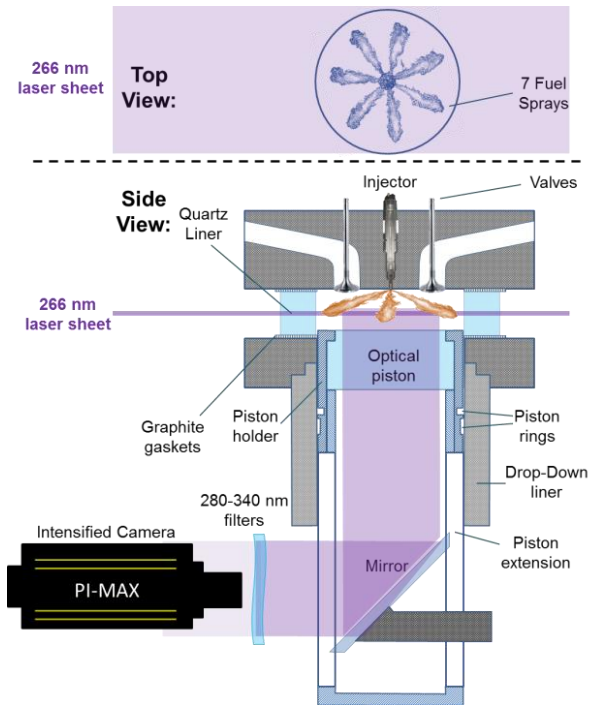
## Research

New combustion concepts are currently actively researched for implementation in internal combustion engines. One of the most promising ones is Partially Premixed Combustion (PPC) which has shown a great potential for reducing NO<sub>x</sub> and soot emissions. This type of combustion improves the indicated efficiency by inducing some kind of charge stratification in the engine.

In this project, the fuel stratification in an optical engine (VOLVO D5) will be studied. The study will focus on the laser diagnostic technique of Fuel tracer Laser Induced Fluorescence (LIF). The project is a concerted effort to raise the level of knowledge on the PPC concept. The schematic of the experimental setup is demonstrated in Figure 1. This technique is supposed to be used to investigate the fuel stratification at ignition timing or TDC position (Figure 2). Quantified results of air/fuel ratio require the knowledge of mixture temperature. Two-color LIF imaging for simultaneous measurement of the thermal and fuel stratification is the further step to improve the knowledge of Partially Premixed Combustion (PPC).



**Figure 2: Fuel distributions for different injection timings.**



**Figure 1: Schematic of Fuel Tracer Laser Induced Fluorescence method.**

## Student Responsibilities

- Literature study of Partially Premixed Combustion (PPC) and Laser Induced Fluorescence technique.
- Getting familiar with the engine setup, engine test cell, optical and laser equipments and performing experiments.
- Post-processing, calibration and improvement of quantified results.

## Requirements

- Master student with an interest in internal combustion engines and laser diagnostic techniques.
- Successful completion of Powertrain Components and Laser Diagnostics courses is a plus.

## Want to work with the number one thermotechnology company in Europe?



### General information

The Bosch Group is a leading global supplier of technology and services. In 2015, 375,000 associates generated sales of 70.6 billion euro. Bosch Thermotechnology is a division of the business sector Energy and Building Technology and has 13,400 associates, generating 3.3 billion euro sales revenue and spending 144 million euro on research and development. Bosch Thermotechnology in Deventer focuses on energy systems for household applications, specifically wall mounted boilers. We are looking for a motivated student for a master project.

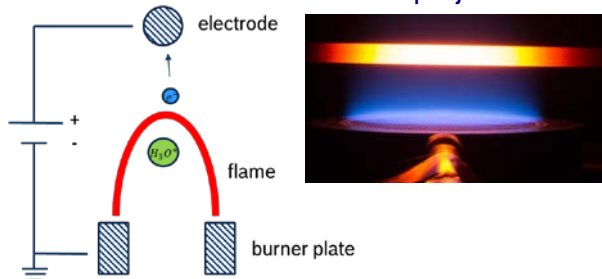


fig. 1: sketch and setup of ionization rod in a premixed flame

### Project description

In current wall mounted boilers, an ionization pin is often used to monitor the presence of a flame. Charged particles are formed in a flame and a potential difference between the ionization pin and the burner causes an electric current to flow. We are interested in detailed simulations of this flame ionization current in wall mounted boilers.

