

Development of a Low-Power Gas Turbine Test Bench for RC-Size Engines
Feasibility Study of ULB as an Energy Hub within a Local Energy
Community Feasibility Study for the Decarbonisation of Heat Supply on
ULB Campuses Pedagogical Integration of Flight Simulators for
Engineering Education Development of a dynamic thermal energy
storage model as a digital twin in a decentralized energy system
Investigation of Coupled CFD Modelling for Microwave Electrification of
Industrial Heating Experimental and OD Modelling Study of Water
Injection in Hydrogen Spark-Ignition Engines for CHP Applications
Development of a Hydrogen–Diesel Dual-Fuel Engine Test Bench and OD
Combustion Model for CHP Applications CFD Modeling of Water Injection
in Hydrogen-Fueled Internal Combustion Engines and Development of a
OD Water Injection Model for CHP Applications Implementation of a
Temperature Control Strategy for CFD-Based Digital Twin of an Industrial
Process Modeling Electric Heating Resistance using multi-physics
approach for industrial implementation Adapted Chemical Reactor
Networks for Fast Combustion Modelling under Variable Operating
Conditions

Program : EM - Energy - M-IREMR-E

Description

Combustion modelling is a central challenge in energy and chemical engineering. Industrial systems such as gas turbines, furnaces, and engines involve strong interactions between fluid dynamics, chemical kinetics, turbulence, and heat transfer. High-fidelity CFD simulations coupled with detailed chemical mechanisms are powerful tools to analyse these systems, but they remain computationally expensive, especially when large reaction mechanisms are considered. This limits their use for parametric studies, design exploration, optimisation, or real-time applications. Reduced-order modelling approaches are therefore needed to retain the main physical and chemical behaviour of reacting flows at a much lower computational cost.

The objective of this master thesis is to investigate adapted Chemical Reactor Networks (CRN) as reduced-order models for combustion systems. A Chemical Reactor Network approximates a complex reacting flow by a set of interconnected ideal reactors, each representing a region of the flow with similar thermochemical properties. In conventional approaches, the network is generated from CFD data for one specific operating condition.

When the operating conditions change, a new CFD simulation is often required to build a new network. This thesis will explore an alternative strategy: reusing a CRN structure obtained from a reference CFD case while modifying only the inlet conditions and operating parameters.

The work will first include a literature review on CRN methods, CFD-based reactor network generation, clustering techniques, and reduced-order modelling for combustion. The student will then generate a CRN from existing CFD data by grouping computational cells into regions with similar thermochemical properties, such as temperature, mixture fraction, residence time, or species concentrations. Each region will be represented as an ideal reactor, and the mass exchanges between regions will define the reactor connectivity. The resulting network will be solved using a chemical kinetics tool such as Cantera.

The main part of the thesis will consist of assessing the robustness of the adapted CRN approach. The student will apply the same reactor network structure to operating conditions different from the reference case, by changing inlet temperature, equivalence ratio, mass flow rate, fuel composition, or other relevant parameters. The CRN predictions will then be compared with reference CFD simulations or experimental data when available. Key quantities may include temperature fields, major species, pollutant formation, heat release, and global combustion efficiency.

The expected outcome is a critical assessment of whether a CRN generated from one CFD case can be reused as a fast predictive tool over a range of operating conditions. The thesis will deliver a literature review, a CFD-to-CRN workflow, a set of adapted CRN simulations, and recommendations on the validity limits and possible improvements of the method. The project requires knowledge of fluid mechanics and thermodynamics, programming skills in Python, and an interest in combustion, CFD, and numerical modelling.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Alessandro Parente (alessandro.parente@ulb.be)

Co-supervisor : Asija Inciardi (asija.inciardi@ulb.be)

Development of a Hydrogen–Diesel Dual-Fuel Engine Test Bench and 0D Combustion Model for CHP Applications

Program : EM - Energy - M-IREMR-E

Description

Hydrogen–diesel dual-fuel engines are a promising solution for improving the efficiency and reducing the carbon intensity of combined heat and power systems. By introducing hydrogen into a conventional diesel engine, it becomes possible to partially substitute fossil fuel while maintaining the robustness, high efficiency, and ignition reliability of diesel combustion. Such systems are particularly relevant for CHP applications, where both mechanical or electrical power and useful heat recovery must be considered. However, hydrogen–diesel operation involves specific combustion challenges, including ignition delay, heat-release control, knock or abnormal combustion risks, NO_x emissions, and the interaction between diesel pilot injection and hydrogen–air combustion.

The objective of this master thesis is to design and implement a dedicated hydrogen–diesel dual-fuel engine test bench within the ULB-ATM laboratory, and to complement this experimental work with the development of a zero-dimensional combustion model. The test bench should enable controlled investigations of combustion behaviour, engine performance, emissions, and heat recovery potential under different operating conditions. The student will first carry out a literature review on hydrogen–diesel dual-fuel combustion, existing experimental setups, safety constraints linked to hydrogen use, and 0D modelling approaches for internal combustion engines.

The main part of the thesis will focus on the design and implementation of the experimental test bench. This will include the definition of the fuel supply architecture, hydrogen injection strategy, diesel operation mode, instrumentation, data acquisition system, safety procedures, and operating protocols. The bench should allow the measurement of relevant quantities such as engine speed, torque or load, fuel consumption, hydrogen flow rate, temperatures, pressures, exhaust composition, and recoverable heat. Particular attention will be paid to safe hydrogen handling, ventilation, leak detection, emergency shutdown, and compatibility with laboratory constraints.

In parallel, the student will develop or adapt a 0D combustion model of the hydrogen–diesel dual-fuel engine. The model should reproduce the main features of the combustion process, including pressure and temperature evolution, ignition delay, heat-release rate, diesel pilot contribution, hydrogen energy fraction, and global engine performance. When experimental data are available, the model will be compared with measurements in order to assess its accuracy and limitations.

The expected outcome is a first experimental and numerical platform for studying hydrogen–diesel dual-fuel engines in CHP conditions. The deliverables will include a literature review, the design and implementation of the test bench, initial experimental

results, a validated or partially validated 0D model, and a preliminary analysis of operating conditions favourable to efficient heat recovery. The thesis will require knowledge of thermodynamics, combustion, heat transfer, and piston engines, as well as programming skills in Python, MATLAB, or a similar environment. Practical skills and the ability to work with the ATM technical team will be important assets.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Cyril Freyling (cyril.freyling@ulb.be)

Experimental and 0D Modelling Study of Water Injection in Hydrogen Spark-Ignition Engines for CHP Applications

Program : EM - Energy - M-IREMR-E

Description

Hydrogen spark-ignition engines are a promising solution for low-carbon combined heat and power applications, where both mechanical or electrical power and useful heat can be produced. However, hydrogen combustion remains challenging because of high combustion temperatures, NO_x emissions, knock, and pre-ignition risks. Water injection is a potential strategy to mitigate these limitations by reducing in-cylinder temperatures and modifying the combustion process. In a CHP context, this temperature control is also important because it affects not only engine efficiency and emissions, but also the amount and quality of recoverable heat.

The objective of this master thesis is to design and implement an experimental setup to study water injection under conditions representative of hydrogen spark-ignition engines. A key question will be to determine whether the injected water enters the engine as liquid droplets, vapour, or a two-phase mixture, depending on injection pressure, temperature, timing, injected quantity, and operating conditions. The student will therefore first carry out a literature review on hydrogen engine combustion, abnormal combustion phenomena, NO_x formation, and water injection strategies in internal combustion engines.

The main part of the thesis will consist of developing a dedicated experimental setup for water injection characterisation. This setup should make it possible to study the evaporation behaviour, droplet dynamics, temperature evolution, and resulting phase of the injected water before its introduction into the engine. Once the methodology has been characterised, the system will be implemented on a real hydrogen spark-ignition engine. Experimental tests will then be used to assess the impact of water injection on combustion behaviour, performance, efficiency, knock tendency, thermal behaviour, and NO_x emissions.

In parallel, the student will develop or adapt a zero-dimensional combustion model of a hydrogen spark-ignition engine including the effects of water injection. The model should account for injected water quantity, evaporation, mixture dilution, temperature reduction, heat-release behaviour, engine performance, and CHP efficiency. When experimental results are available, the model will be compared with measurements in order to assess its validity and limitations.

The expected outcome is a first experimental and numerical framework for analysing water injection in hydrogen spark-ignition engines. The main deliverables will be a literature review, the design and implementation of the water-injection test setup, a first implementation on the hydrogen engine test bench, and a validated or partially validated 0D model. The thesis will require good knowledge of thermodynamics, heat transfer, and

piston engines, as well as programming skills in Python, MATLAB, or a similar environment. Practical skills and the ability to work with the ATM technical team will be important assets.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Cyril Freyling (cyril.freyling@ulb.b)

Development of a dynamic thermal energy storage model as a digital twin in a decentralized energy system

Program : EM - Energy - M-IREMR-E

Description

In an attempt to reduce the impact of climate change on our planet, we are shifting away from fossil fuels toward more renewable energy sources. However, integrating more renewable energy sources, such as solar and wind, comes with its challenges. To maximize the use of energy produced by renewable sources, storage will become increasingly important in energy systems. This makes it possible to use excess energy at later times when necessary and to balance the energy production and demand curves more efficiently. When analyzing energy consumption, after electricity and transportation, heating for space heating and hot water production is a substantial part of our energy needs. An efficient way to meet our electricity and heating needs is to use combined heat and power (CHP) units, such as micro gas turbines (MGT) or internal combustion engines (ICE), where the excess heat from the exhaust gas can be used to heat water for district heating networks (DHN). Oftentimes, electricity production is the main driver in the CHP units, so reliable heat storage is necessary to benefit later. The thesis will focus on developing a dynamic model of thermal energy storage (TES) that accounts for thermal inertia. This model can then be used as a digital twin, an accurate but fast model that receives information from the physical system and can be used for real-time optimization. The TES can be implemented in an energy system that needs to be optimized to ensure that the available power and heat match demand, and it can also be used to reduce fossil fuel emissions or utilization costs. The modeling, optimization, and control of the energy system can be used to predict our ideal energy generation mix and also allow us to adapt our plan in case of disturbances, e.g., more clouds than expected, which reduces available solar energy.

First, the student conducts an extensive literature review on thermal energy storage and examines how it is modeled to balance accuracy and computational speed. Once the student has developed an idea for this model, it will be implemented in Python. During this phase, different methods can be explored and compared to results in the literature. The thermal energy storage model will be integrated into an available district heating network model. The control system will be developed to demonstrate its use in optimizing the heating network.

The student does not need any prior knowledge of energy systems or thermal energy storage, but should be interested in learning. As this project will mainly consist of programming, basic knowledge of Python is required.

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| Language | EN (english) |
| Open to other master's programs | Yes |

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| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Zoraida Nti (zoraida.nti@ulb.be)

Feasibility Study for the Decarbonisation of Heat Supply on ULB Campuses

Program : EM - Energy - M-IREMR-E

Description

The objective of this master thesis is to perform a first feasibility study on the decarbonisation of heat supply on ULB campuses, in close collaboration with the ULB cellule énergie. At present, the university's heat demand is mainly covered by natural gas boilers using CH₄. The aim of the thesis is to assess possible pathways to reduce or eliminate fossil fuel use for heating, while taking into account the technical, economic, operational, and spatial constraints of university campuses.

The work will first consist of characterising the current heat demand and heat production infrastructure. The student will analyse available data on gas consumption, heating networks, boiler rooms, building uses, occupancy patterns, temperature levels, and seasonal demand profiles. Particular attention will be paid to the distinction between peak heat demand, annual heat consumption, supply temperatures, and the flexibility of the buildings, since these elements strongly influence the feasibility of low-carbon heating solutions.

The student will then identify and compare a broad range of decarbonisation options. These may include heat pumps, geothermal energy, shallow geothermal storage, connection to existing or future district heating networks, heat recovery from local sources, solar thermal systems, biomass where relevant, hybrid systems combining gas and low-carbon technologies, and progressive electrification strategies. The analysis should also consider demand-side measures, such as reducing supply temperatures, improving control strategies, exploiting thermal inertia, and prioritising building-level efficiency improvements when they enable more efficient low-carbon heat production.

A simplified modelling framework will then be developed to compare several transition scenarios. These may include a reference scenario based on the current CH₄ supply, partial electrification through heat pumps, geothermal-assisted heating, hybrid systems for peak demand, and more integrated campus-scale solutions combining storage, heat recovery, and demand management. The comparison should estimate key indicators such as energy consumption, fossil fuel reduction, CO₂ emissions, peak electrical power, seasonal performance, investment cost, operating cost, spatial requirements, implementation complexity, and robustness of supply.

Finally, the thesis will address practical aspects in collaboration with the ULB cellule énergie. This includes data availability, technical constraints in existing buildings, compatibility with current heating networks, regulatory aspects, phasing of investments, and the identification of priority sites or pilot projects. The expected outcome is a structured feasibility report assessing which decarbonisation pathways are most promising for ULB campuses, under which conditions they could be implemented, and what further

studies would be required. The work will provide quantitative first estimates and a roadmap toward a progressive reduction of CH₄-based heating on campus.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Feasibility Study of ULB as an Energy Hub within a Local Energy Community

Program : EM - Energy - M-IREMR-E

Description

The objective of this master thesis is to perform a first feasibility study on the potential role of ULB as an energy hub within a local energy community, at the scale of the urban block or neighbourhood surrounding the university campus. The project will be carried out in close interaction with the ULB cellule énergie, with the aim of evaluating how the university's buildings, energy infrastructure, consumption profiles, and potential local production assets could contribute to a collective energy strategy.

The work will focus on identifying the technical potential for ULB to act as a local energy hub. This includes assessing opportunities for photovoltaic production, demand-side management, heat recovery, battery or thermal storage, electric vehicle charging, and possible interactions with neighbouring buildings or users. The analysis should consider both electrical and thermal energy flows, and evaluate whether coupling these vectors could bring additional value at neighbourhood scale.

The student will then develop a simplified modelling framework to compare several energy-community scenarios. These may include a reference case without energy sharing, a scenario with increased local renewable production, a scenario including flexible loads or storage, and a more integrated energy-hub scenario. The model should estimate key indicators such as self-consumption, self-sufficiency, peak power reduction, CO₂ emissions, energy costs, and possible benefits for participating users. The level of modelling will remain compatible with a first feasibility study, while being sufficiently detailed to support concrete recommendations.

Finally, the thesis will address practical and organisational aspects in collaboration with the ULB cellule énergie. This may include data availability, regulatory constraints, metering requirements, governance models, and the identification of priority actions for a future demonstrator. The expected outcome is a structured feasibility report assessing whether, and under which conditions, ULB could become a central actor in a local energy community. The work will provide both quantitative first estimates and a roadmap for further technical, economic, and institutional development.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Modelling of a hybrid hydrogen PEMFC / Heat Pump micro combined heat and power system

Program : EM - Energy - M-IREMR-E

Description

Combined heat and power systems (CHP) based on hydrogen fuelled PEMFCs (Proton Exchange Membrane Fuel Cells) present an attractive solution for decentralized, low carbon heat and power production. Its global efficiency can reach up to 85%, but as a standalone system, it cannot cover large space heating demands during cold seasons due to the limited heat production that is retrieved from the PEMFC cooling system. Therefore, a novel idea consists in investigating a system in which a PEMFC exclusively powers an air-source heat pump (ASHP), forming a tightly coupled, grid-independent heating unit, and leveraging its high coefficient of performance in the process.

The master's thesis will consist of developing the digital twin of an experimental facility investigating the performance of such CHP system. Particular care will be taken on modelling the stratified domestic water tank and sizing the air-source heat pump to guarantee that the whole CHP system satisfies energy demands throughout the year.

The student will also investigate the behaviour of a sized PEMFC-HP system deployed as a CHP unit within a residential energy community, and to determine which cases favour the use of a PEMFC-HP system (with regards to hydrogen supply cost, electricity tariffs, community demand profiles, and climate) offers advantages over competing alternatives.

Prerequisites:

- Interest in sustainability and renewable energy
- Programming in Python and/or MATLAB
- Background in electrical engineering, thermodynamics, energy systems, or building technologies

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| Language | EN (english) |
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Patrick Hendrick (patrick.hendrick@ulb.be)

Co-supervisor : Bilal Outirba (bilal.outirba@ulb.be)

Analysis of Heat and Mass Transport During Hydrogen Bubble Growth in Water Electrolysis

Program : EM - Energy - M-IREMR-E

Description

Hydrogen can be produced by splitting water through electrochemical reactions in electrolysis. Although the process is overall endothermic, additional heat can be generated locally, most notably through Joule heating at the electrode surface. This localized heating modifies the temperature field near the growing hydrogen bubble, creating temperature gradients that induce thermocapillary (Marangoni) flows along the bubble interface. In addition to thermal effects, concentration gradients of surface active species such as ions or dissolved gases can also alter surface tension, resulting in solutal Marangoni convection. These interfacial flows strongly affect bubble growth, shape, and detachment dynamics. Understanding these coupled effects requires the ability to accurately resolve the local temperature and concentration fields around the bubble. However, measuring both fields at the same time remains a significant experimental challenge.

Previous studies have demonstrated that at high applied potentials, Joule heating dominates, and thermocapillary effects become the primary drivers of interfacial motion, while solutal effects can often be neglected. Various optical techniques such as Schlieren imaging, laser induced fluorescence, and interferometry have been used to study these fields.

Mach Zehnder interferometry stands out as a noninvasive and calibration free technique for resolving instantaneous temperature fields with high sensitivity.

This thesis will focus on hydrogen bubble dynamics on a microelectrode in acidic electrolysis, using two complementary experimental techniques:

- Mach Zehnder Interferometry, to quantify the temperature field near the electrode and at the base of the bubble, especially when concentration variations are negligible.
- High speed visualization, to qualitatively capture the bubble inception, growth, and detachment processes.
- Complementary Schlieren imaging may be used for qualitative validation as done in the previous study [1].

Methodology

1. Literature survey

The student will begin by familiarising themselves with the topic. A thorough review of recent literature, especially on interferometric and visualisation techniques applied to gas-evolving electrodes, will help define the research scope and objectives.

2. Experimental set-up

The student will work with the existing electrolysis cell, Mach Zehnder interferometer, and high-speed imaging system available at the TIPS laboratory. This phase will involve hands-on training with laser alignment, optical adjustments, electrode handling, and system calibration. The student will also participate in test runs to optimise measurement conditions and gain confidence in operating the setup independently.