A detailed model was developed by TU/e. It will be your task to optimize and validate this model with 1D, 2D and 3D simulations and comparing results with available measurements and literature results. We are especially interested in the flame behavior under the influence of heat losses.

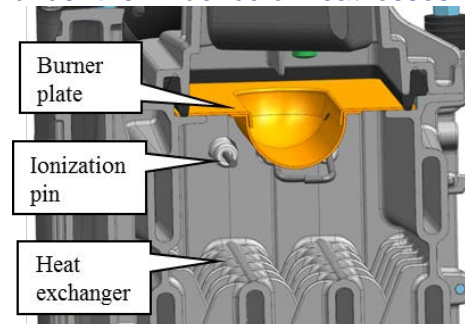


fig. 2: inside of wall mounted boiler showing burner plate and location of ionization pin.

### Project outline:

- Set up and verify the TU/e ionization model in the TU/e code chem1d
- Create flamelet databases and perform FGM validation study using ANSYS Fluent
- Optimize the coefficients in the ionization mechanism using available measurements
- Perform 3D simulations of Bosch appliances and compare with measurements

### Student profile:

- MSc. student in mechanical engineering, physics or comparable study
- Interested in fluid dynamics, CFD simulations and combustion

For more information contact

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## Multiphase and Reactive Flows

### MSc project "Combustion of Polyethylene"

#### Combustion of Polyethylene - a combined experimental and theoretical study

##### Background

In the 1980's DSM has developed a process to align UHMWPE molecules via a solution spin process into Dyneema® -fibers. These fibers, due to their exceptional combination of high strength and low weight, are frequently used to produce specialized end-products such as bullet proof vests, airplane cockpit doors, etc. Often these end-products must meet so-called flame retardancy requirements, making it essential to understand the combustion behavior of Ultra-High-Molecular Weight Polyethylene (UHMWPE) and its composites that constitute the end-products.

##### Research – the challenge and tasks

We would like you to model the solid state degradation and subsequent gas-phase combustion of neat UHMWPE. Your work builds on pillars already developed at the DSM Materials Science Center (solid state degradation model) and at the Combustion Technology group at TUE (Chem1D, gas phase combustion model); support will be provided by parties from both TUE and DSM side. In parallel to your modeling effort you will perform combustion experiments at DSM MSC to obtain two of the main combustion characteristics of UHMWPE (time to ignition,  $t_{ig}$ , and rate of heat release,  $rh_r$ ) that should serve as a verification of your modeling work.

##### Requirements

- Project is intended for a master student willing to develop in materials science, able to contribute to modeling the combustion of polymeric solids.
- Student should be willing to spend ~50% of his/her time at the DSM Materials Science Center.

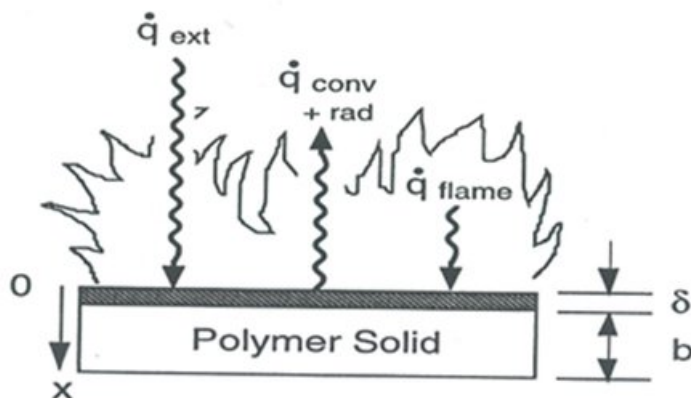


Fig 1. Schematic of UHMWPE combustion calculation.

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# Master Graduation project: A novel method for NO LIF

ir. N.C.J. Maes and dr. N.J. Dam

## Research

High amounts of Nitric Oxides (NO) are considered as a crucial barrier in the development of modern heavy-duty Diesel engines. The goal of this project is the development of a robust method to detect NO in typical Diesel engine circumstances.