3. Measurement campaign and data analysis

The student will conduct experiments to visualise hydrogen bubble growth on microelectrodes using high-speed imaging and Mach Zehnder interferometry. Interferometric data will be analysed to extract local temperature fields, while high-speed recordings will be used to characterise bubble shape, growth, and detachment dynamics. Post-processing and analysis will be carried out using MATLAB. If numerical simulation results are available, they will be compared with the experimental data. In parallel, the student will measure the refractive index, density, and viscosity of the electrolyte across different concentrations and temperatures, using the available facilities at the TIPs laboratory, ULB.

4. Reporting

☐ Weekly meetings with the supervisor to define tasks and discuss outcomes and practicalities.

☐ Monthly meeting with the team and the promotor to verify the progress and discuss follow-up

☐ Final presentation

References

[1]. A. Babich, A. Bashkatov, X. Yang, G. Mutschke, and K. Eckert, "In-situ measurements of temperature field and Marangoni convection at hydrogen bubbles using schlieren and PTV techniques," *Int. J. Heat Mass Transf.*, vol. 215, p. 124466, 2023.

[2]. J. Massing, G. Mutschke, D. Baczymalski, S. S. Hossain, X. Yang, K. Eckert, and C. Cierpka, "Thermocapillary convection during hydrogen evolution at microelectrodes," *Electrochimica Acta*, vol. 297, pp. 929–940, 2019.

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| Language | EN (english) |
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Pierre Colinet (pierre.colinet@ulb.be)

Co-supervisor : Senthil Kumar Parimalanathan (senthil.parimalanathan@ulb.be)

Topics offered to students by other
master's programs

TARGET PROGRAM

EM – ENERGY Engineering

Analysis of Heat and Mass Transport During Hydrogen Bubble Growth in Water Electrolysis

Program : Chemical & Materials engineering - M-IRMAE

Description

Hydrogen can be produced by splitting water through electrochemical reactions in electrolysis. Although the process is overall endothermic, additional heat can be generated locally, most notably through Joule heating at the electrode surface. This localized heating modifies the temperature field near the growing hydrogen bubble, creating temperature gradients that induce thermocapillary (Marangoni) flows along the bubble interface.

In addition to thermal effects, concentration gradients of surface active species such as ions or dissolved gases can also alter surface tension, resulting in solutal Marangoni convection. These interfacial flows strongly affect bubble growth, shape, and detachment dynamics. Understanding these coupled effects requires the ability to accurately resolve the local temperature and concentration fields around the bubble. However, measuring both fields at the same time remains a significant experimental challenge.

Previous studies have demonstrated that at high applied potentials, Joule heating dominates, and thermocapillary effects become the primary drivers of interfacial motion, while solutal effects can often be neglected. Various optical techniques such as Schlieren imaging, laser induced fluorescence, and interferometry have been used to study these fields.

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- High speed visualization, to qualitatively capture the bubble inception, growth, and detachment processes.
- Complementary Schlieren imaging may be used for qualitative validation as done in the previous study [1].

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4. Reporting

- ☐ Weekly meetings with the supervisor(s) to define tasks and discuss outcomes and practicalities.
- ☐ Monthly meeting with the team to verify the progress and discuss follow-up
- ☐ Final presentation

References

- [1]. A. Babich, A. Bashkatov, X. Yang, G. Mutschke, and K. Eckert, "In-situ measurements of temperature field and Marangoni convection at hydrogen bubbles using schlieren and PTV techniques," *Int. J. Heat Mass Transf.*, vol. 215, p. 124466, 2023.
- [2]. J. Massing, G. Mutschke, D. Baczymalski, S. S. Hossain, X. Yang, K. Eckert, and C. Cierpka, "Thermocapillary convection during hydrogen evolution at microelectrodes," *Electrochimica Acta*, vol. 297, pp. 929–940, 2019.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRARE, M-IRCBS, M-IRCNE, M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Number of topics | 2 |

Supervision

Supervisor : Pierre Colinet (pierre.colinet@ulb.be)

Co-supervisor : Senthil Kumar Parimalanathan (senthil.parimalanathan@ulb.be)

Design and development of advanced drones for water quality assessment.

Program : Electrical engineering - M-IRELE

Description

This thesis develops further on previous theses in which drones have been developed for water quality assessment. Two types of drones have been developed. An aerial drone and a vessel based drone. For students from EM, this thesis will be about the optimisation of the drones and the development of algorithmq for energy optimised way point planning. For students from electric engineering and computerscience the focus will be on the development of algorithms for fleet management and multi-drone co-operative measurement campaigns.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 2 |

Supervision

Supervisor : Abdellah Touhafi (abdellah.touhafi@gmail.com)

Modeling Electric Heating Resistance using multi-physics approach for industrial implementation

Program : EM - Aeronautics - M-IREMR-A

Description

Electric heating elements are widely used in high-temperature industrial processes because they can deliver controlled thermal energy without direct combustion. However, these components operate under severe conditions, where electrical, thermal, and mechanical phenomena are strongly coupled. Current flowing through the resistance generates Joule heating, which leads to high temperature gradients, thermal expansion, deformation, and mechanical stresses. In some configurations, electromagnetic forces may also contribute to displacement or instability. A predictive understanding of these coupled effects is therefore essential to improve performance, reliability, lifetime, and safety in industrial applications.

The objective of this master thesis is to improve an existing multiphysics model of electric heating resistances. The model will combine electromagnetic modelling, Joule heating, heat transfer, thermal expansion, and mechanical stress analysis. The aim is to simulate how operating conditions, geometrical configurations, and material properties influence the deformation and potential failure of heating elements under realistic industrial loads. Particular attention will be paid to high-temperature materials such as molybdenum or industrial resistance materials, using appropriate temperature-dependent properties when available.

The thesis will first include a literature review on multiphysics modelling strategies for electrically heated components and on the main industrial challenges associated with high-temperature electric heating. The student will then work on the improvement of the existing numerical model, using ANSYS or an equivalent simulation platform. This will involve coupling the electromagnetic problem, including current distribution and possibly Lorentz forces, with the thermal problem through Joule heat generation, and with the mechanical problem through thermal expansion and stress analysis.

The improved model will then be used to simulate representative operating scenarios. The student will analyse the effect of current intensity, resistance geometry, boundary conditions, material properties, and symmetrical or asymmetrical configurations on temperature fields, electromagnetic forces, deformation, and stress levels. These simulations will help identify critical situations that may lead to excessive deformation, contact between components, local overheating, breakage, or mechanical instability.

The expected outcome is a validated or critically assessed multiphysics modelling framework for high-temperature electric heating elements. The thesis should provide a clearer understanding of the mechanisms leading to deformation or failure, as well as practical recommendations for safer and more efficient design and operation. The deliverables will include a literature review, an improved numerical model, a parametric analysis of operating conditions, and design guidelines

concerning resistance geometry, power control strategies, material selection, and industrial implementation.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Jetnis Avdijaj (jetnis.avdijaj@ulb.be)

Implementation of a Temperature Control Strategy for CFD-Based Digital Twin of an Industrial Process

Program : EM - Aeronautics - M-IREMR-A

Description

Industrial thermal processes require precise temperature regulation to ensure product quality, energy efficiency, operational stability, and safety. In the context of digitalisation and decarbonisation, digital twins are becoming important tools to predict system behaviour, evaluate operating strategies, and support process optimisation. However, high-fidelity CFD models are often used mainly for offline analysis and are rarely coupled with dynamic control strategies. Adding control capabilities to such models is therefore an important step toward predictive and controllable virtual representations of industrial systems.

The objective of this master thesis is to develop and implement a temperature regulation system for an existing CFD model of an industrial thermal process. The aim is to move from a purely predictive CFD simulation toward a controlled numerical environment, where boundary conditions or operating parameters can be adjusted dynamically in order to reach and maintain a target temperature. This work will contribute to the development of a digital twin framework by combining physics-based modelling, control algorithms, and simulation outputs that can be exploited for future real-time or near-real-time applications.

The thesis will first include a literature review on temperature control strategies for thermal systems, including PID control, advanced control approaches, and model predictive control. The student will also review digital twin architectures for industrial processes and existing methods for integrating control loops with CFD environments such as ANSYS Fluent. Particular attention will be paid to the practical constraints associated with coupling a CFD solver and an external controller, including data exchange, time stepping, numerical stability, and computational cost.

The main part of the thesis will consist of designing and implementing a control strategy for the selected CFD model. Depending on the case study, the controller may act on inlet temperature, mass flow rate, heating power, wall heat flux, or another relevant operating variable. The control algorithm will be coupled to the CFD simulation and tested under different operating scenarios, such as changes in heat demand, disturbances, set-point variations, or modified boundary conditions. The control performance will be assessed in terms of response time, overshoot, stability, robustness, and ability to maintain the desired temperature distribution.

Finally, the thesis will analyse how the controlled CFD model can support the development of a digital twin. This includes identifying which simulation outputs are relevant for monitoring and decision support, what level of model reduction or acceleration may be required, and how control parameters can be optimised for robust operation. The expected outcome is a working control-oriented CFD framework, a critical assessment of its performance and limitations, and recommendations for future integration into an industrial digital twin platform.

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|---------------------------------|--|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Jetnis Avdijaj (jetnis.avdijaj@ulb.be)

CFD Modeling of Water Injection in Hydrogen-Fueled Internal Combustion Engines and Development of a 0D Water Injection Model for CHP Applications

Program : EM - Aeronautics - M-IREMR-A

Description

Hydrogen-fuelled internal combustion engines are a promising solution for low-carbon combined heat and power applications, where both useful mechanical or electrical power and recoverable heat can be produced. However, hydrogen combustion presents several challenges, including high in-cylinder temperatures, NO_x emissions, knock, and pre-ignition risks. Water injection is a potential strategy to mitigate these issues by reducing combustion temperatures and influencing mixture formation, evaporation processes, and combustion behaviour. In a CHP context, understanding these effects is particularly important because water injection may affect not only engine efficiency and emissions, but also the thermal balance and heat recovery potential of the system.

The objective of this master thesis is to develop a CFD model to study water injection in a hydrogen spark-ignition engine. The model will be used to analyse the evaporation process, droplet behaviour, vapour distribution, and the effect of water injection on in-cylinder temperature and combustion characteristics. The thesis will first include a literature review on hydrogen combustion in spark-ignition engines, water injection strategies, spray evaporation, two-phase flow modelling, and CFD approaches relevant to hydrogen-fuelled engines.

The main part of the thesis will consist of building a numerical CFD model of the engine configuration. Depending on the available data and geometry, the model may focus on the intake system, the combustion chamber, or a simplified representative domain. It should include the hydrogen-air mixture, the water injection system, and the relevant heat and mass transfer phenomena. Particular attention will be paid to the physical state of the injected water under different operating conditions, in order to determine whether it remains as liquid droplets, evaporates into vapour, or forms a two-phase mixture. The influence of injection timing, injected mass, droplet size, pressure, temperature, and flow conditions will be analysed.

The CFD model will then be used to investigate how water injection affects hydrogen combustion. The student will study its influence on in-cylinder temperature, mixture dilution, heat-release behaviour, thermal gradients, knock tendency, and NO_x-related temperature reduction. These results will help identify the main mechanisms through which water injection can improve or degrade engine performance in CHP-relevant operating conditions.

Finally, the CFD results will support the development of a simplified zero-dimensional model of water injection for hydrogen engines. This 0D model should reproduce the main effects of evaporation, temperature reduction, mixture dilution, and combustion modification, while remaining suitable for fast parametric studies or future system-level CHP simulations. The expected outcome is a CFD-based understanding of water injection in hydrogen spark-ignition engines, together with a first reduced-order modelling approach that can be reused in further experimental or numerical work.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Cyril Freyling (cyril.freyling@ulb.be)

Investigation of Coupled CFD Modelling for Microwave Electrification of Industrial Heating

Program : EM - Aeronautics - M-IREMR-A

Description

The objective of this master thesis is to investigate coupled modelling strategies in CFD for the study of microwave electrification applied to industrial heating processes. The work is positioned in the context of the E-HEAT proposal and, more broadly, of industrial heat decarbonisation, where replacing fossil-fuel-based heating by electrified technologies requires reliable numerical tools. The focus of the thesis is therefore not to design a complete microwave heating system, but to explore how electromagnetic energy deposition can be coupled with heat transfer and fluid-flow models in a CFD environment.

The thesis will first consist of reviewing the physical phenomena and numerical approaches involved in microwave heating. The student will analyse how microwave radiation interacts with materials, how electromagnetic power is absorbed, and how this absorbed power can be represented as a volumetric heat source in a CFD model. Particular attention will be paid to the coupling between electromagnetic fields, temperature-dependent material properties, heat conduction, convection, radiation, and possible flow effects. The objective is to identify the main modelling assumptions, coupling strategies, and numerical difficulties associated with such multiphysics simulations.

The student will then develop and test one or several simplified coupled CFD models on a representative configuration. Depending on the chosen level of complexity, the electromagnetic field may be represented through an imposed power deposition profile, a simplified analytical model, or a coupling with an external electromagnetic solver. This source term will then be integrated into a CFD model solving the thermal and, where relevant, fluid-flow problem. The work should compare different coupling levels, from weak one-way coupling to more advanced approaches where the temperature field modifies the material properties and therefore the absorbed microwave power.

A parametric study will be carried out to assess the sensitivity of the coupled model to key assumptions and input parameters. These may include microwave power, spatial distribution of the heat source, dielectric properties, temperature dependence of material parameters, geometry, boundary conditions, flow rate, and thermal losses.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Pedagogical Integration of Flight Simulators for Engineering Education

Program : EM - Aeronautics - M-IREMR-A

Description

The project will focus on transforming the existing simulators into structured teaching platforms, allowing students to connect theoretical notions of flight mechanics, aircraft performance, stability, control, and aircraft design with hands-on simulation activities.

The work will first consist of analysing the current state of the simulator infrastructure. This includes the hardware configuration, cockpit interfaces, flight simulation software, available aircraft models, visualisation systems, data extraction possibilities, and operational limitations. The student will identify what remains to be completed or improved in order to obtain a robust, repeatable, and easy-to-use laboratory setup. Particular attention will be paid to usability, reliability, documentation, and the ability to run exercises with groups of students in a teaching context.

A second part of the thesis will focus on the integration of the OAD software environment. OAD presents its tools as covering the aircraft development process from conceptual design to flight-test analysis, with applications including aircraft design, UAV/aircraft optimisation, and flight performance analysis. The objective will be to investigate how such tools can be combined with the flight simulators in order to create a coherent workflow: from preliminary aircraft design and performance estimation to simulation-based evaluation of flight behaviour.

The student will then design a first set of pedagogical activities for engineering students. These activities may address topics such as take-off and landing performance, climb rate, stall behaviour, static and dynamic stability, control response, flight envelope exploration, and the influence of aircraft design parameters on flight performance. The aim is not only to provide demonstrations, but to build laboratory sessions in which students formulate hypotheses, run simulations, collect data, analyse results, and compare them with theoretical models.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@hotmail.com)

Development of a Low-Power Gas Turbine Test Bench for RC-Size Engines

Program : EM - Aeronautics - M-IREMR-A

Description

The objective of this master thesis is to carry out the preliminary study, design, and first implementation of a low-power gas turbine test bench based on RC-size turbojet engines. The bench is intended for use in engineering laboratory sessions, where students will be able to observe and analyse the operation of a real gas turbine in a safe, compact, and didactic environment. Although RC-size engines are small, they reproduce the essential features of gas turbine operation: air compression, combustion, turbine expansion, exhaust acceleration, transient behaviour, thermal constraints, and fuel consumption. They therefore provide an attractive and affordable platform for hands-on teaching in propulsion, turbomachinery, energy conversion, and experimental methods.

The thesis will first consist of a pre-study phase. The student will analyse the technical, pedagogical, and safety requirements of such a bench. This includes identifying the type and size of engine to be used, the expected thrust and thermal loads, the constraints linked to indoor or semi-indoor operation, noise levels, exhaust management, fuel storage, and safety procedures. A review of existing educational gas turbine benches and RC turbine test setups will be carried out in order to define a realistic concept adapted to university laboratory use.

Based on this analysis, the student will develop the mechanical and functional design of the test bench. This will include the design of the supporting structure, engine mounting system, thrust measurement arrangement, protective shielding, access to the engine for maintenance, fuel system integration, and space for future instrumentation. The work will involve producing technical drawings and CAD models, selecting suitable components, defining a bill of materials, and justifying the main design choices in terms of safety, robustness, cost, ease of use, and pedagogical value.

A key objective of the thesis will then be to manufacture or assemble a first version of the bench. Depending on the progress of the project, this prototype should allow the safe installation of the engine and prepare the bench for future experimental campaigns. Particular attention will be paid to modularity, so that additional sensors such as thermocouples, pressure probes, fuel flow meters, load cells, vibration sensors, or data acquisition systems can be integrated in later stages.

The expected outcome is a complete pre-design study and a first operational or partially operational prototype of a gas turbine laboratory bench. The deliverables will include the technical specifications, CAD drawings, component selection, assembly documentation, safety analysis, and recommendations for future instrumentation and laboratory exercises. This thesis is therefore mainly an engineering design and development project, with a strong practical dimension and a clear teaching objective

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| Language | EN (english) |
| Open to other master's programs | Yes |

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| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Topics offered to students by other
master's programs

TARGET PROGRAM

EM – ENERGY Engineering

Propagating Site Wind-Climate Uncertainty to Wind Turbine Loads

Program : EM - Aeronautics - M-IREMR-A

Description

See document below for context and work description

Link : https://vub-my.sharepoint.com/personal/goncalo_granjal_cruz_vub_be/_layouts/15/onedrive.aspx?id=%2Fpersonal%2Fgoncalo%5Fgranjal%5Fcruz%5Fvub%5Fbe%2FDocuments%2FMaster%20thesis%20topics%2F2026%2D2027%2FXX%5FFLOW%5FMSc%5FUncTurbineLoads%2FXX%5FFLOW%5FMSc%5FUncTurbineLoads%2Epdf&parent=%2Fpersonal%2Fgoncalo%5Fgranjal%5Fcruz%5Fvub%5Fbe%2FDocuments%2FMaster%20thesis%20topics%2F2026%2D2027%2FXX%5FFLOW%5FMSc%5FUncTurbineLoads&ga=1

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E |
| Number of topics | 1 |

Supervision

Supervisor

Mark Runacres (Mark.Runacres@vub.be)

Co-supervisor

Gonçalo Granjal Cruz (goncalo.granjal.cruz@vub.be)

Material Screening for Laser-Ablation Micropropulsion Using a Torsional Pendulum Thrust Balance

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to experimentally compare candidate materials for laser-ablation micropropulsion using a torsional pendulum thrust or impulse balance. Laser propulsion refers to concepts in which laser radiation transfers momentum to a spacecraft or target. In laser-ablation propulsion, laser energy is absorbed by a material surface, causing rapid heating, vaporization, plasma formation, or material ejection. The recoil from the ejected material produces a small impulse, making this approach relevant for micropropulsion, attitude control, precision positioning, and possibly remote momentum transfer to small objects or debris.

The work will build on an existing torsional pendulum setup previously developed for laser-propulsion studies. The main objective is to determine how material properties such as composition, rigidity, porosity, optical absorption, surface roughness, and internal structure influence the impulse generated by pulsed laser ablation. The student will first review the principles of laser propulsion, pulsed laser ablation, micropropulsion, and impulse measurement, with attention to key quantities such as impulse bit, momentum coupling coefficient, laser fluence, ablation threshold, repeatability, and surface degradation.

Experimentally, small material samples will be mounted on the torsional pendulum and irradiated by a laser under controlled conditions. The recoil impulse produced by each laser pulse will induce an angular displacement or oscillation, from which the impulse can be estimated using the pendulum calibration, geometry, torsional stiffness, damping, and moment of inertia. The first phase will focus on calibration and validation of the measurement system, including sensitivity, noise floor, repeatability, damping behaviour, and uncertainty.

The second phase will test standard reference materials such as aluminium, copper, graphite, polymers, black coatings, adhesive tapes, or commercial absorptive films. These results will provide baseline data on how optical absorption, thermal conductivity, melting or vaporization behaviour, and surface morphology affect impulse generation. A third phase will investigate custom or engineered materials, such as porous materials, composites with carbon or metallic fillers, multilayer coatings, polymer matrices, foams, aerogels, or surface-treated samples. Laser parameters such as pulse energy, spot size, repetition rate, incidence angle, number of pulses, and target position will be controlled as carefully as possible.

The analysis will compare impulse bit, impulse as a function of laser energy or fluence, estimated momentum coupling coefficient, repeatability over multiple shots, and surface degradation after irradiation. The expected outcome is a calibrated comparative assessment of materials for laser-ablation micropropulsion. The thesis should rank candidate materials according to propulsion-

relevant performance metrics and provide recommendations for future vacuum-compatible laser-propulsion experiments.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRMAE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Calibration of colour-changing hygroscopic materials for water detection in lunar-regolith simulants

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to experimentally assess whether colour-changing hygroscopic materials can be used as simple indicators for detecting and semi-quantifying water in sand or lunar-regolith simulants. The detection of water on the Moon is a major challenge for future exploration, as water may occur as adsorbed molecules, hydroxyl groups, frost, ice grains, or concentrated deposits in permanently shadowed regions. While advanced instruments such as infrared spectrometers, neutron detectors, mass spectrometers, and thermal analysis systems can provide detailed measurements, there is also interest in developing simple, low-cost, robust indicators capable of giving rapid evidence of water or humidity in contact with granular materials.

The work will focus on humidity-sensitive materials that change colour when they absorb or adsorb water, such as silica-gel-based indicators, cobalt-free humidity cards, functional salts, porous films, or humidity-sensitive polymers. The student will first review lunar water detection, regolith properties, hygroscopic materials, and colourimetric sensing. Particular attention will be paid to clarifying what such indicators can detect, since colour-change materials are mainly sensitive to available molecular water or vapour-phase humidity, and not necessarily to chemically bound hydroxyl groups.

The experimental work will consist in preparing sand or lunar-regolith simulant samples with controlled water contents, introduced gravimetrically by adding known masses of water to dry granular material. Candidate indicator materials will then be exposed to these samples under reproducible conditions, for example in direct contact with the grains, partially buried in the medium, placed in the headspace of a sealed vial, or separated by a porous membrane. These configurations will help determine whether the response is driven by liquid contact, vapour-phase humidity, or local moisture gradients.

Colour changes will be recorded over time using photography, scanning, or a simple optical imaging setup under controlled lighting. Quantitative image analysis will be used to extract RGB, HSV, or CIELAB colour parameters and generate calibration curves relating colour response to known water content. The analysis will also evaluate response time, sensitivity, repeatability, reversibility after drying, and detection limit. Additional tests may examine the influence of grain size, porosity, mineral composition, sample geometry, temperature, and equilibration time.

The expected outcome is a calibrated proof-of-concept assessment of colour-changing hygroscopic materials for water detection in regolith-like media. The thesis should determine whether this approach is suitable for qualitative detection, semi-quantitative estimation, or only laboratory screening, and provide recommendations for future development of simple regolith-contact water indicators for lunar exploration.

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|---------------------------------|---------------------------------|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Electromagnetic Shielding Properties of Standard and Custom Materials from 100 MHz to 10 GHz

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to develop and validate a practical experimental methodology for comparing the electromagnetic shielding performance of standard and custom materials in the 100 MHz–10 GHz frequency range. Electromagnetic shielding is increasingly important in aerospace systems, electronics, telecommunications, biomedical devices, sensor platforms, and space instrumentation, where sensitive components must be protected from external electromagnetic interference while limiting unwanted emissions. Classical metallic shielding solutions can be highly effective, but they are often heavy, rigid, or difficult to integrate into multifunctional structures.

The work will explore alternative shielding materials whose performance can be tuned through composition, thickness, porosity, rigidity, conductivity, magnetic response, or internal structure. Examples include conductive polymer composites, carbon-loaded elastomers, metallized textiles, porous conductive foams, graphene- or carbon-black-based films, magnetic particle composites, and multilayer hybrid materials. The laboratory has access to a vector network analyser and two probes covering approximately 100 MHz to 10 GHz, which will be used to establish a comparative testing platform.

The student will first review the principles of electromagnetic shielding, including reflection, absorption, multiple internal reflections, conductivity, magnetic permeability, skin depth, and frequency-dependent attenuation. The experimental work will then focus on defining a repeatable measurement protocol in which a material sample is placed between or near transmitting and receiving probes. Measurements with and without the sample will be used to estimate attenuation as a function of frequency, for example through relative changes in transmission parameters such as S_{21} . Particular attention will be paid to calibration, probe positioning, sample size, edge leakage, distance between probes, background noise, environmental reflections, and repeatability.

Reference materials such as aluminium foil, copper foil, stainless-steel mesh, conductive tape, metallized films, carbon-loaded sheets, ferrite-containing materials, or commercial EMI shielding fabrics will first be tested to establish baseline behaviour. Custom materials will then be fabricated or selected with controlled variations in composition, filler content, thickness, porosity, rigidity, and multilayer structure. The analysis will compare frequency-dependent attenuation curves and assess how material parameters influence shielding performance. Where possible, results may also be normalized by thickness or areal density to evaluate lightweight shielding efficiency.

The expected outcome is a validated laboratory-scale methodology for screening electromagnetic shielding materials. The thesis should identify promising material families, quantify the influence of composition and structure on attenuation, and clarify the limitations of the probe-based setup compared with standardized certification methods. It should also provide recommendations for

improving the platform, for example through a dedicated sample holder, shielding box, coaxial fixture, absorber-lined enclosure, or free-space measurement geometry.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Torsional Pendulum Micro-Thrust Balance for Electrospray Propulsion

Preparation

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to adapt and validate a torsional pendulum thrust-balance setup for the measurement of very small forces relevant to electrospray propulsion. Electrospray propulsion is a promising micropropulsion technology for CubeSats, small satellites, precision attitude control, drag compensation, and formation flying. It relies on the electrostatic acceleration of charged droplets, ions, or ion-droplet mixtures emitted from a conductive liquid under a strong electric field. Although the resulting thrust is typically in the micro-newton or sub-micro-newton range, it can be highly controllable and efficient, making it attractive for precision space applications.

A key experimental challenge is the reliable measurement of such small forces. Before developing a complete electrospray thruster, the laboratory needs a calibrated micro-thrust measurement platform. The work will therefore build on an existing torsional pendulum previously developed for laser propulsion studies and assess whether it can be adapted to electrospray-relevant force ranges. The thesis will focus on the measurement principle, calibration strategy, sensitivity, noise sources, and compatibility with future high-voltage operation.

The student will first review electrospray propulsion, Taylor cone formation, electrohydrodynamic emission, charged-particle acceleration, and micro-thrust measurement techniques. The experimental work will then consist in analysing the existing pendulum design and identifying the required modifications in terms of arm length, torsional stiffness, moment of inertia, damping, mechanical stability, displacement readout, electrical isolation, and future integration of a high-voltage emitter.

The first experimental phase will focus on calibration without electrospray operation. Known small forces may be applied using calibrated masses, electrostatic or magnetic forces, controlled mechanical displacement, or another suitable method. The system will be characterized in terms of linearity, sensitivity, minimum detectable force, response time, noise floor, drift, and repeatability. A second phase will investigate artefacts such as air currents, vibrations, acoustic noise, cable stiffness, electrostatic coupling, thermal drift, and mechanical hysteresis, with possible mitigation through shielding, damping, improved mounting, optical readout, or signal filtering.

The expected outcome is a calibrated and experimentally characterized torsional pendulum micro-thrust balance suitable as a foundation for future electrospray propulsion experiments. The thesis should determine whether the setup can reach electrospray-relevant force levels, identify the dominant limitations, and provide design recommendations for later integration with a high-voltage electrospray emitter and, eventually, a vacuum-compatible thrust-measurement platform.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Visibility of quantum dots under solar excitation

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to assess whether quantum dot fluorescence can be detected or visually observed under solar or solar-like excitation. Quantum dots are semiconductor nanocrystals with size-dependent optical properties. They can absorb light over a broad spectral range and emit fluorescence at specific wavelengths, making them attractive for optical sensing, imaging, security marking, diagnostics, photonics, and space-related detection concepts. However, while quantum dots are often clearly visible under UV lamps or controlled laboratory excitation, their visibility under sunlight is less straightforward because fluorescence must compete with broadband background illumination, reflection, scattering, and ambient light.

The objective of the thesis is to evaluate which optical parameters control the detectability of quantum dots under realistic illumination conditions. The student will first review the basic photophysics of quantum dots, including absorption, emission, quantum yield, Stokes shift, photobleaching, and surface passivation, together with basic concepts related to solar spectral irradiance, atmospheric filtering, and optical visibility. Selected quantum dot samples, provided as liquid dispersions, coated substrates, polymer films, or dried spots, will then be characterized experimentally.

The experimental work will include absorption and emission measurements using available techniques such as UV-Vis spectroscopy, fluorescence spectroscopy, reflectance measurements, and optical imaging. The student will investigate how the fluorescence signal depends on concentration, substrate, emission wavelength, excitation source, and viewing conditions. Where available, tests may be performed using a solar simulator, broadband lamp, UV source, or controlled illumination setup in order to compare laboratory excitation with more realistic solar-like conditions.

In parallel, the student will develop a simplified predictive model to estimate the fluorescence signal generated under Earth-surface and space-relevant illumination scenarios. This model may combine incident spectral irradiance, sample absorbance, emission efficiency, emission spectrum, and background reflectance. The analysis will compare the expected fluorescence signal with the optical background in order to determine whether visual detection is realistic or whether instrumental detection would be required.

The expected outcome is a quantitative proof-of-concept assessment of quantum dot visibility under solar excitation. The thesis should identify the key parameters controlling detectability, including quantum yield, absorption spectrum, emission wavelength, sample loading, substrate contrast, and illumination spectrum, and provide recommendations for future applications in sensing, marking, or space-related optical detection.

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| Language | EN (english) |
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| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Iorio Carlo (carlo.iorio@ulb.be)

Influence of non-Newtonian fluids on droplet coalescence and interfacial behaviour

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to experimentally investigate how the rheology of a non-Newtonian subphase influences droplet coalescence and interfacial behaviour. Droplet coalescence, the process by which two droplets or interfaces merge into a single liquid body, is central to many applications, including emulsions, coatings, spraying, inkjet printing, microfluidics, oil–water separation, pharmaceutical formulations, and food processing. Although often described using Newtonian fluids, many practical systems involve complex fluids such as polymer solutions, biological fluids, gels, suspensions, or surfactant-rich mixtures. Their rheological properties may strongly affect interface deformation, thin-film drainage, surface stability, and merging dynamics.

The objective of the thesis is to compare Newtonian and non-Newtonian systems under controlled experimental conditions, with particular attention to surface tension, surface pressure, surfactant effects, and coalescence behaviour. The student will first review the literature on droplet coalescence, interfacial tension, surfactant transport, and non-Newtonian rheology. Model fluids will then be selected, including a Newtonian reference fluid and one or more non-Newtonian systems, such as polymer-containing solutions or weakly structured fluids.

Experiments will be carried out using a Langmuir trough or another available interfacial measurement setup. The student will vary parameters such as surfactant concentration, subphase composition, and fluid rheology in order to evaluate their influence on the interface. Depending on the available configuration, the work may include surface pressure–area measurements, imaging of droplet approach and coalescence, measurement of coalescence time, observation of interface deformation, or indirect assessment of interface stability.

The analysis will focus on comparing surface tension or surface pressure data, characteristic response times, concentration-dependent trends, and coalescence behaviour between Newtonian and non-Newtonian systems. Where available, rheological information such as viscosity or shear-rate dependence will be used to interpret the results. The observations will be compared with simplified models from capillarity, viscous flow, interfacial rheology, and surfactant transport.

The expected outcome is an improved experimental understanding of how non-Newtonian fluid properties influence interface stability and droplet coalescence. The thesis should identify the dominant physical parameters, assess the role of surfactants and subphase composition, and provide guidance for future studies of coalescence in complex fluids.

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| Language | FR |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Electrochromic Coatings for Active Thermal Control in Space : Experimental Assessment

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to experimentally assess the potential of electrochromic coatings as active thermal-control materials. Electrochromic materials reversibly change their optical properties when an electrical voltage is applied. While they are mainly known for smart-window applications, where they regulate light transmission and solar heat gain, the same principle could be used to control the thermal behaviour of a surface. By switching between coloured and bleached states, an electrochromic coating may modify the amount of radiation absorbed by a surface and therefore influence its temperature under illumination.

The main objective of the thesis is to determine whether electrical switching of an electrochromic coating can produce a measurable and controllable change in thermal behaviour under laboratory conditions. The student will first review the basic principles of electrochromic materials, optical switching mechanisms, smart-window technologies, and possible applications in thermal management. A safe and reproducible experimental protocol will then be defined for testing electrochromic samples.

Experiments will involve activating the coating using a DC power supply, potentiostat, or equivalent voltage-control system, depending on the available materials. The samples will be tested in different optical states under identical heating conditions, using a lamp, heated stage, hot plate, or solar-simulator-like source if available. Surface temperature will be monitored using thermocouples, contact sensors, or infrared imaging. The same sample will be compared in its coloured and bleached states, and repeated switching cycles will be performed to assess reversibility, hysteresis, degradation, and repeatability.

The analysis will focus on temperature–time curves, heating and cooling rates, maximum temperature differences, switching time, and stability over multiple cycles. Where possible, a simple energy-balance interpretation may be used to relate the observed thermal response to changes in optical properties.

The expected outcome is a proof-of-concept validation of electrochromic coatings for active thermal control. The thesis should determine whether voltage-induced optical switching produces a significant temperature modulation, identify the main limiting factors, and provide recommendations for future active thermal-control coating experiments.

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| Language | FR |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Experimental assessment of thermochromic coatings for passive thermal regulation in space

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to experimentally assess the potential of thermochromic coatings as passive thermal-regulation materials. Such coatings modify their optical properties with temperature, typically switching between a darker, more absorbing state and a lighter, more reflective state. This behaviour could be exploited to regulate surface temperature without active control, by increasing heat absorption when the surface is cold and reducing absorption when it becomes warm. The concept is relevant for systems exposed to alternating heating and cooling conditions, such as outdoor devices, building surfaces, spacecraft components, scientific payloads, or autonomous sensors.

The work will focus on determining whether the colour change of thermochromic coatings produces a measurable and repeatable thermal effect under controlled day–night-like cycling. The student will first conduct a short literature review on thermochromic materials, passive thermal control, and radiative heat transfer. Coated samples and reference surfaces, such as black, white, metallic, or uncoated substrates, will then be tested under identical cyclic heating and cooling conditions. Experiments may use laboratory equipment such as lamps, hot plates, Peltier elements, heated stages, or environmental chambers. Surface temperatures will be monitored using thermocouples, contact probes, infrared measurements, or a combination of these methods, while colour changes may be documented visually.

The analysis will compare temperature–time curves for the thermochromic and reference samples. Key quantities will include the switching temperature range, maximum and minimum temperatures, heating and cooling rates, hysteresis, reversibility, and cycle-to-cycle repeatability. Where relevant, a simple energy-balance model may be used to interpret the results and relate the observed thermal response to absorbed radiation and surface properties.

The expected outcome is a proof-of-concept evaluation of thermochromic coatings for passive thermal regulation. The thesis should determine whether the selected coating provides a significant thermal benefit, under which conditions this effect is most visible, and what parameters should be improved for future applications.

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|---------------------------------|----------------------|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-E, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Analysis of Heat and Mass Transport During Hydrogen Bubble Growth in Water Electrolysis

Program : Chemical & Materials engineering - M-IRMAE

Description

Hydrogen can be produced by splitting water through electrochemical reactions in electrolysis. Although the process is overall endothermic, additional heat can be generated locally, most notably through Joule heating at the electrode surface. This localized heating modifies the temperature field near the growing hydrogen bubble, creating temperature gradients that induce thermocapillary (Marangoni) flows along the bubble interface.

In addition to thermal effects, concentration gradients of surface active species such as ions or dissolved gases can also alter surface tension, resulting in solutal Marangoni convection. These interfacial flows strongly affect bubble growth, shape, and detachment dynamics. Understanding these coupled effects requires the ability to accurately resolve the local temperature and concentration fields around the bubble. However, measuring both fields at the same time remains a significant experimental challenge.

Previous studies have demonstrated that at high applied potentials, Joule heating dominates, and thermocapillary effects become the primary drivers of interfacial motion, while solutal effects can often be neglected. Various optical techniques such as Schlieren imaging, laser induced fluorescence, and interferometry have been used to study these fields.

Mach Zehnder interferometry stands out as a noninvasive and calibration free technique for resolving instantaneous temperature fields with high sensitivity.

This thesis will focus on hydrogen bubble dynamics on a microelectrode in acidic electrolysis, using two complementary experimental techniques:

- Mach Zehnder Interferometry, to quantify the temperature field near the electrode and at the base of the bubble, especially when concentration variations are negligible.
- High speed visualization, to qualitatively capture the bubble inception, growth, and detachment processes.
- Complementary Schlieren imaging may be used for qualitative validation as done in the previous study [1].