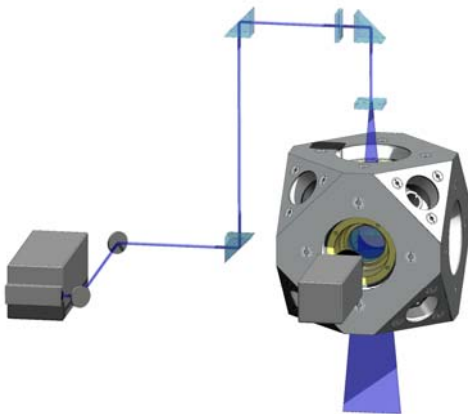


Figure 1. Example how NO LIF could be applied in heavy-duty Diesel spray research.

## Approach

Several excitation strategies exist and have been used to detect NO fluorescence up to date. Most of these strategies, however, involve complicated and potentially unsteady laser systems. A new approach, which recently became available, could simplify things considerably. Although expected to be less efficient at atmospheric conditions compared to conventional approaches, the method holds the potential of increasing robustness and efficiency under typical Diesel engine circumstances due to pressure broadening of the excitation spectrum.

## Student responsibilities

### Tasks

- Study the new strategy of NO LIF (literature study + spectral simulations)
- Compare the strategy with at least one conventional approach
- *Optional:* implement the technique in an optically accessible Diesel engine environment

### Requirements

- Completion of “Advanced combustion diagnostics using laser techniques (4P620)” is essential, “Optics the manipulation of light (4P660)” is a plus
- Interest in spectroscopy and laser diagnostics

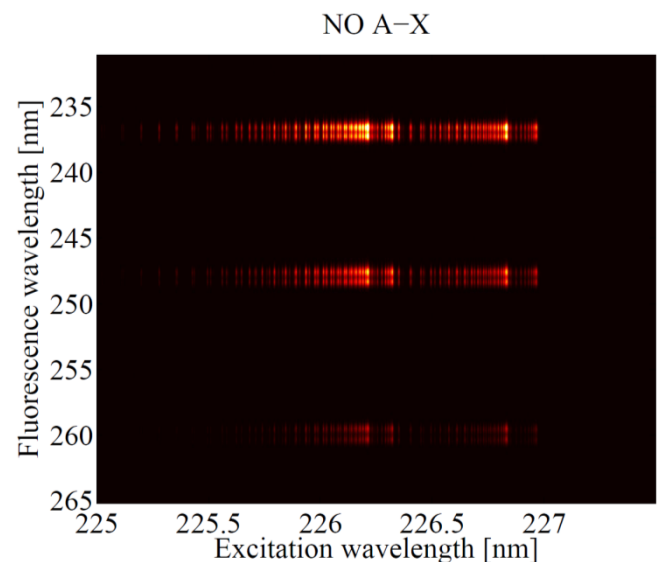


Figure 2. Excitation and fluorescence spectrum of NO using a dye-laser, courtesy of P.C. Bakker.

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**inMotion**  
WWW.INMOTION.TUE.NL

# Direct injection Wankel engine

Graduation/BEP/SEP/Open Space

## Background

The goal of InMotion is to design, engineer and build a series-hybrid race car. The IM01 will be a platform for various research projects at the TU/e in cooperation with various automotive companies. This race car will become a showcase for the latest high-tech innovations in automotive research. Its goal is to participate in the world



*Render of the IM01 racecar*

famous 24 hours of Le Mans race. The IM01 will have the dimensions of a Le Mans LMP1 race car with four electric motors and a top speed of approximately 360km/h. A hotspot rotary generator will be added as a range extender, making the IM01 a series-hybrid vehicle. Furthermore energy will be recovered with regenerative braking. The IM01 will have active vehicle dynamics, active aerodynamics, drive-by-wire and a full carbon chassis.