Methodology

1. Literature survey

The student will begin by familiarising themselves with the topic. A thorough review of recent literature, especially on interferometric and visualisation techniques applied to gas-evolving electrodes, will help define the research scope and objectives.

2. Experimental set-up

The student will work with the existing electrolysis cell, Mach Zehnder interferometer, and high-speed imaging system available at the TIPS laboratory. This phase will involve hands-on training with laser alignment, optical adjustments, electrode handling, and system calibration. The student will also participate in test runs to optimise measurement conditions and gain confidence in operating the setup independently.

3. Measurement campaign and data analysis

The student will conduct experiments to visualise hydrogen bubble growth on microelectrodes using high-speed imaging and Mach Zehnder interferometry. Interferometric data will be analysed to extract local temperature fields, while high-speed recordings will be used to characterise bubble shape, growth, and detachment dynamics. Post-processing and analysis will be carried out using MATLAB. If numerical simulation results are available, they will be compared with the experimental data. In parallel, the student will measure the refractive index, density, and viscosity of the electrolyte across different concentrations and temperatures, using the available facilities at the TIPs laboratory, ULB.

4. Reporting

- ☐ Weekly meetings with the supervisor(s) to define tasks and discuss outcomes and practicalities.
- ☐ Monthly meeting with the team to verify the progress and discuss follow-up
- ☐ Final presentation

References

- [1]. A. Babich, A. Bashkatov, X. Yang, G. Mutschke, and K. Eckert, "In-situ measurements of temperature field and Marangoni convection at hydrogen bubbles using schlieren and PTV techniques," *Int. J. Heat Mass Transf.*, vol. 215, p. 124466, 2023.
- [2]. J. Massing, G. Mutschke, D. Baczymalski, S. S. Hossain, X. Yang, K. Eckert, and C. Cierpka, "Thermocapillary convection during hydrogen evolution at microelectrodes," *Electrochimica Acta*, vol. 297, pp. 929–940, 2019.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRARE, M-IRCBS, M-IRCNE, M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Number of topics | 2 |

Supervision

Supervisor : Pierre Colinet (pierre.colinet@ulb.be)

Co-supervisor : Senthil Kumar Parimalanathan (senthil.parimalanathan@ulb.be)

Design and development of advanced drones for water quality assessment.

Program : Electrical engineering - M-IRELE

Description

This thesis develops further on previous theses in which drones have been developed for water quality assessment. Two types of drones have been developed. An aerial drone and a vessel based drone. For students from EM, this thesis will be about the optimisation of the drones and the development of algorithmq for energy optimised way point planning. For students from electric engineering and computerscience the focus will be on the development of algorithms for fleet management and multi-drone co-operative measurement campaigns.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 2 |

Supervision

Supervisor : Abdellah Touhafi (abdellah.touhafi@gmail.com)

Modeling Electric Heating Resistance using multi-physics approach for industrial implementation

Program : EM - Aeronautics - M-IREMR-A

Description

Electric heating elements are widely used in high-temperature industrial processes because they can deliver controlled thermal energy without direct combustion. However, these components operate under severe conditions, where electrical, thermal, and mechanical phenomena are strongly coupled. Current flowing through the resistance generates Joule heating, which leads to high temperature gradients, thermal expansion, deformation, and mechanical stresses. In some configurations, electromagnetic forces may also contribute to displacement or instability. A predictive understanding of these coupled effects is therefore essential to improve performance, reliability, lifetime, and safety in industrial applications.

The objective of this master thesis is to improve an existing multiphysics model of electric heating resistances. The model will combine electromagnetic modelling, Joule heating, heat transfer, thermal expansion, and mechanical stress analysis. The aim is to simulate how operating conditions, geometrical configurations, and material properties influence the deformation and potential failure of heating elements under realistic industrial loads. Particular attention will be paid to high-temperature materials such as molybdenum or industrial resistance materials, using appropriate temperature-dependent properties when available.

The thesis will first include a literature review on multiphysics modelling strategies for electrically heated components and on the main industrial challenges associated with high-temperature electric heating. The student will then work on the improvement of the existing numerical model, using ANSYS or an equivalent simulation platform. This will involve coupling the electromagnetic problem, including current distribution and possibly Lorentz forces, with the thermal problem through Joule heat generation, and with the mechanical problem through thermal expansion and stress analysis.

The improved model will then be used to simulate representative operating scenarios. The student will analyse the effect of current intensity, resistance geometry, boundary conditions, material properties, and symmetrical or asymmetrical configurations on temperature fields, electromagnetic forces, deformation, and stress levels. These simulations will help identify critical situations that may lead to excessive deformation, contact between components, local overheating, breakage, or mechanical instability.

The expected outcome is a validated or critically assessed multiphysics modelling framework for high-temperature electric heating elements. The thesis should provide a clearer understanding of the mechanisms leading to deformation or failure, as well as practical recommendations for safer and more efficient design and operation. The deliverables will include a literature review, an improved numerical model, a parametric analysis of operating conditions, and design guidelines

concerning resistance geometry, power control strategies, material selection, and industrial implementation.

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|---------------------------------|--|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Jetnis Avdijaj (jetnis.avdijaj@ulb.be)

Implementation of a Temperature Control Strategy for CFD-Based Digital Twin of an Industrial Process

Program : EM - Aeronautics - M-IREMR-A

Description

Industrial thermal processes require precise temperature regulation to ensure product quality, energy efficiency, operational stability, and safety. In the context of digitalisation and decarbonisation, digital twins are becoming important tools to predict system behaviour, evaluate operating strategies, and support process optimisation. However, high-fidelity CFD models are often used mainly for offline analysis and are rarely coupled with dynamic control strategies. Adding control capabilities to such models is therefore an important step toward predictive and controllable virtual representations of industrial systems.

The objective of this master thesis is to develop and implement a temperature regulation system for an existing CFD model of an industrial thermal process. The aim is to move from a purely predictive CFD simulation toward a controlled numerical environment, where boundary conditions or operating parameters can be adjusted dynamically in order to reach and maintain a target temperature. This work will contribute to the development of a digital twin framework by combining physics-based modelling, control algorithms, and simulation outputs that can be exploited for future real-time or near-real-time applications.

The thesis will first include a literature review on temperature control strategies for thermal systems, including PID control, advanced control approaches, and model predictive control. The student will also review digital twin architectures for industrial processes and existing methods for integrating control loops with CFD environments such as ANSYS Fluent. Particular attention will be paid to the practical constraints associated with coupling a CFD solver and an external controller, including data exchange, time stepping, numerical stability, and computational cost.

The main part of the thesis will consist of designing and implementing a control strategy for the selected CFD model. Depending on the case study, the controller may act on inlet temperature, mass flow rate, heating power, wall heat flux, or another relevant operating variable. The control algorithm will be coupled to the CFD simulation and tested under different operating scenarios, such as changes in heat demand, disturbances, set-point variations, or modified boundary conditions. The control performance will be assessed in terms of response time, overshoot, stability, robustness, and ability to maintain the desired temperature distribution.

Finally, the thesis will analyse how the controlled CFD model can support the development of a digital twin. This includes identifying which simulation outputs are relevant for monitoring and decision support, what level of model reduction or acceleration may be required, and how control parameters can be optimised for robust operation. The expected outcome is a working control-oriented CFD framework, a critical assessment of its performance and limitations, and recommendations for future integration into an industrial digital twin platform.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Jetnis Avdijaj (jetnis.avdijaj@ulb.be)

CFD Modeling of Water Injection in Hydrogen-Fueled Internal Combustion Engines and Development of a 0D Water Injection Model for CHP Applications

Program : EM - Aeronautics - M-IREMR-A

Description

Hydrogen-fuelled internal combustion engines are a promising solution for low-carbon combined heat and power applications, where both useful mechanical or electrical power and recoverable heat can be produced. However, hydrogen combustion presents several challenges, including high in-cylinder temperatures, NO_x emissions, knock, and pre-ignition risks. Water injection is a potential strategy to mitigate these issues by reducing combustion temperatures and influencing mixture formation, evaporation processes, and combustion behaviour. In a CHP context, understanding these effects is particularly important because water injection may affect not only engine efficiency and emissions, but also the thermal balance and heat recovery potential of the system.

The objective of this master thesis is to develop a CFD model to study water injection in a hydrogen spark-ignition engine. The model will be used to analyse the evaporation process, droplet behaviour, vapour distribution, and the effect of water injection on in-cylinder temperature and combustion characteristics. The thesis will first include a literature review on hydrogen combustion in spark-ignition engines, water injection strategies, spray evaporation, two-phase flow modelling, and CFD approaches relevant to hydrogen-fuelled engines.

The main part of the thesis will consist of building a numerical CFD model of the engine configuration. Depending on the available data and geometry, the model may focus on the intake system, the combustion chamber, or a simplified representative domain. It should include the hydrogen-air mixture, the water injection system, and the relevant heat and mass transfer phenomena. Particular attention will be paid to the physical state of the injected water under different operating conditions, in order to determine whether it remains as liquid droplets, evaporates into vapour, or forms a two-phase mixture. The influence of injection timing, injected mass, droplet size, pressure, temperature, and flow conditions will be analysed.

The CFD model will then be used to investigate how water injection affects hydrogen combustion. The student will study its influence on in-cylinder temperature, mixture dilution, heat-release behaviour, thermal gradients, knock tendency, and NO_x-related temperature reduction. These results will help identify the main mechanisms through which water injection can improve or degrade engine performance in CHP-relevant operating conditions.

Finally, the CFD results will support the development of a simplified zero-dimensional model of water injection for hydrogen engines. This 0D model should reproduce the main effects of evaporation, temperature reduction, mixture dilution, and combustion modification, while remaining suitable for fast parametric studies or future system-level CHP simulations. The expected outcome is a CFD-based understanding of water injection in hydrogen spark-ignition engines, together with a first reduced-order modelling approach that can be reused in further experimental or numerical work.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Cyril Freyling (cyril.freyling@ulb.be)

Investigation of Coupled CFD Modelling for Microwave Electrification of Industrial Heating

Program : EM - Aeronautics - M-IREMR-A

Description

The objective of this master thesis is to investigate coupled modelling strategies in CFD for the study of microwave electrification applied to industrial heating processes. The work is positioned in the context of the E-HEAT proposal and, more broadly, of industrial heat decarbonisation, where replacing fossil-fuel-based heating by electrified technologies requires reliable numerical tools. The focus of the thesis is therefore not to design a complete microwave heating system, but to explore how electromagnetic energy deposition can be coupled with heat transfer and fluid-flow models in a CFD environment.

The thesis will first consist of reviewing the physical phenomena and numerical approaches involved in microwave heating. The student will analyse how microwave radiation interacts with materials, how electromagnetic power is absorbed, and how this absorbed power can be represented as a volumetric heat source in a CFD model. Particular attention will be paid to the coupling between electromagnetic fields, temperature-dependent material properties, heat conduction, convection, radiation, and possible flow effects. The objective is to identify the main modelling assumptions, coupling strategies, and numerical difficulties associated with such multiphysics simulations.

The student will then develop and test one or several simplified coupled CFD models on a representative configuration. Depending on the chosen level of complexity, the electromagnetic field may be represented through an imposed power deposition profile, a simplified analytical model, or a coupling with an external electromagnetic solver. This source term will then be integrated into a CFD model solving the thermal and, where relevant, fluid-flow problem. The work should compare different coupling levels, from weak one-way coupling to more advanced approaches where the temperature field modifies the material properties and therefore the absorbed microwave power.

A parametric study will be carried out to assess the sensitivity of the coupled model to key assumptions and input parameters. These may include microwave power, spatial distribution of the heat source, dielectric properties, temperature dependence of material parameters, geometry, boundary conditions, flow rate, and thermal losses.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Pedagogical Integration of Flight Simulators for Engineering Education

Program : EM - Aeronautics - M-IREMR-A

Description

The project will focus on transforming the existing simulators into structured teaching platforms, allowing students to connect theoretical notions of flight mechanics, aircraft performance, stability, control, and aircraft design with hands-on simulation activities.

The work will first consist of analysing the current state of the simulator infrastructure. This includes the hardware configuration, cockpit interfaces, flight simulation software, available aircraft models, visualisation systems, data extraction possibilities, and operational limitations. The student will identify what remains to be completed or improved in order to obtain a robust, repeatable, and easy-to-use laboratory setup. Particular attention will be paid to usability, reliability, documentation, and the ability to run exercises with groups of students in a teaching context.

A second part of the thesis will focus on the integration of the OAD software environment. OAD presents its tools as covering the aircraft development process from conceptual design to flight-test analysis, with applications including aircraft design, UAV/aircraft optimisation, and flight performance analysis. The objective will be to investigate how such tools can be combined with the flight simulators in order to create a coherent workflow: from preliminary aircraft design and performance estimation to simulation-based evaluation of flight behaviour.

The student will then design a first set of pedagogical activities for engineering students. These activities may address topics such as take-off and landing performance, climb rate, stall behaviour, static and dynamic stability, control response, flight envelope exploration, and the influence of aircraft design parameters on flight performance. The aim is not only to provide demonstrations, but to build laboratory sessions in which students formulate hypotheses, run simulations, collect data, analyse results, and compare them with theoretical models.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@hotmail.com)

Development of a Low-Power Gas Turbine Test Bench for RC-Size Engines

Program : EM - Aeronautics - M-IREMR-A

Description

The objective of this master thesis is to carry out the preliminary study, design, and first implementation of a low-power gas turbine test bench based on RC-size turbojet engines. The bench is intended for use in engineering laboratory sessions, where students will be able to observe and analyse the operation of a real gas turbine in a safe, compact, and didactic environment. Although RC-size engines are small, they reproduce the essential features of gas turbine operation: air compression, combustion, turbine expansion, exhaust acceleration, transient behaviour, thermal constraints, and fuel consumption. They therefore provide an attractive and affordable platform for hands-on teaching in propulsion, turbomachinery, energy conversion, and experimental methods.

The thesis will first consist of a pre-study phase. The student will analyse the technical, pedagogical, and safety requirements of such a bench. This includes identifying the type and size of engine to be used, the expected thrust and thermal loads, the constraints linked to indoor or semi-indoor operation, noise levels, exhaust management, fuel storage, and safety procedures. A review of existing educational gas turbine benches and RC turbine test setups will be carried out in order to define a realistic concept adapted to university laboratory use.

Based on this analysis, the student will develop the mechanical and functional design of the test bench. This will include the design of the supporting structure, engine mounting system, thrust measurement arrangement, protective shielding, access to the engine for maintenance, fuel system integration, and space for future instrumentation. The work will involve producing technical drawings and CAD models, selecting suitable components, defining a bill of materials, and justifying the main design choices in terms of safety, robustness, cost, ease of use, and pedagogical value.

A key objective of the thesis will then be to manufacture or assemble a first version of the bench. Depending on the progress of the project, this prototype should allow the safe installation of the engine and prepare the bench for future experimental campaigns. Particular attention will be paid to modularity, so that additional sensors such as thermocouples, pressure probes, fuel flow meters, load cells, vibration sensors, or data acquisition systems can be integrated in later stages.

The expected outcome is a complete pre-design study and a first operational or partially operational prototype of a gas turbine laboratory bench. The deliverables will include the technical specifications, CAD drawings, component selection, assembly documentation, safety analysis, and recommendations for future instrumentation and laboratory exercises. This thesis is therefore mainly an engineering design and development project, with a strong practical dimension and a clear teaching objective

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| Language | EN (english) |
| Open to other master's programs | Yes |

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| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Topics offered to students by other
master's programs

TARGET PROGRAM

EM – ENERGY Engineering

Reliability enhancement for complex systems via AI-based time-dependent reconfiguration

Program : Physical engineering - M- IRPH

Description

Classical reliability techniques, based on Boolean logics, are well established in the treatment of multi-component systems. Yet those methods actually rely on some assumptions: components are assumed to display a binary operation (i.e. they are fully working or fully failed), and the logics of the system is considered static.

Complex industrial systems are increasingly designed to tolerate certain failures while maintaining an acceptable level of operational performance. For such systems, reliability can no longer be estimated on the basis of the previous assumptions (binary components and static logics). An alternative is to consider it as a dynamic variable depending on the performance threshold at which the system will be considered to have failed.

Traditionally, improving reliability involves modifying the architecture or adding redundancies, which entails significant costs and constraints. The proposed thesis aims to analyze the approach proposed in a very recent work and to further extend it. It focuses on improving the reliability of specific systems without hardware modifications. Simulation is used to model complex architectures and represent progressive degradation phenomena, depending on the location of components, and common failure modes. Artificial Intelligence is combined with the simulation to treat time-dependent reconfigurations in the allocation of functions between components that are still operational, in order to slow down performance degradation and delay the crossing of a critical failure threshold.

Reference

Cahoreau P., et al. (2026). New approach to improving the reliability of complex systems by combining dynamic simulation and artificial intelligence. Proceedings of the 2025 conference, "Intelligences Artificielles et Humaines : nouvelles synergies pour le Management des Risques", Grenoble, October 2026.

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|---------------------------------|-----------------------------|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-E, M-IREMI, M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Pierre-Etienne LABEAU (pierre.etienne.labeau@ulb.be)

Degradation processes with imperfect maintenance: from theoretical models to industrial applications

Program : Physical engineering - M- IRPH

Description

Industrial assets are subject to aging: their performances decrease as a function of time, and this is often revealed by an increasing proneness to fail. In order to monitor and limit the progression of degradation phenomena, these assets are subject to various types of inspections and maintenance actions, in order to (partly) rejuvenate them before considering their replacement. Given the costs associated with these activities, realistic models are necessary as a basis for sound asset management. Those models are required to describe the assets' lifetime and expected lifetime extension, as well as the evolution of their degradation level and the impact of imperfect maintenance.

The thesis will first consist of updating a state of the art of those models and proposing a critical review of their characteristics. Some more realistic features of imperfect maintenance models will be discussed, introduced in models and compared to existing models on various applications.

References

- Doyen, L. and Gaudoin, O. (2004). Classes of imperfect repair models based on reduction of failure intensity or virtual age. *Reliability Engineering and System Safety*, 84, 45-56.
- Wu, S. and Clements-Croome, D. (2005). Preventive maintenance models with random maintenance quality. *Reliability Engineering and System Safety*, 90, 99-105.
- Kahle, W. (2019). Imperfect repair in degradation processes: A Kijima-type approach: Imperfect repair in degradation processes. *Applied Stochastic Models in Business and Industry*, 35.
<https://doi.org/10.1002/asmb.2438>
- Kahle, W., Mercier, S., & Paroissin, C. (2016). *Degradation Processes in Reliability* (Inc. John Wiley & Sons, Éd.). <https://doi.org/10.1002/9781119307488>

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-E, M-IREMI |
| Number of topics | 1 |

Supervision

Supervisor : Pierre-Etienne LABEAU (pierre.etienne.labeau@ulb.be)

Propagating Site Wind-Climate Uncertainty to Wind Turbine Loads

Program : EM - Aeronautics - M-IREMR-A

Description

See document below for context and work description

Link : https://vub-my.sharepoint.com/personal/goncalo_granjal_cruz_vub_be/_layouts/15/onedrive.aspx?id=%2Fpersonal%2Fgoncalo%5Fgranjal%5Fcruz%5Fvub%5Fbe%2FDocuments%2FMaster%20thesis%20topics%2F2026%2D2027%2FXX%5FFLOW%5FMSc%5FUncTurbineLoads%2FXX%5FFLOW%5FMSc%5FUncTurbineLoads%2Epdf&parent=%2Fpersonal%2Fgoncalo%5Fgranjal%5Fcruz%5Fvub%5Fbe%2FDocuments%2FMaster%20thesis%20topics%2F2026%2D2027%2FXX%5FFLOW%5FMSc%5FUncTurbineLoads&ga=1

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E |
| Number of topics | 1 |

Supervision

Supervisor

Mark Runacres (Mark.Runacres@vub.be)

Co-supervisor

Gonçalo Granjal Cruz (goncalo.granjal.cruz@vub.be)

Material Screening for Laser-Ablation Micropropulsion Using a Torsional Pendulum Thrust Balance

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to experimentally compare candidate materials for laser-ablation micropropulsion using a torsional pendulum thrust or impulse balance. Laser propulsion refers to concepts in which laser radiation transfers momentum to a spacecraft or target. In laser-ablation propulsion, laser energy is absorbed by a material surface, causing rapid heating, vaporization, plasma formation, or material ejection. The recoil from the ejected material produces a small impulse, making this approach relevant for micropropulsion, attitude control, precision positioning, and possibly remote momentum transfer to small objects or debris.

The work will build on an existing torsional pendulum setup previously developed for laser-propulsion studies. The main objective is to determine how material properties such as composition, rigidity, porosity, optical absorption, surface roughness, and internal structure influence the impulse generated by pulsed laser ablation. The student will first review the principles of laser propulsion, pulsed laser ablation, micropropulsion, and impulse measurement, with attention to key quantities such as impulse bit, momentum coupling coefficient, laser fluence, ablation threshold, repeatability, and surface degradation.

Experimentally, small material samples will be mounted on the torsional pendulum and irradiated by a laser under controlled conditions. The recoil impulse produced by each laser pulse will induce an angular displacement or oscillation, from which the impulse can be estimated using the pendulum calibration, geometry, torsional stiffness, damping, and moment of inertia. The first phase will focus on calibration and validation of the measurement system, including sensitivity, noise floor, repeatability, damping behaviour, and uncertainty.

The second phase will test standard reference materials such as aluminium, copper, graphite, polymers, black coatings, adhesive tapes, or commercial absorptive films. These results will provide baseline data on how optical absorption, thermal conductivity, melting or vaporization behaviour, and surface morphology affect impulse generation. A third phase will investigate custom or engineered materials, such as porous materials, composites with carbon or metallic fillers, multilayer coatings, polymer matrices, foams, aerogels, or surface-treated samples. Laser parameters such as pulse energy, spot size, repetition rate, incidence angle, number of pulses, and target position will be controlled as carefully as possible.

The analysis will compare impulse bit, impulse as a function of laser energy or fluence, estimated momentum coupling coefficient, repeatability over multiple shots, and surface degradation after irradiation. The expected outcome is a calibrated comparative assessment of materials for laser-ablation micropropulsion. The thesis should rank candidate materials according to propulsion-

relevant performance metrics and provide recommendations for future vacuum-compatible laser-propulsion experiments.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRMAE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Calibration of colour-changing hygroscopic materials for water detection in lunar-regolith simulants

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to experimentally assess whether colour-changing hygroscopic materials can be used as simple indicators for detecting and semi-quantifying water in sand or lunar-regolith simulants. The detection of water on the Moon is a major challenge for future exploration, as water may occur as adsorbed molecules, hydroxyl groups, frost, ice grains, or concentrated deposits in permanently shadowed regions. While advanced instruments such as infrared spectrometers, neutron detectors, mass spectrometers, and thermal analysis systems can provide detailed measurements, there is also interest in developing simple, low-cost, robust indicators capable of giving rapid evidence of water or humidity in contact with granular materials.

The work will focus on humidity-sensitive materials that change colour when they absorb or adsorb water, such as silica-gel-based indicators, cobalt-free humidity cards, functional salts, porous films, or humidity-sensitive polymers. The student will first review lunar water detection, regolith properties, hygroscopic materials, and colourimetric sensing. Particular attention will be paid to clarifying what such indicators can detect, since colour-change materials are mainly sensitive to available molecular water or vapour-phase humidity, and not necessarily to chemically bound hydroxyl groups.

The experimental work will consist in preparing sand or lunar-regolith simulant samples with controlled water contents, introduced gravimetrically by adding known masses of water to dry granular material. Candidate indicator materials will then be exposed to these samples under reproducible conditions, for example in direct contact with the grains, partially buried in the medium, placed in the headspace of a sealed vial, or separated by a porous membrane. These configurations will help determine whether the response is driven by liquid contact, vapour-phase humidity, or local moisture gradients.

Colour changes will be recorded over time using photography, scanning, or a simple optical imaging setup under controlled lighting. Quantitative image analysis will be used to extract RGB, HSV, or CIELAB colour parameters and generate calibration curves relating colour response to known water content. The analysis will also evaluate response time, sensitivity, repeatability, reversibility after drying, and detection limit. Additional tests may examine the influence of grain size, porosity, mineral composition, sample geometry, temperature, and equilibration time.

The expected outcome is a calibrated proof-of-concept assessment of colour-changing hygroscopic materials for water detection in regolith-like media. The thesis should determine whether this approach is suitable for qualitative detection, semi-quantitative estimation, or only laboratory screening, and provide recommendations for future development of simple regolith-contact water indicators for lunar exploration.

| | |
|---------------------------------|---------------------------------|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Electromagnetic Shielding Properties of Standard and Custom Materials from 100 MHz to 10 GHz

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to develop and validate a practical experimental methodology for comparing the electromagnetic shielding performance of standard and custom materials in the 100 MHz–10 GHz frequency range. Electromagnetic shielding is increasingly important in aerospace systems, electronics, telecommunications, biomedical devices, sensor platforms, and space instrumentation, where sensitive components must be protected from external electromagnetic interference while limiting unwanted emissions. Classical metallic shielding solutions can be highly effective, but they are often heavy, rigid, or difficult to integrate into multifunctional structures.

The work will explore alternative shielding materials whose performance can be tuned through composition, thickness, porosity, rigidity, conductivity, magnetic response, or internal structure. Examples include conductive polymer composites, carbon-loaded elastomers, metallized textiles, porous conductive foams, graphene- or carbon-black-based films, magnetic particle composites, and multilayer hybrid materials. The laboratory has access to a vector network analyser and two probes covering approximately 100 MHz to 10 GHz, which will be used to establish a comparative testing platform.

The student will first review the principles of electromagnetic shielding, including reflection, absorption, multiple internal reflections, conductivity, magnetic permeability, skin depth, and frequency-dependent attenuation. The experimental work will then focus on defining a repeatable measurement protocol in which a material sample is placed between or near transmitting and receiving probes. Measurements with and without the sample will be used to estimate attenuation as a function of frequency, for example through relative changes in transmission parameters such as S_{21} . Particular attention will be paid to calibration, probe positioning, sample size, edge leakage, distance between probes, background noise, environmental reflections, and repeatability.

Reference materials such as aluminium foil, copper foil, stainless-steel mesh, conductive tape, metallized films, carbon-loaded sheets, ferrite-containing materials, or commercial EMI shielding fabrics will first be tested to establish baseline behaviour. Custom materials will then be fabricated or selected with controlled variations in composition, filler content, thickness, porosity, rigidity, and multilayer structure. The analysis will compare frequency-dependent attenuation curves and assess how material parameters influence shielding performance. Where possible, results may also be normalized by thickness or areal density to evaluate lightweight shielding efficiency.

The expected outcome is a validated laboratory-scale methodology for screening electromagnetic shielding materials. The thesis should identify promising material families, quantify the influence of composition and structure on attenuation, and clarify the limitations of the probe-based setup compared with standardized certification methods. It should also provide recommendations for

improving the platform, for example through a dedicated sample holder, shielding box, coaxial fixture, absorber-lined enclosure, or free-space measurement geometry.

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|---------------------------------|---|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Torsional Pendulum Micro-Thrust Balance for Electrospray Propulsion Preparation

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to adapt and validate a torsional pendulum thrust-balance setup for the measurement of very small forces relevant to electrospray propulsion. Electrospray propulsion is a promising micropropulsion technology for CubeSats, small satellites, precision attitude control, drag compensation, and formation flying. It relies on the electrostatic acceleration of charged droplets, ions, or ion-droplet mixtures emitted from a conductive liquid under a strong electric field. Although the resulting thrust is typically in the micro-newton or sub-micro-newton range, it can be highly controllable and efficient, making it attractive for precision space applications.

A key experimental challenge is the reliable measurement of such small forces. Before developing a complete electrospray thruster, the laboratory needs a calibrated micro-thrust measurement platform. The work will therefore build on an existing torsional pendulum previously developed for laser propulsion studies and assess whether it can be adapted to electrospray-relevant force ranges. The thesis will focus on the measurement principle, calibration strategy, sensitivity, noise sources, and compatibility with future high-voltage operation.

The student will first review electrospray propulsion, Taylor cone formation, electrohydrodynamic emission, charged-particle acceleration, and micro-thrust measurement techniques. The experimental work will then consist in analysing the existing pendulum design and identifying the required modifications in terms of arm length, torsional stiffness, moment of inertia, damping, mechanical stability, displacement readout, electrical isolation, and future integration of a high-voltage emitter.

The first experimental phase will focus on calibration without electrospray operation. Known small forces may be applied using calibrated masses, electrostatic or magnetic forces, controlled mechanical displacement, or another suitable method. The system will be characterized in terms of linearity, sensitivity, minimum detectable force, response time, noise floor, drift, and repeatability. A second phase will investigate artefacts such as air currents, vibrations, acoustic noise, cable stiffness, electrostatic coupling, thermal drift, and mechanical hysteresis, with possible mitigation through shielding, damping, improved mounting, optical readout, or signal filtering.

The expected outcome is a calibrated and experimentally characterized torsional pendulum micro-thrust balance suitable as a foundation for future electrospray propulsion experiments. The thesis should determine whether the setup can reach electrospray-relevant force levels, identify the dominant limitations, and provide design recommendations for later integration with a high-voltage electrospray emitter and, eventually, a vacuum-compatible thrust-measurement platform.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Visibility of quantum dots under solar excitation

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to assess whether quantum dot fluorescence can be detected or visually observed under solar or solar-like excitation. Quantum dots are semiconductor nanocrystals with size-dependent optical properties. They can absorb light over a broad spectral range and emit fluorescence at specific wavelengths, making them attractive for optical sensing, imaging, security marking, diagnostics, photonics, and space-related detection concepts. However, while quantum dots are often clearly visible under UV lamps or controlled laboratory excitation, their visibility under sunlight is less straightforward because fluorescence must compete with broadband background illumination, reflection, scattering, and ambient light.

The objective of the thesis is to evaluate which optical parameters control the detectability of quantum dots under realistic illumination conditions. The student will first review the basic photophysics of quantum dots, including absorption, emission, quantum yield, Stokes shift, photobleaching, and surface passivation, together with basic concepts related to solar spectral irradiance, atmospheric filtering, and optical visibility. Selected quantum dot samples, provided as liquid dispersions, coated substrates, polymer films, or dried spots, will then be characterized experimentally.

The experimental work will include absorption and emission measurements using available techniques such as UV-Vis spectroscopy, fluorescence spectroscopy, reflectance measurements, and optical imaging. The student will investigate how the fluorescence signal depends on concentration, substrate, emission wavelength, excitation source, and viewing conditions. Where available, tests may be performed using a solar simulator, broadband lamp, UV source, or controlled illumination setup in order to compare laboratory excitation with more realistic solar-like conditions.

In parallel, the student will develop a simplified predictive model to estimate the fluorescence signal generated under Earth-surface and space-relevant illumination scenarios. This model may combine incident spectral irradiance, sample absorbance, emission efficiency, emission spectrum, and background reflectance. The analysis will compare the expected fluorescence signal with the optical background in order to determine whether visual detection is realistic or whether instrumental detection would be required.

The expected outcome is a quantitative proof-of-concept assessment of quantum dot visibility under solar excitation. The thesis should identify the key parameters controlling detectability, including quantum yield, absorption spectrum, emission wavelength, sample loading, substrate contrast, and illumination spectrum, and provide recommendations for future applications in sensing, marking, or space-related optical detection.

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| Language | EN (english) |
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| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Iorio Carlo (carlo.iorio@ulb.be)

Influence of non-Newtonian fluids on droplet coalescence and interfacial behaviour

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to experimentally investigate how the rheology of a non-Newtonian subphase influences droplet coalescence and interfacial behaviour. Droplet coalescence, the process by which two droplets or interfaces merge into a single liquid body, is central to many applications, including emulsions, coatings, spraying, inkjet printing, microfluidics, oil–water separation, pharmaceutical formulations, and food processing. Although often described using Newtonian fluids, many practical systems involve complex fluids such as polymer solutions, biological fluids, gels, suspensions, or surfactant-rich mixtures. Their rheological properties may strongly affect interface deformation, thin-film drainage, surface stability, and merging dynamics.

The objective of the thesis is to compare Newtonian and non-Newtonian systems under controlled experimental conditions, with particular attention to surface tension, surface pressure, surfactant effects, and coalescence behaviour. The student will first review the literature on droplet coalescence, interfacial tension, surfactant transport, and non-Newtonian rheology. Model fluids will then be selected, including a Newtonian reference fluid and one or more non-Newtonian systems, such as polymer-containing solutions or weakly structured fluids.

Experiments will be carried out using a Langmuir trough or another available interfacial measurement setup. The student will vary parameters such as surfactant concentration, subphase composition, and fluid rheology in order to evaluate their influence on the interface. Depending on the available configuration, the work may include surface pressure–area measurements, imaging of droplet approach and coalescence, measurement of coalescence time, observation of interface deformation, or indirect assessment of interface stability.

The analysis will focus on comparing surface tension or surface pressure data, characteristic response times, concentration-dependent trends, and coalescence behaviour between Newtonian and non-Newtonian systems. Where available, rheological information such as viscosity or shear-rate dependence will be used to interpret the results. The observations will be compared with simplified models from capillarity, viscous flow, interfacial rheology, and surfactant transport.

The expected outcome is an improved experimental understanding of how non-Newtonian fluid properties influence interface stability and droplet coalescence. The thesis should identify the dominant physical parameters, assess the role of surfactants and subphase composition, and provide guidance for future studies of coalescence in complex fluids.

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|---------------------------------|---------------------------------|
| Language | FR |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Electrochromic Coatings for Active Thermal Control in Space : Experimental Assessment

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to experimentally assess the potential of electrochromic coatings as active thermal-control materials. Electrochromic materials reversibly change their optical properties when an electrical voltage is applied. While they are mainly known for smart-window applications, where they regulate light transmission and solar heat gain, the same principle could be used to control the thermal behaviour of a surface. By switching between coloured and bleached states, an electrochromic coating may modify the amount of radiation absorbed by a surface and therefore influence its temperature under illumination.

The main objective of the thesis is to determine whether electrical switching of an electrochromic coating can produce a measurable and controllable change in thermal behaviour under laboratory conditions. The student will first review the basic principles of electrochromic materials, optical switching mechanisms, smart-window technologies, and possible applications in thermal management. A safe and reproducible experimental protocol will then be defined for testing electrochromic samples.

Experiments will involve activating the coating using a DC power supply, potentiostat, or equivalent voltage-control system, depending on the available materials. The samples will be tested in different optical states under identical heating conditions, using a lamp, heated stage, hot plate, or solar-simulator-like source if available. Surface temperature will be monitored using thermocouples, contact sensors, or infrared imaging. The same sample will be compared in its coloured and bleached states, and repeated switching cycles will be performed to assess reversibility, hysteresis, degradation, and repeatability.

The analysis will focus on temperature–time curves, heating and cooling rates, maximum temperature differences, switching time, and stability over multiple cycles. Where possible, a simple energy-balance interpretation may be used to relate the observed thermal response to changes in optical properties.

The expected outcome is a proof-of-concept validation of electrochromic coatings for active thermal control. The thesis should determine whether voltage-induced optical switching produces a significant temperature modulation, identify the main limiting factors, and provide recommendations for future active thermal-control coating experiments.

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| Language | FR |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Experimental assessment of thermochromic coatings for passive thermal regulation in space

Program : EM - Aeronautics - M-IREMR-A

Description

This thesis aims to experimentally assess the potential of thermochromic coatings as passive thermal-regulation materials. Such coatings modify their optical properties with temperature, typically switching between a darker, more absorbing state and a lighter, more reflective state. This behaviour could be exploited to regulate surface temperature without active control, by increasing heat absorption when the surface is cold and reducing absorption when it becomes warm. The concept is relevant for systems exposed to alternating heating and cooling conditions, such as outdoor devices, building surfaces, spacecraft components, scientific payloads, or autonomous sensors.

The work will focus on determining whether the colour change of thermochromic coatings produces a measurable and repeatable thermal effect under controlled day–night-like cycling. The student will first conduct a short literature review on thermochromic materials, passive thermal control, and radiative heat transfer. Coated samples and reference surfaces, such as black, white, metallic, or uncoated substrates, will then be tested under identical cyclic heating and cooling conditions. Experiments may use laboratory equipment such as lamps, hot plates, Peltier elements, heated stages, or environmental chambers. Surface temperatures will be monitored using thermocouples, contact probes, infrared measurements, or a combination of these methods, while colour changes may be documented visually.

The analysis will compare temperature–time curves for the thermochromic and reference samples. Key quantities will include the switching temperature range, maximum and minimum temperatures, heating and cooling rates, hysteresis, reversibility, and cycle-to-cycle repeatability. Where relevant, a simple energy-balance model may be used to interpret the results and relate the observed thermal response to absorbed radiation and surface properties.

The expected outcome is a proof-of-concept evaluation of thermochromic coatings for passive thermal regulation. The thesis should determine whether the selected coating provides a significant thermal benefit, under which conditions this effect is most visible, and what parameters should be improved for future applications.