## Assignment

This specific assignment involves testing and analyzing the combustion inside a Wankel engine which is adapted to direct injection. The goal of this research is to verify a positive effect on the thermal efficiency by applying direct injection and variation of the injection timing. The Wankel engine is going to be the main power source for the IM01. The main advantage is the possibility for high specific power. Therefore it is ideal for a race car. The main disadvantage of the Wankel engine is the high emission output and low thermal efficiency. This has to be addressed, and will be with this research. A fully operational test stand has already been built to measure anything needed for this research. The deliverables of this project will be an extensive comparison of the test results of direct injection to the combustion behavior with normal port fuel injection, to be able to predict the gains in performance. The behavior with normal injection has already been mapped.

## MSc project "Matching type, configuration and efficiency of various small turbines to a real world automotive application"



**INTRODUCTION** Goal of this research is matching different types of turbine (for example, [figure 1](#)

[\[https://static.tue.nl/fileadmin/content/faculteiten/wtb/Onderzoek/Onderzoeksgroepen/Combustion\\_Technology/figure1.png\]](https://static.tue.nl/fileadmin/content/faculteiten/wtb/Onderzoek/Onderzoeksgroepen/Combustion_Technology/figure1.png)) with wedacs for real world automotive application. Based on previous studies, different turbine maps can be compared to determine a suitable turbine automotive industry. Next the turbine is investigated and experimented, results will be analyzed and the turbine will be improved and further investigated.

**BACKGROUND** Two problems of gasoline powered vehicles are throttle losses and increasing electrical load of new vehicles. Throttle losses reduce engine efficiency at part load and the inefficiently mounted alternator introduces significant losses. A new solution to these problems regarding to throttle losses is Waste Energy Driven Air Conditioning System (WEDACS). A turbine throttles the air and recovers part of the throttle losses. A high speed and high efficiency generator coupled to the turbine converts the recovered energy to electricity. In addition, air cools down over the turbine as a result of expansion. This cool air can cool A/C fluid in a heat exchanger, thereby assisting the A/C compressor. In this way the engine has to produce less power and fuel is saved. Thus far, most effort has been put into increasing the efficiency of a variable geometry turbine (VGT) since it can handle the largest variation of mass flow rate and pressure of all turbines, [figure 1](#). Another type of turbine, however, might be interesting for this application because of its simplicity. Depending on its efficiency at various operation points, an impulse turbine is potentially a better candidate for application in WEDACS.

**EXPERIMENTAL APPARATUS** To reliably test the efficiency, a test rig is developed. The test rig is dedicated to the turbocharger application and consists of a pressure regulator, connected to the turbine and consequently a high flow capacity compressed air grid. For this experiment, a standard Garrett turbocharger is used. The setup is fitted with different thermocouples, pressure- and rotation sensors. see [figure 2](#)

[\[https://static.tue.nl/fileadmin/content/faculteiten/wtb/Onderzoek/Onderzoeksgroepen/Combustion\\_Technology/figure2.png\]](https://static.tue.nl/fileadmin/content/faculteiten/wtb/Onderzoek/Onderzoeksgroepen/Combustion_Technology/figure2.png)

**GRADUATION PROJECT** The goal of the project is to find the optimal turbine for wedacs purposes, based on previous research. Every turbine has different turbine maps, each size is related to other working areas. For wedacs a specific working area is needed, these maps can be normalised to compare one and other. The best fit can be optimized and tested according to various parameters:

Rpm, air leakage gaps, high pressure (HP) stages, low pressure (LP) stages, multiple stages, parallel or serial, BSR, mass flow and pressure ratio (PR).

**Where** Technical University Eindhoven, Mechanical Engineering, Dept. Combustion Technology, Eindhoven

**Type** Experimental project

**How** Design and experiment with radial and axial turbines

**When** starting date negotiable

**Skills** Hands on mentality, experimental interest, matlab for analysing

**Note** Literature study, desinging, experiments, analyzing, conclusion

**Contact** Michel Cuijpers, [m.c.m.cuijpers@tue.nl](mailto:m.c.m.cuijpers@tue.nl)



## MSc project "Mobilising heavy hydrocarbons with Sub Critical Water"

### Technical University Eindhoven, Mechanical Engineering, Dept. Combustion Technology

**subject:** Mobilising heavy hydrocarbons with Sub critical water

**type:** Experimental project

**how:** Implement sample box in set up, which extract sample from the expelled gasflow

**why:** During the depletion of an oil well, approximately 30% crude oil remains behind. The crude oil that remains, has a high viscosity and consequently quite hard to extract from the well. By using sub critical water, the heavy hydrocarbons (crude oil) can be broken down and creating a lower viscosity, during this process it is not clear if there is hydrogen formation. Investigate whether hydrogen is formed during mobilization of heavy hydrocarbons, and if so, is it an interesting extra energy source or is it a problematic occurrence.