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|---------------------------------|----------------------|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-E, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Analysis of Heat and Mass Transport During Hydrogen Bubble Growth in Water Electrolysis

Program : Chemical & Materials engineering - M-IRMAE

Description

Hydrogen can be produced by splitting water through electrochemical reactions in electrolysis. Although the process is overall endothermic, additional heat can be generated locally, most notably through Joule heating at the electrode surface. This localized heating modifies the temperature field near the growing hydrogen bubble, creating temperature gradients that induce thermocapillary (Marangoni) flows along the bubble interface.

In addition to thermal effects, concentration gradients of surface active species such as ions or dissolved gases can also alter surface tension, resulting in solutal Marangoni convection. These interfacial flows strongly affect bubble growth, shape, and detachment dynamics. Understanding these coupled effects requires the ability to accurately resolve the local temperature and concentration fields around the bubble. However, measuring both fields at the same time remains a significant experimental challenge.

Previous studies have demonstrated that at high applied potentials, Joule heating dominates, and thermocapillary effects become the primary drivers of interfacial motion, while solutal effects can often be neglected. Various optical techniques such as Schlieren imaging, laser induced fluorescence, and interferometry have been used to study these fields.

Mach Zehnder interferometry stands out as a noninvasive and calibration free technique for resolving instantaneous temperature fields with high sensitivity.

This thesis will focus on hydrogen bubble dynamics on a microelectrode in acidic electrolysis, using two complementary experimental techniques:

- Mach Zehnder Interferometry, to quantify the temperature field near the electrode and at the base of the bubble, especially when concentration variations are negligible.
- High speed visualization, to qualitatively capture the bubble inception, growth, and detachment processes.
- Complementary Schlieren imaging may be used for qualitative validation as done in the previous study [1].

Methodology

1. Literature survey

The student will begin by familiarising themselves with the topic. A thorough review of recent literature, especially on interferometric and visualisation techniques applied to gas-evolving electrodes, will help define the research scope and objectives.

2. Experimental set-up

The student will work with the existing electrolysis cell, Mach Zehnder interferometer, and high-speed imaging system available at the TIPS laboratory. This phase will involve hands-on training with laser alignment, optical adjustments, electrode handling, and system calibration. The student will also participate in test runs to optimise measurement conditions and gain confidence in operating the setup independently.

3. Measurement campaign and data analysis

The student will conduct experiments to visualise hydrogen bubble growth on microelectrodes using high-speed imaging and Mach Zehnder interferometry. Interferometric data will be analysed to extract local temperature fields, while high-speed recordings will be used to characterise bubble shape, growth, and detachment dynamics. Post-processing and analysis will be carried out using MATLAB. If numerical simulation results are available, they will be compared with the experimental data. In parallel, the student will measure the refractive index, density, and viscosity of the electrolyte across different concentrations and temperatures, using the available facilities at the TIPS laboratory, ULB.

4. Reporting

- ☐ Weekly meetings with the supervisor(s) to define tasks and discuss outcomes and practicalities.
- ☐ Monthly meeting with the team to verify the progress and discuss follow-up
- ☐ Final presentation

References

- [1]. A. Babich, A. Bashkatov, X. Yang, G. Mutschke, and K. Eckert, "In-situ measurements of temperature field and Marangoni convection at hydrogen bubbles using schlieren and PTV techniques," *Int. J. Heat Mass Transf.*, vol. 215, p. 124466, 2023.
- [2]. J. Massing, G. Mutschke, D. Baczyzmalski, S. S. Hossain, X. Yang, K. Eckert, and C. Cierpka, "Thermocapillary convection during hydrogen evolution at microelectrodes," *Electrochimica Acta*, vol. 297, pp. 929–940, 2019.

| | |
|---------------------------------|---|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRARE, M-IRCBS, M-IRCNE, M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Number of topics | 2 |

Supervision

Supervisor : Pierre Colinet (pierre.colinet@ulb.be)

Co-supervisor : Senthil Kumar Parimalanathan (senthil.parimalanathan@ulb.be)

Design and development of advanced drones for water quality assessment.

Program : Electrical engineering - M-IRELE

Description

This thesis develops further on previous theses in which drones have been developed for water quality assessment. Two types of drones have been developed. An aerial drone and a vessel based drone. For students from EM, this thesis will be about the optimisation of the drones and the development of algorithmq for energy optimised way point planning. For students from electric engineering and computerscience the focus will be on the development of algorithms for fleet management and multi-drone co-operative measurement campaigns.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 2 |

Supervision

Supervisor : Abdellah Touhafi (abdellah.touhafi@gmail.com)

Modeling Electric Heating Resistance using multi-physics approach for industrial implementation

Program : EM - Aeronautics - M-IREMR-A

Description

Electric heating elements are widely used in high-temperature industrial processes because they can deliver controlled thermal energy without direct combustion. However, these components operate under severe conditions, where electrical, thermal, and mechanical phenomena are strongly coupled. Current flowing through the resistance generates Joule heating, which leads to high temperature gradients, thermal expansion, deformation, and mechanical stresses. In some configurations, electromagnetic forces may also contribute to displacement or instability. A predictive understanding of these coupled effects is therefore essential to improve performance, reliability, lifetime, and safety in industrial applications.

The objective of this master thesis is to improve an existing multiphysics model of electric heating resistances. The model will combine electromagnetic modelling, Joule heating, heat transfer, thermal expansion, and mechanical stress analysis. The aim is to simulate how operating conditions, geometrical configurations, and material properties influence the deformation and potential failure of heating elements under realistic industrial loads. Particular attention will be paid to high-temperature materials such as molybdenum or industrial resistance materials, using appropriate temperature-dependent properties when available.

The thesis will first include a literature review on multiphysics modelling strategies for electrically heated components and on the main industrial challenges associated with high-temperature electric heating. The student will then work on the improvement of the existing numerical model, using ANSYS or an equivalent simulation platform. This will involve coupling the electromagnetic problem, including current distribution and possibly Lorentz forces, with the thermal problem through Joule heat generation, and with the mechanical problem through thermal expansion and stress analysis.

The improved model will then be used to simulate representative operating scenarios. The student will analyse the effect of current intensity, resistance geometry, boundary conditions, material properties, and symmetrical or asymmetrical configurations on temperature fields, electromagnetic forces, deformation, and stress levels. These simulations will help identify critical situations that may lead to excessive deformation, contact between components, local overheating, breakage, or mechanical instability.

The expected outcome is a validated or critically assessed multiphysics modelling framework for high-temperature electric heating elements. The thesis should provide a clearer understanding of the mechanisms leading to deformation or failure, as well as practical recommendations for safer and more efficient design and operation. The deliverables will include a literature review, an improved numerical model, a parametric analysis of operating conditions, and design guidelines

concerning resistance geometry, power control strategies, material selection, and industrial implementation.

| | |
|---------------------------------|--|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Jetnis Avdijaj (jetnis.avdijaj@ulb.be)

Implementation of a Temperature Control Strategy for CFD-Based Digital Twin of an Industrial Process

Program : EM - Aeronautics - M-IREMR-A

Description

Industrial thermal processes require precise temperature regulation to ensure product quality, energy efficiency, operational stability, and safety. In the context of digitalisation and decarbonisation, digital twins are becoming important tools to predict system behaviour, evaluate operating strategies, and support process optimisation. However, high-fidelity CFD models are often used mainly for offline analysis and are rarely coupled with dynamic control strategies. Adding control capabilities to such models is therefore an important step toward predictive and controllable virtual representations of industrial systems.

The objective of this master thesis is to develop and implement a temperature regulation system for an existing CFD model of an industrial thermal process. The aim is to move from a purely predictive CFD simulation toward a controlled numerical environment, where boundary conditions or operating parameters can be adjusted dynamically in order to reach and maintain a target temperature. This work will contribute to the development of a digital twin framework by combining physics-based modelling, control algorithms, and simulation outputs that can be exploited for future real-time or near-real-time applications.

The thesis will first include a literature review on temperature control strategies for thermal systems, including PID control, advanced control approaches, and model predictive control. The student will also review digital twin architectures for industrial processes and existing methods for integrating control loops with CFD environments such as ANSYS Fluent. Particular attention will be paid to the practical constraints associated with coupling a CFD solver and an external controller, including data exchange, time stepping, numerical stability, and computational cost.

The main part of the thesis will consist of designing and implementing a control strategy for the selected CFD model. Depending on the case study, the controller may act on inlet temperature, mass flow rate, heating power, wall heat flux, or another relevant operating variable. The control algorithm will be coupled to the CFD simulation and tested under different operating scenarios, such as changes in heat demand, disturbances, set-point variations, or modified boundary conditions. The control performance will be assessed in terms of response time, overshoot, stability, robustness, and ability to maintain the desired temperature distribution.

Finally, the thesis will analyse how the controlled CFD model can support the development of a digital twin. This includes identifying which simulation outputs are relevant for monitoring and decision support, what level of model reduction or acceleration may be required, and how control parameters can be optimised for robust operation. The expected outcome is a working control-oriented CFD framework, a critical assessment of its performance and limitations, and recommendations for future integration into an industrial digital twin platform.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Jetnis Avdijaj (jetnis.avdijaj@ulb.be)

CFD Modeling of Water Injection in Hydrogen-Fueled Internal Combustion Engines and Development of a 0D Water Injection Model for CHP Applications

Program : EM - Aeronautics - M-IREMR-A

Description

Hydrogen-fuelled internal combustion engines are a promising solution for low-carbon combined heat and power applications, where both useful mechanical or electrical power and recoverable heat can be produced. However, hydrogen combustion presents several challenges, including high in-cylinder temperatures, NO_x emissions, knock, and pre-ignition risks. Water injection is a potential strategy to mitigate these issues by reducing combustion temperatures and influencing mixture formation, evaporation processes, and combustion behaviour. In a CHP context, understanding these effects is particularly important because water injection may affect not only engine efficiency and emissions, but also the thermal balance and heat recovery potential of the system.

The objective of this master thesis is to develop a CFD model to study water injection in a hydrogen spark-ignition engine. The model will be used to analyse the evaporation process, droplet behaviour, vapour distribution, and the effect of water injection on in-cylinder temperature and combustion characteristics. The thesis will first include a literature review on hydrogen combustion in spark-ignition engines, water injection strategies, spray evaporation, two-phase flow modelling, and CFD approaches relevant to hydrogen-fuelled engines.

The main part of the thesis will consist of building a numerical CFD model of the engine configuration. Depending on the available data and geometry, the model may focus on the intake system, the combustion chamber, or a simplified representative domain. It should include the hydrogen-air mixture, the water injection system, and the relevant heat and mass transfer phenomena. Particular attention will be paid to the physical state of the injected water under different operating conditions, in order to determine whether it remains as liquid droplets, evaporates into vapour, or forms a two-phase mixture. The influence of injection timing, injected mass, droplet size, pressure, temperature, and flow conditions will be analysed.

The CFD model will then be used to investigate how water injection affects hydrogen combustion. The student will study its influence on in-cylinder temperature, mixture dilution, heat-release behaviour, thermal gradients, knock tendency, and NO_x-related temperature reduction. These results will help identify the main mechanisms through which water injection can improve or degrade engine performance in CHP-relevant operating conditions.

Finally, the CFD results will support the development of a simplified zero-dimensional model of water injection for hydrogen engines. This 0D model should reproduce the main effects of evaporation, temperature reduction, mixture dilution, and combustion modification, while remaining suitable for fast parametric studies or future system-level CHP simulations. The expected outcome is a CFD-based understanding of water injection in hydrogen spark-ignition engines, together with a first reduced-order modelling approach that can be reused in further experimental or numerical work.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Cyril Freyling (cyril.freyling@ulb.be)

Investigation of Coupled CFD Modelling for Microwave Electrification of Industrial Heating

Program : EM - Aeronautics - M-IREMR-A

Description

The objective of this master thesis is to investigate coupled modelling strategies in CFD for the study of microwave electrification applied to industrial heating processes. The work is positioned in the context of the E-HEAT proposal and, more broadly, of industrial heat decarbonisation, where replacing fossil-fuel-based heating by electrified technologies requires reliable numerical tools. The focus of the thesis is therefore not to design a complete microwave heating system, but to explore how electromagnetic energy deposition can be coupled with heat transfer and fluid-flow models in a CFD environment.

The thesis will first consist of reviewing the physical phenomena and numerical approaches involved in microwave heating. The student will analyse how microwave radiation interacts with materials, how electromagnetic power is absorbed, and how this absorbed power can be represented as a volumetric heat source in a CFD model. Particular attention will be paid to the coupling between electromagnetic fields, temperature-dependent material properties, heat conduction, convection, radiation, and possible flow effects. The objective is to identify the main modelling assumptions, coupling strategies, and numerical difficulties associated with such multiphysics simulations.

The student will then develop and test one or several simplified coupled CFD models on a representative configuration. Depending on the chosen level of complexity, the electromagnetic field may be represented through an imposed power deposition profile, a simplified analytical model, or a coupling with an external electromagnetic solver. This source term will then be integrated into a CFD model solving the thermal and, where relevant, fluid-flow problem. The work should compare different coupling levels, from weak one-way coupling to more advanced approaches where the temperature field modifies the material properties and therefore the absorbed microwave power.

A parametric study will be carried out to assess the sensitivity of the coupled model to key assumptions and input parameters. These may include microwave power, spatial distribution of the heat source, dielectric properties, temperature dependence of material parameters, geometry, boundary conditions, flow rate, and thermal losses.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Pedagogical Integration of Flight Simulators for Engineering Education

Program : EM - Aeronautics - M-IREMR-A

Description

The project will focus on transforming the existing simulators into structured teaching platforms, allowing students to connect theoretical notions of flight mechanics, aircraft performance, stability, control, and aircraft design with hands-on simulation activities.

The work will first consist of analysing the current state of the simulator infrastructure. This includes the hardware configuration, cockpit interfaces, flight simulation software, available aircraft models, visualisation systems, data extraction possibilities, and operational limitations. The student will identify what remains to be completed or improved in order to obtain a robust, repeatable, and easy-to-use laboratory setup. Particular attention will be paid to usability, reliability, documentation, and the ability to run exercises with groups of students in a teaching context.

A second part of the thesis will focus on the integration of the OAD software environment. OAD presents its tools as covering the aircraft development process from conceptual design to flight-test analysis, with applications including aircraft design, UAV/aircraft optimisation, and flight performance analysis. The objective will be to investigate how such tools can be combined with the flight simulators in order to create a coherent workflow: from preliminary aircraft design and performance estimation to simulation-based evaluation of flight behaviour.

The student will then design a first set of pedagogical activities for engineering students. These activities may address topics such as take-off and landing performance, climb rate, stall behaviour, static and dynamic stability, control response, flight envelope exploration, and the influence of aircraft design parameters on flight performance. The aim is not only to provide demonstrations, but to build laboratory sessions in which students formulate hypotheses, run simulations, collect data, analyse results, and compare them with theoretical models.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@hotmail.com)

Development of a Low-Power Gas Turbine Test Bench for RC-Size Engines

Program : EM - Aeronautics - M-IREMR-A

Description

The objective of this master thesis is to carry out the preliminary study, design, and first implementation of a low-power gas turbine test bench based on RC-size turbojet engines. The bench is intended for use in engineering laboratory sessions, where students will be able to observe and analyse the operation of a real gas turbine in a safe, compact, and didactic environment. Although RC-size engines are small, they reproduce the essential features of gas turbine operation: air compression, combustion, turbine expansion, exhaust acceleration, transient behaviour, thermal constraints, and fuel consumption. They therefore provide an attractive and affordable platform for hands-on teaching in propulsion, turbomachinery, energy conversion, and experimental methods.

The thesis will first consist of a pre-study phase. The student will analyse the technical, pedagogical, and safety requirements of such a bench. This includes identifying the type and size of engine to be used, the expected thrust and thermal loads, the constraints linked to indoor or semi-indoor operation, noise levels, exhaust management, fuel storage, and safety procedures. A review of existing educational gas turbine benches and RC turbine test setups will be carried out in order to define a realistic concept adapted to university laboratory use.

Based on this analysis, the student will develop the mechanical and functional design of the test bench. This will include the design of the supporting structure, engine mounting system, thrust measurement arrangement, protective shielding, access to the engine for maintenance, fuel system integration, and space for future instrumentation. The work will involve producing technical drawings and CAD models, selecting suitable components, defining a bill of materials, and justifying the main design choices in terms of safety, robustness, cost, ease of use, and pedagogical value.

A key objective of the thesis will then be to manufacture or assemble a first version of the bench. Depending on the progress of the project, this prototype should allow the safe installation of the engine and prepare the bench for future experimental campaigns. Particular attention will be paid to modularity, so that additional sensors such as thermocouples, pressure probes, fuel flow meters, load cells, vibration sensors, or data acquisition systems can be integrated in later stages.

The expected outcome is a complete pre-design study and a first operational or partially operational prototype of a gas turbine laboratory bench. The deliverables will include the technical specifications, CAD drawings, component selection, assembly documentation, safety analysis, and recommendations for future instrumentation and laboratory exercises. This thesis is therefore mainly an engineering design and development project, with a strong practical dimension and a clear teaching objective

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|---------------------------------|--------------|
| Language | EN (english) |
| Open to other master's programs | Yes |

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| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Optimal Bidding Strategies for PEM Electrolysers in Electricity and Balancing Markets

Program : EM - Energy - M-IREMR-E

Description

Green hydrogen produced by water electrolysis is expected to play an important role in the decarbonisation of industrial sectors that are difficult to electrify directly, such as steel production, chemicals, refining, and heavy transport. However, electrolytic hydrogen remains more expensive than fossil-based hydrogen and natural gas, mainly because of the high investment cost of electrolysers and the strong influence of electricity prices on operating costs. One possible way to improve the economic performance of electrolysers is to exploit their operational flexibility. Since PEM electrolysers can behave as controllable electrical loads, they may adjust their consumption according to electricity market conditions and potentially provide flexibility services to the power system.

The objective of this master thesis is to develop an optimisation-based trading algorithm for a PEM electrolyser participating in electricity and balancing markets. The work will build on an existing framework developed in a previous master thesis, and will improve it by moving from deterministic perfect-foresight optimisation towards a more realistic rolling-horizon strategy based on imperfect forecasts. The thesis may also investigate probabilistic or stochastic optimisation approaches to account for uncertainty in electricity prices, reserve activation, and market outcomes. The literature review will therefore cover not only electrolyser operation, but also related flexibility assets such as batteries and demand-response systems, in order to identify relevant modelling strategies for market participation.

The student will first develop a simplified optimisation model for a single PEM electrolyser operating in the Belgian electricity market. Depending on the progress of the work, the first tests may also be performed on more academic or simplified case studies before moving to realistic market data. The initial model will focus on electricity purchase, hydrogen production, and possible revenues from balancing or ancillary service markets such as FCR, aFRR, and mFRR. It will then be progressively extended to include technical and intertemporal constraints, such as ramping limits, minimum operating load, start-up and shut-down constraints, hydrogen storage, and possibly hydrogen demand requirements.

A central part of the thesis will be the critical comparison of modelling and optimisation choices. The student will be expected not only to apply an existing model, but also to define, justify, and assess their own methodological approach. Several strategies may be compared, such as deterministic rolling-horizon optimisation, scenario-based stochastic optimisation, robust optimisation, or forecast-based heuristic strategies. Their performance will be evaluated in terms of hydrogen production cost, market revenues, operating profile, reserve availability, computational complexity, and sensitivity to forecast quality.

The expected outcome is a structured assessment of whether participation in electricity and balancing markets can significantly improve the business case for PEM electrolysers, and under which technical and market conditions this value is maximised. Depending on progress, the study may also compare the value of electrolyser flexibility across several European countries. The thesis requires basic knowledge of energy systems, hydrogen technologies, and electricity markets,

together with programming skills in Python, Julia, MATLAB, or a similar environment. An interest in optimisation, data analysis, and market modelling is essential.

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|---------------------------------|--|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Butrind Avdijaj (Butrint.Avdijaj@ulb.be)

Data-driven discovery of an interpretable turbulence-chemistry closure using Kolmogorov-Arnold Networks

Program : EM - Energy - M-IREMR-E

Description

Large Eddy Simulation (LES) of turbulent combustion requires subgrid-scale closures for turbulence-chemistry interactions. The Partially Stirred Reactor (PaSR) model parameterises the cell reacting fraction γ as a function of the Damköhler number: $\gamma=1/(1+Da)$ [1]. However, Da alone as a 1D formulation cannot capture the full thermo-physical behaviour of the flame.

Freitas et al. [2] demonstrated that Sparse Symbolic Regression can identify improved functional forms of γ from Direct Numerical Simulation (DNS) data. Piu et al. [3] further showed that a neural-network correction to γ improves heat release rate prediction across a wide range of LES filter widths. This thesis extends that line of work and employs a Kolmogorov-Arnold Network (KAN) [4] as the modelling architecture. Unlike standard neural networks, KANs represent high-dimensional functions through learnable univariate spline activations on each edge, making them interpretable and straightforward for symbolic equation extraction.

Research activities and goals:

A priori analysis and feature selection: Using a 3D DNS database, filtered fields will be analysed across multiple filter widths to evaluate which physical quantities carry the most important information for γ . Correlation and sensitivity analysis are to be used to assess feature relevance and guide input selection.

KAN training: A KAN will be trained on the selected feature pool to learn the mapping from the filtered thermo-physical quantities to γ . Regularisation will be employed to encourage the network to identify and retain only the important variables, pruning irrelevant connections and yielding a sparse and interpretable architecture.

Symbolic equation extraction: Because KANs decompose high-dimensional functions into univariate spline activations, the trained network will be directly used to extract a compact algebraic expression for γ . The discovered equation will be validated (a priori) against DNS data.

Student profile:

Background in fluid mechanics, thermodynamics & combustion

Experience with Python and machine learning

Familiarity with turbulent combustion modelling & CFD is a plus

References:

[1] Péquin, A., Iavarone, S., Malpica Galassi, R., & Parente, A. (2022). The partially stirred reactor model for combustion closure in large eddy simulations: Physical principles, sub-models for the cell reacting fraction, and open challenges. *Physics of Fluids*, 34(5), 055122. <https://doi.org/10.1063/5.0090970>

[2] Freitas, R. S. M., Pequin, A., Galassi, R. M., Attili, A., & Parente, A. (2023). Model identification in reactor-based combustion closures using sparse symbolic regression. *Combustion and Flame*, 255, 112925. <https://doi.org/10.1016/j.combustflame.2023.112925>

[3] Piu, L., Péquin, A., Freitas, R. S. M., Iavarone, S., Pitsch, H., & Parente, A. (2025). A data-driven approach to refine the partially stirred reactor closure for turbulent premixed flames. *Flow, Turbulence and Combustion*, 115(3), 1235–1260. <https://doi.org/10.1007/s10494-024-00626-3>

[4] Liu, Z., Wang, Y., Vaidya, S., Ruele, F., Halverson, J., Soljačić, M., Hou, T. Y., & Tegmark, M. (2025). KAN: Kolmogorov-Arnold Networks. *International Conference on Learning Representations (ICLR)*

2025. arXiv. <https://doi.org/10.48550/arXiv.2404.19756>

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRMAE, M-IRIFS |
| Number of topics | 1 |

Supervision

Supervisor : Alessandro Parente (alessandro.parente@ulb.be)

Co-supervisor : Alberto Procacci (alberto.procacci@ulb.be)

CFD modelling of power kites in OpenFOAM

Program : EM - Energy - M-IREMR-E

Description

Clean energy generation from wind is an essential pillar of the energy transition. The share of wind energy in the electricity production of the European Union reached 19% in 2024 and the installed capacity of on-land and offshore wind energy generation is expected to grow from 231 GW today to 351 GW in 2030.

In addition to conventional wind turbines, large power kites, similar to the sails used in kite surfing, can be used to extract power from high-altitude wind. This technology, known as airborne wind energy, is home to a rich eco-system of start-up companies, including KitePower, a Dutch company developing leading-edge inflatable (LEI) kites for renewable power generation.

In order to accurately predict and optimize the performance of power kites, it is necessary to better understand the complex flow physics around the system, e.g. the local interaction between the wind flow and the shape of the LEI kite as well as the resulting wake behind the system. When using computational fluid dynamics (CFD), different levels of fidelity can be used to model those systems: Local flow phenomena are typically investigated using body-resolving simulations, while wakes are often investigated using actuator techniques, such as the actuator line model (ALM).

The ALM technique is commonly used to simulate the wakes of large wind turbines with long, slender blades. In this approach, the turbine blades are represented as a series of discrete segments characterized by the aerodynamic polars of their corresponding 2D airfoil sections. The local flow interaction is then computed using a combination of velocity sampling and force distribution techniques. The objective of this Master thesis is twofold: first, to characterize the local and near-wake aerodynamics of an LEI kite using mid- and high-fidelity CFD techniques; and second, to assess the accuracy of classical ALM formulations for curved bodies against body-resolved reference simulations.

More information can be found in the accompanying document (see link).

https://vub-my.sharepoint.com/:b:/g/personal/thomas_haas_vub_be/IQCXTnho2O66QrYpapHw-H1HAWD2BJ3S-wSW7_ydwMzPW1U?e=hbQrBH

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| Language | EN (english) |
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| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A |
| Number of topics | 1 |

Supervision

Supervisor : Mark Runacres (Mark.Runacres@vub.be)

CFD modelling of wakes of floating offshore wind turbines in OpenFOAM

Program : EM - Energy - M-IREMR-E

Description

Clean energy generation from wind is an essential pillar of the energy transition. The share of wind energy in the electricity production of the European Union reached 19% in 2024 and the installed capacity of on-land and offshore wind energy generation is expected to grow from 231 GW today to 351 GW in 2030.

In order to accurately predict and optimize the performance of wind turbines and wind farms, it is necessary to better understand the complex flow physics of wind energy systems. This includes the local interaction between the wind flow and the turbine components, the effects of platform motion on the loads of floating offshore wind turbines, or the impact of upstream turbine wakes on the performance of a wind farm.

This work examines how the motion of floating offshore wind turbine (FOWT) platforms influences wakes dynamics and their interaction with the rotor. In particular, the effects of surge and pitch motions on the shedding and coherence of blade tip vortices in the turbine near-wake are investigated, along with their influence on rotor loads and far-wake development and recovery.

Wind turbine wakes can be modelled using different levels of fidelity, from low-fidelity engineering wake models to high-fidelity computational fluid dynamics (CFD) simulations, balancing modelling accuracy with computational effort. The objective of this Master thesis is to employ mid-fidelity CFD techniques to simulate, investigate, and better understand the characteristics of the wake of floating offshore wind turbines.

More information can be found in the accompanying document (see link).

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| | |
|---------------------------------|---------------|
| Language | FR (français) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A |
| Number of topics | 1 |

Supervision

Supervisor : Mark Runacres (Mark.Runacres@vub.be)

From Near Wake to Far Wake in Floating Offshore Wind Turbines: an Aerodynamic Perspective

Program : EM - Energy - M-IREMR-E

Description

Floating offshore wind turbines (FOWTs) extend the reach of wind energy to deep-water sites inaccessible to fixed-bottom technology. As global renewable energy targets continue to grow, the efficient exploitation of these sites becomes essential.

Unlike their fixed-bottom counterparts, FOWTs are mounted on moored floating platforms that undergo six-degree-of-freedom (6-DOF) motion driven by wave and wind loads. These motions modify the rotor inflow and can influence wake recovery, turbulence levels, and wake meandering. The wakes of FOWTs are critical for optimising wind farm layouts. Roll, pitch, and surge have all been found to aid wake replenishment; however, it remains unclear which motion effects must be retained in simplified wake models.

Several farm-flow models already exist. A prominent example is FAST.Farm, a low-fidelity tool that couples an implementation of the dynamic wake meandering model with OpenFAST. However, FAST.Farm may lack accuracy in certain regimes, meaning that higher-fidelity models based on computational fluid dynamics methods, such as OpenFOAM, may be required. These high-fidelity approaches, however, suffer from substantial computational cost, making them unsuitable for early-stage design. A possible middle ground is to replace the turbine representation in the low-fidelity model with a mid-fidelity, data-driven model developed in-house within the FLOW research group. This could reduce the computational demand while maintaining sufficient accuracy.

This master's thesis will investigate how the wake of a FOWT evolves from the near wake to the far wake, and how this evolution differs from the fixed-bottom case, using available low-fidelity farm-flow models. The results will then be compared, for tailored and relevant test cases, with high-fidelity model predictions. Model predictions will be validated against available wind-tunnel data and, where possible, against published higher-fidelity simulations. The study will focus on aerodynamic quantities such as velocity deficit, wake width, turbulence intensity, wake-centre displacement, and wake recovery rate. Finally, an attempt will be made to extend existing modular farm-flow models with an in-house aerodynamic turbine model, and the resulting predictions will be compared against simplified engineering wake models.

https://vub-my.sharepoint.com/:b:/g/personal/gulliver_orian_van_essche_vub_be/IQBVQ9VPEp8JQgoCmdSeF5VUASPTebMLG-sOSGlcOCogGue4?e=z5ZxDv

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|---------------------------------|----------------------------|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-A, M-IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Mark Runacres (mark.runacres@vub.be)

Co-supervisor : Gulliver Van Essche (gulliver.orian.van.essche@vub.be)

Data-Driven Modelling of Motion-Induced Wake Dynamics in Floating Offshore Wind Turbines

Program : EM - Energy - M-IREMR-E

Description

Floating offshore wind turbines (FOWTs) extend the reach of wind energy to deep-water sites, inaccessible to fixed-bottom technology. As global renewable energy targets increasingly grow, the efficient exploitation of these sites becomes essential.

Unlike their fixed-bottom counterparts, FOWTs are mounted on moored floating platforms that undergo six-degree-of-freedom (6-DOF) motion driven by wave and wind loads. This periodic platform motion fundamentally alters rotor aerodynamics and generates unsteady, motion-induced wake dynamics that are not captured by classical static wake models. These dynamic wakes propagate downstream and affect the loads and power output of turbines operating in a farm, making accurate and fast wake predictions a prerequisite for real-time wind farm control and fatigue load management.

High-fidelity computational tools (e.g., CFD) can resolve motion-induced wake effects, but their computational cost prohibits real-time or control applications. Data-driven reduced order models (ROMs), learn compact input to output representations of complex dynamics directly from data, and the FLOW research group has established in-house expertise in such methods. The Nettuno experiment provides an open experimental dataset for this purpose, with synchronised measurements of platform kinematics, rotor loads, stream-wise wake velocity and rotor speed. This combination of inputs (platform motion) and outputs (wake velocity, rotor loads) is ideally suited to training and validating data-driven ROMs.

The goal of this thesis is to develop and validate a data-driven ROM that maps platform motion signals to dynamic wake velocity profiles and rotor loads, using the Nettuno dataset as the primary training and validation resource.

https://vub-my.sharepoint.com/:b:/g/personal/gulliver_orian_van_essche_vub_be/IQBVQ9VPEp8JQqoCmdSeF5VUASPTebMLG-sOSGlcOCogGue4?e=z5ZxDv

| | |
|---------------------------------|----------------------------|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-A, M-IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Mark Runacres (mark.runacres@vub.be)

Co-supervisor : Gulliver Van Essche (gulliver.orian.van.essche@vub.be)

Stochastic modelling of load profiles for urban energy systems

Program : EM - Energy - M-IREMR-E

Description

The climate disruptions experienced globally over the past decades require a profound transformation of our societies, particularly of our energy systems. In urban environments such as the Brussels-Capital Region, space heating currently accounts for nearly 50% of total final energy consumption. As natural gas remains the dominant energy source to meet this demand, building heating systems must be decarbonised to achieve carbon neutrality targets by 2050.

Most decarbonisation plans rely on relatively rigid and conservative demand modelling. Yet demand estimation forms the basis for optimising decarbonisation pathways. Traditionally, the assessment of thermal demand (heating and cooling) is based on modelling the physical envelope of buildings and the technological systems installed within them. When the spatial and temporal scale of analysis increases – as in long-term urban or regional studies – numerous simplifying and often rigid assumptions are introduced to represent the entire building stock.

However, this aggregated approach tends to overlook the individuality of each building, both from a technical perspective (architectural characteristics, energy systems, and sector of activity) and from a social perspective (comfort preferences and user behaviours). Failing to account for these individual factors also leads to the neglect of other, more systemic dimensions, whether technical (e.g. network peak loads), social (e.g. usage inequalities), or legal (e.g. regulation and heritage protection). Consequently, urban transition strategies could be biased or even hindered.

The objective of this thesis is twofold: first, to highlight the unique characteristics of buildings; and second, to assess the systemic flexibility potential of energy demand through a disaggregated modelling approach.

The project is divided into two parts. First, the student will develop synthetic and stochastic demand-profile generators for gas and electricity consumption. Second, the model will be applied at the scale of the Brussels-Capital Region to evaluate the impact of different socio-technical demand-evolution scenarios.

The stochastic framework will make the underlying assumptions explicit and enable the quantification of uncertainty. The quality of the generated profiles will be assessed using currently available real-world consumption data. In particular, the student will analyse the impact of societal changes such as energy sharing practices or slow heating strategies on future demand scenarios.

A basic knowledge of Python and an interest in urban energy systems are essential prerequisites.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS |
| Number of topics | 1 |

Supervision

Supervisor : Procacci Alberto (alberto.procacci@ulb.be)

Co-supervisor : Coussement Axel (axel.coussement@ulb.be)

Can machine learning methods approximate the optimal power flow solution for electric transmission systems?

Program : EM - Energy - M-IREMR-E

Description

Context

Optimal Power Flow (OPF) determines the optimal operating point of a power system satisfying its physical and operational constraints. This problem already being non-linear, non-convex and computationally expensive, gets increasingly more complex with the increasing penetration of Renewable Energy Sources (RES). This evergrowing complexity motivates the growing interest in machine learning (ML) as a way to produce fast approximate solutions. However, applying ML to the operation of power systems is not straightforward as the problem is high-dimensional, physics imposes hard constraints, and model relevance depends on the operating regime of each power system case. This thesis takes the Power Grid Library for OPF Benchmarking (PGLib-OPF) as its experimental playground. This open dataset is a collection of AC transmission test cases curated for OPF, ranging from small pedagogical networks to realistic grids with thousands of buses.

Research question

How well do machine learning methods approximate OPF on the cases from the PGLib dataset, and what insights can be extracted on why they succeed or fail across cases and operating conditions?

Approach

The student will (i) familiarise with the provided OPF solvers and the PGLib dataset, (ii) generate labelled train/test data by perturbing case loads and re-solving, (iii) apply standard ML techniques (e.g. regression, random forests, MLPs...) to predict OPF outputs, (iv) evaluate prediction accuracy, optimality gap, constraint violations, and computational speed-up against the solver, and (v) analyse which case characteristics (size, congestion regime, topology...) correlate with model performance. An optional extension, time permitting, would explore graph-aware model architecture.

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|---------------------------------|--------------------|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Alberto Procacci (alberto.procacci@ulb.be)

Co-supervisor

Coussement Axel (axel.coussement@ulb.be)

Development of a Low-Power Gas Turbine Test Bench for RC-Size Engines
Feasibility Study of ULB as an Energy Hub within a Local Energy Community
Feasibility Study for the Decarbonisation of Heat Supply on ULB Campuses
Pedagogical Integration of Flight Simulators for Engineering Education
Development of a dynamic thermal energy storage model as a digital twin in a decentralized energy system
Investigation of Coupled CFD Modelling for Microwave Electrification of Industrial Heating
Experimental and OD Modelling Study of Water Injection in Hydrogen Spark-Ignition Engines for CHP Applications
Development of a Hydrogen–Diesel Dual-Fuel Engine Test Bench and OD Combustion Model for CHP Applications
CFD Modeling of Water Injection in Hydrogen-Fueled Internal Combustion Engines and Development of a OD Water Injection Model for CHP Applications
Implementation of a Temperature Control Strategy for CFD-Based Digital Twin of an Industrial Process
Modeling Electric Heating Resistance using multi-physics approach for industrial implementation
Adapted Chemical Reactor Networks for Fast Combustion Modelling under Variable Operating Conditions

Program : EM - Energy - M-IREMR-E

Description

Combustion modelling is a central challenge in energy and chemical engineering. Industrial systems such as gas turbines, furnaces, and engines involve strong interactions between fluid dynamics, chemical kinetics, turbulence, and heat transfer. High-fidelity CFD simulations coupled with detailed chemical mechanisms are powerful tools to analyse these systems, but they remain computationally expensive, especially when large reaction mechanisms are considered. This limits their use for parametric studies, design exploration, optimisation, or real-time applications. Reduced-order modelling approaches are therefore needed to retain the main physical and chemical behaviour of reacting flows at a much lower computational cost.

The objective of this master thesis is to investigate adapted Chemical Reactor Networks (CRN) as reduced-order models for combustion systems. A Chemical Reactor Network approximates a complex reacting flow by a set of interconnected ideal reactors, each representing a region of the flow with similar thermochemical properties. In conventional approaches, the network is generated from CFD data for one specific operating condition. When the operating conditions change, a new CFD simulation is often required to build a new network. This thesis will explore an alternative strategy: reusing a CRN structure obtained from a reference CFD case while modifying only the inlet conditions and operating parameters.