**when:** starting date, negotiable.

**keywords:** Heavy oil – Kerogen – Subcritical water – Solution – Cracking - Hydrogen

**first weeks action:**

- literature study, reading into subject
- Assist regular experiments, to learn to use Set-up
- Investigate sample box possibilities, available
- Implement improvement into set up
- Experiments
- Analyses

**skills:** Hands on mentality, experimental interest, matlab for analysing

**Note:** No chemical engineering needed, and also not included in project.

**contact:** Michel Cuijpers, [m.c.m.cuijpers@tue.nl](mailto:m.c.m.cuijpers@tue.nl)



## **Reageren / Contact**

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## Multiphase and Reactive Flows

### MSc project "Thermo-acoustic stability of combustion in central-heating boilers"

#### *Context of the work*

In continuation of the previous work, the problem of noiseless combustion in central heating boilers equipped by premixed burners remains the focus point of the present project. Prediction and elimination of thermo-acoustic instability of combustion is the ultimate target to achieve within the research program.

#### *Description of the assigned work within the student final project*

The flame description via its Transfer Function (TF) should be combined with the boiler description giving the possibility for the prediction of the (in)stability of a burner-with-boiler combination. The principal target of the present R&D phase is to develop a scientific approach to combine relevant acoustic properties of elements of the boiler/burner. Final output of the work is the model of the thermo-acoustic behaviour of the complete boiler. In the next step the modelling will facilitate the selection of an appropriate burner and/or implementation of passive element providing acoustically stable operation of the boiler for the required operational range.

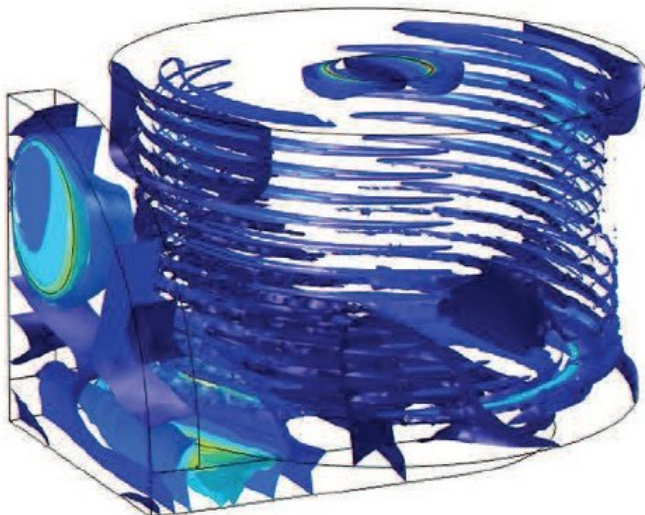
#### *Work package 1: COMSOL modelling of hot boiler parts.*

The finite element modelling (FEM) software COMSOL will be used to model parts of the boiler which have a complicated geometry and/or temperature distribution and cannot be characterised with a simple network modelling approach. The output of the FEM modelling will suggest the corresponding acoustic element Transfer Matrix TM (frequency response) which can be consequently used within the network model (WP 2) of a complete boiler. The correctness of the model will be validated via a comparison with the measured TM at room temperature conditions. Extension to the real working temperature will be done solely via modelling.

#### *Work package 2: Development of acoustic network model of a boiler.*

The data about acoustic properties of all parts or block (assembly) of elements of a boiler will be represented by its transfer matrices. The cumulative boiler acoustic model will be constructed by combining the TM's of all elements into a single closed model. The experimental facility developed earlier, will be used to validate and tune the model parameters using intermediate results/output of the network model.

The method to analyse the boiler network model will be developed aiming to extract information about the boiler stability and if an operation point is unstable to determine the instability frequencies. Next the results of the modelling can be compared with boiler test results conducted at test facility.



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