The work will first include a literature review on CRN methods, CFD-based reactor network

generation, clustering techniques, and reduced-order modelling for combustion. The student will then generate a CRN from existing CFD data by grouping computational cells into regions with similar thermochemical properties, such as temperature, mixture fraction, residence time, or species concentrations. Each region will be represented as an ideal reactor, and the mass exchanges between regions will define the reactor connectivity. The resulting network will be solved using a chemical kinetics tool such as Cantera.

The main part of the thesis will consist of assessing the robustness of the adapted CRN approach. The student will apply the same reactor network structure to operating conditions different from the reference case, by changing inlet temperature, equivalence ratio, mass flow rate, fuel composition, or other relevant parameters. The CRN predictions will then be compared with reference CFD simulations or experimental data when available. Key quantities may include temperature fields, major species, pollutant formation, heat release, and global combustion efficiency.

The expected outcome is a critical assessment of whether a CRN generated from one CFD case can be reused as a fast predictive tool over a range of operating conditions. The thesis will deliver a literature review, a CFD-to-CRN workflow, a set of adapted CRN simulations, and recommendations on the validity limits and possible improvements of the method. The project requires knowledge of fluid mechanics and thermodynamics, programming skills in Python, and an interest in combustion, CFD, and numerical modelling.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Alessandro Parente (alessandro.parente@ulb.be)

Co-supervisor : Asija Inciardi (asija.inciardi@ulb.be)

Development of a Hydrogen–Diesel Dual-Fuel Engine Test Bench and 0D Combustion Model for CHP Applications

Program : EM - Energy - M-IREMR-E

Description

Hydrogen–diesel dual-fuel engines are a promising solution for improving the efficiency and reducing the carbon intensity of combined heat and power systems. By introducing hydrogen into a conventional diesel engine, it becomes possible to partially substitute fossil fuel while maintaining the robustness, high efficiency, and ignition reliability of diesel combustion. Such systems are particularly relevant for CHP applications, where both mechanical or electrical power and useful heat recovery must be considered. However, hydrogen–diesel operation involves specific combustion challenges, including ignition delay, heat-release control, knock or abnormal combustion risks, NO_x emissions, and the interaction between diesel pilot injection and hydrogen–air combustion.

The objective of this master thesis is to design and implement a dedicated hydrogen–diesel dual-fuel engine test bench within the ULB-ATM laboratory, and to complement this experimental work with the development of a zero-dimensional combustion model. The test bench should enable controlled investigations of combustion behaviour, engine performance, emissions, and heat recovery potential under different operating conditions. The student will first carry out a literature review on hydrogen–diesel dual-fuel combustion, existing experimental setups, safety constraints linked to hydrogen use, and 0D modelling approaches for internal combustion engines.

The main part of the thesis will focus on the design and implementation of the experimental test bench. This will include the definition of the fuel supply architecture, hydrogen injection strategy, diesel operation mode, instrumentation, data acquisition system, safety procedures, and operating protocols. The bench should allow the measurement of relevant quantities such as engine speed, torque or load, fuel consumption, hydrogen flow rate, temperatures, pressures, exhaust composition, and recoverable heat. Particular attention will be paid to safe hydrogen handling, ventilation, leak detection, emergency shutdown, and compatibility with laboratory constraints.

In parallel, the student will develop or adapt a 0D combustion model of the hydrogen–diesel dual-fuel engine. The model should reproduce the main features of the combustion process, including pressure and temperature evolution, ignition delay, heat-release rate, diesel pilot contribution, hydrogen energy fraction, and global engine performance. When experimental data are available, the model will be compared with measurements in order to assess its accuracy and limitations.

The expected outcome is a first experimental and numerical platform for studying hydrogen–diesel dual-fuel engines in CHP conditions. The deliverables will include a literature review, the design and implementation of the test bench, initial experimental results, a validated or partially validated 0D model, and a preliminary analysis of operating conditions favourable to efficient heat recovery. The thesis will require knowledge of thermodynamics, combustion, heat transfer, and piston engines, as

well as programming skills in Python, MATLAB, or a similar environment. Practical skills and the ability to work with the ATM technical team will be important assets.

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|---------------------------------|--|
| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Cyril Freyling (cyril.freyling@ulb.be)

Experimental and 0D Modelling Study of Water Injection in Hydrogen Spark-Ignition Engines for CHP Applications

Program : EM - Energy - M-IREMR-E

Description

Hydrogen spark-ignition engines are a promising solution for low-carbon combined heat and power applications, where both mechanical or electrical power and useful heat can be produced. However, hydrogen combustion remains challenging because of high combustion temperatures, NO_x emissions, knock, and pre-ignition risks. Water injection is a potential strategy to mitigate these limitations by reducing in-cylinder temperatures and modifying the combustion process. In a CHP context, this temperature control is also important because it affects not only engine efficiency and emissions, but also the amount and quality of recoverable heat.

The objective of this master thesis is to design and implement an experimental setup to study water injection under conditions representative of hydrogen spark-ignition engines. A key question will be to determine whether the injected water enters the engine as liquid droplets, vapour, or a two-phase mixture, depending on injection pressure, temperature, timing, injected quantity, and operating conditions. The student will therefore first carry out a literature review on hydrogen engine combustion, abnormal combustion phenomena, NO_x formation, and water injection strategies in internal combustion engines.

The main part of the thesis will consist of developing a dedicated experimental setup for water injection characterisation. This setup should make it possible to study the evaporation behaviour, droplet dynamics, temperature evolution, and resulting phase of the injected water before its introduction into the engine. Once the methodology has been characterised, the system will be implemented on a real hydrogen spark-ignition engine. Experimental tests will then be used to assess the impact of water injection on combustion behaviour, performance, efficiency, knock tendency, thermal behaviour, and NO_x emissions.

In parallel, the student will develop or adapt a zero-dimensional combustion model of a hydrogen spark-ignition engine including the effects of water injection. The model should account for injected water quantity, evaporation, mixture dilution, temperature reduction, heat-release behaviour, engine performance, and CHP efficiency. When experimental results are available, the model will be compared with measurements in order to assess its validity and limitations.

The expected outcome is a first experimental and numerical framework for analysing water injection in hydrogen spark-ignition engines. The main deliverables will be a literature review, the design and implementation of the water-injection test setup, a first implementation on the hydrogen engine test bench, and a validated or partially validated 0D model. The thesis will require good knowledge of thermodynamics, heat transfer, and piston engines, as well as programming skills in Python, MATLAB, or a similar environment. Practical skills and the ability to work with the ATM technical team will be important assets.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Cyril Freyling (cyril.freyling@ulb.b)

Development of a dynamic thermal energy storage model as a digital twin in a decentralized energy system

Program : EM - Energy - M-IREMR-E

Description

In an attempt to reduce the impact of climate change on our planet, we are shifting away from fossil fuels toward more renewable energy sources. However, integrating more renewable energy sources, such as solar and wind, comes with its challenges. To maximize the use of energy produced by renewable sources, storage will become increasingly important in energy systems. This makes it possible to use excess energy at later times when necessary and to balance the energy production and demand curves more efficiently. When analyzing energy consumption, after electricity and transportation, heating for space heating and hot water production is a substantial part of our energy needs. An efficient way to meet our electricity and heating needs is to use combined heat and power (CHP) units, such as micro gas turbines (MGT) or internal combustion engines (ICE), where the excess heat from the exhaust gas can be used to heat water for district heating networks (DHN). Oftentimes, electricity production is the main driver in the CHP units, so reliable heat storage is necessary to benefit later.

The thesis will focus on developing a dynamic model of thermal energy storage (TES) that accounts for thermal inertia. This model can then be used as a digital twin, an accurate but fast model that receives information from the physical system and can be used for real-time optimization. The TES can be implemented in an energy system that needs to be optimized to ensure that the available power and heat match demand, and it can also be used to reduce fossil fuel emissions or utilization costs. The modeling, optimization, and control of the energy system can be used to predict our ideal energy generation mix and also allow us to adapt our plan in case of disturbances, e.g., more clouds than expected, which reduces available solar energy.

First, the student conducts an extensive literature review on thermal energy storage and examines how it is modeled to balance accuracy and computational speed. Once the student has developed an idea for this model, it will be implemented in Python. During this phase, different methods can be explored and compared to results in the literature. The thermal energy storage model will be integrated into an available district heating network model. The control system will be developed to demonstrate its use in optimizing the heating network.

The student does not need any prior knowledge of energy systems or thermal energy storage, but should be interested in learning. As this project will mainly consist of programming, basic knowledge of Python is required.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Zoraida Nti (zoraida.nti@ulb.be)

Feasibility Study for the Decarbonisation of Heat Supply on ULB Campuses

Program : EM - Energy - M-IREMR-E

Description

The objective of this master thesis is to perform a first feasibility study on the decarbonisation of heat supply on ULB campuses, in close collaboration with the ULB cellule énergie. At present, the university's heat demand is mainly covered by natural gas boilers using CH₄. The aim of the thesis is to assess possible pathways to reduce or eliminate fossil fuel use for heating, while taking into account the technical, economic, operational, and spatial constraints of university campuses.

The work will first consist of characterising the current heat demand and heat production infrastructure. The student will analyse available data on gas consumption, heating networks, boiler rooms, building uses, occupancy patterns, temperature levels, and seasonal demand profiles. Particular attention will be paid to the distinction between peak heat demand, annual heat consumption, supply temperatures, and the flexibility of the buildings, since these elements strongly influence the feasibility of low-carbon heating solutions.

The student will then identify and compare a broad range of decarbonisation options. These may include heat pumps, geothermal energy, shallow geothermal storage, connection to existing or future district heating networks, heat recovery from local sources, solar thermal systems, biomass where relevant, hybrid systems combining gas and low-carbon technologies, and progressive electrification strategies. The analysis should also consider demand-side measures, such as reducing supply temperatures, improving control strategies, exploiting thermal inertia, and prioritising building-level efficiency improvements when they enable more efficient low-carbon heat production.

A simplified modelling framework will then be developed to compare several transition scenarios. These may include a reference scenario based on the current CH₄ supply, partial electrification through heat pumps, geothermal-assisted heating, hybrid systems for peak demand, and more integrated campus-scale solutions combining storage, heat recovery, and demand management. The comparison should estimate key indicators such as energy consumption, fossil fuel reduction, CO₂ emissions, peak electrical power, seasonal performance, investment cost, operating cost, spatial requirements, implementation complexity, and robustness of supply.

Finally, the thesis will address practical aspects in collaboration with the ULB cellule énergie. This includes data availability, technical constraints in existing buildings, compatibility with current heating networks, regulatory aspects, phasing of investments, and the identification of priority sites or pilot projects. The expected outcome is a structured feasibility report assessing which decarbonisation pathways are most promising for ULB campuses, under which conditions they could be implemented, and what further studies would be required. The work will provide quantitative first estimates and a roadmap toward a progressive reduction of CH₄-based heating on campus.

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| Language | EN (english) |
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| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Feasibility Study of ULB as an Energy Hub within a Local Energy Community

Program : EM - Energy - M-IREMR-E

Description

The objective of this master thesis is to perform a first feasibility study on the potential role of ULB as an energy hub within a local energy community, at the scale of the urban block or neighbourhood surrounding the university campus. The project will be carried out in close interaction with the ULB cellule énergie, with the aim of evaluating how the university's buildings, energy infrastructure, consumption profiles, and potential local production assets could contribute to a collective energy strategy.

The work will focus on identifying the technical potential for ULB to act as a local energy hub. This includes assessing opportunities for photovoltaic production, demand-side management, heat recovery, battery or thermal storage, electric vehicle charging, and possible interactions with neighbouring buildings or users. The analysis should consider both electrical and thermal energy flows, and evaluate whether coupling these vectors could bring additional value at neighbourhood scale.

The student will then develop a simplified modelling framework to compare several energy-community scenarios. These may include a reference case without energy sharing, a scenario with increased local renewable production, a scenario including flexible loads or storage, and a more integrated energy-hub scenario. The model should estimate key indicators such as self-consumption, self-sufficiency, peak power reduction, CO₂ emissions, energy costs, and possible benefits for participating users. The level of modelling will remain compatible with a first feasibility study, while being sufficiently detailed to support concrete recommendations.

Finally, the thesis will address practical and organisational aspects in collaboration with the ULB cellule énergie. This may include data availability, regulatory constraints, metering requirements, governance models, and the identification of priority actions for a future demonstrator. The expected outcome is a structured feasibility report assessing whether, and under which conditions, ULB could become a central actor in a local energy community. The work will provide both quantitative first estimates and a roadmap for further technical, economic, and institutional development.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Modelling of a hybrid hydrogen PEMFC / Heat Pump micro combined heat and power system

Program : EM - Energy - M-IREMR-E

Description

Combined heat and power systems (CHP) based on hydrogen fuelled PEMFCs (Proton Exchange Membrane Fuel Cells) present an attractive solution for decentralized, low carbon heat and power production. Its global efficiency can reach up to 85%, but at as a standalone system, it cannot cover large space heating demands during cold seasons due to the limited heat production that is retrieved from the PEMFC cooling system. Therefore, a novel idea consists in investigating a system in which a PEMFC exclusively powers an air-source heat pump (ASHP), forming a tightly coupled, grid-independent heating unit, and leveraging its high coefficient of performance in the process. The master's thesis will consist of developing the digital twin of an experimental facility investigating the performance of such CHP system. Particular care will be taken on modelling the stratified domestic water tank and sizing the air-source heat pump to guarantee that the whole CHP system satisfies energy demands throughout the year.

The student will also investigate the behaviour of a sized PEMFC-HP system deployed as a CHP unit within a residential energy community, and to determine which cases favour the use of a PEMFC-HP system (with regards to hydrogen supply cost, electricity tariffs, community demand profiles, and climate) offers advantages over competing alternatives.

Prerequisites:

- Interest in sustainability and renewable energy
- Programming in Python and/or MATLAB
- Background in electrical engineering, thermodynamics, energy systems, or building technologies

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| Language | EN (english) |
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Patrick Hendrick (patrick.hendrick@ulb.be)

Co-supervisor : Bilal Outirba (bilal.outirba@ulb.be)

Analysis of Heat and Mass Transport During Hydrogen Bubble Growth in Water Electrolysis

Program : EM - Energy - M-IREMR-E

Description

Hydrogen can be produced by splitting water through electrochemical reactions in electrolysis. Although the process is overall endothermic, additional heat can be generated locally, most notably through Joule heating at the electrode surface. This localized heating modifies the temperature field near the growing hydrogen bubble, creating temperature gradients that induce thermocapillary (Marangoni) flows along the bubble interface.

In addition to thermal effects, concentration gradients of surface active species such as ions or dissolved gases can also alter surface tension, resulting in solutal Marangoni convection. These interfacial flows strongly affect bubble growth, shape, and detachment dynamics. Understanding these coupled effects requires the ability to accurately resolve the local temperature and concentration fields around the bubble. However, measuring both fields at the same time remains a significant experimental challenge.

Previous studies have demonstrated that at high applied potentials, Joule heating dominates, and thermocapillary effects become the primary drivers of interfacial motion, while solutal effects can often be neglected. Various optical techniques such as Schlieren imaging, laser induced fluorescence, and interferometry have been used to study these fields.

Mach Zehnder interferometry stands out as a noninvasive and calibration free technique for resolving instantaneous temperature fields with high sensitivity.

This thesis will focus on hydrogen bubble dynamics on a microelectrode in acidic electrolysis, using two complementary experimental techniques:

- Mach Zehnder Interferometry, to quantify the temperature field near the electrode and at the base of the bubble, especially when concentration variations are negligible.
- High speed visualization, to qualitatively capture the bubble inception, growth, and detachment processes.
- Complementary Schlieren imaging may be used for qualitative validation as done in the previous study [1].

Methodology

1. Literature survey

The student will begin by familiarising themselves with the topic. A thorough review of recent literature, especially on interferometric and visualisation techniques applied to gas-evolving electrodes, will help define the research scope and objectives.

2. Experimental set-up

The student will work with the existing electrolysis cell, Mach Zehnder interferometer, and high-speed imaging system available at the TIPS laboratory. This phase will involve hands-on training with laser alignment, optical adjustments, electrode handling, and system calibration. The student will also participate in test runs to optimise measurement conditions and gain confidence in operating the setup independently.

3. Measurement campaign and data analysis

The student will conduct experiments to visualise hydrogen bubble growth on microelectrodes using high-speed imaging and Mach Zehnder interferometry. Interferometric data will be analysed to extract local temperature fields, while high-speed recordings will be used to characterise bubble shape, growth, and detachment dynamics. Post-processing and analysis will be carried out using MATLAB. If numerical simulation results are available, they will be compared with the experimental data. In parallel, the student will measure the refractive index, density, and viscosity of the electrolyte across different concentrations and temperatures, using the available facilities at the TIPs laboratory, ULB.

4. Reporting

- ☐ Weekly meetings with the supervisor to define tasks and discuss outcomes and practicalities.
- ☐ Monthly meeting with the team and the promotor to verify the progress and discuss follow-up
- ☐ Final presentation

References

- [1]. A. Babich, A. Bashkatov, X. Yang, G. Mutschke, and K. Eckert, "In-situ measurements of temperature field and Marangoni convection at hydrogen bubbles using schlieren and PTV techniques," *Int. J. Heat Mass Transf.*, vol. 215, p. 124466, 2023.
- [2]. J. Massing, G. Mutschke, D. Baczyzmalski, S. S. Hossain, X. Yang, K. Eckert, and C. Cierpka, "Thermocapillary convection during hydrogen evolution at microelectrodes," *Electrochimica Acta*, vol. 297, pp. 929–940, 2019.

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|---------------------------------|--------------|
| Language | EN (english) |
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Pierre Colinet (pierre.colinet@ulb.be)

Co-supervisor : Senthil Kumar Parimalanathan (senthil.parimalanathan@ulb.be)

Electro-Mechanical Engineering – Energy

Master Thesis Topics (M-IREMR-E)

Academic year 2026–2027

Critical Parameter Identification for Low-Temperature Cycling of Lithium-Ion Batteries for safety reasons.

Program : EM - Energy - M-IREMR-E

Description

Cycling lithium-ion batteries at low temperatures induces characteristic degradation effects, including increased internal resistance, lithium plating, change SEI behavior, and modified heat-generation patterns. This thesis investigates how these parameters evolve under controlled low-temperature cycling conditions. The student will perform cycling experiments at selected ambient temperatures, analyze the resulting changes in key electrochemical parameters, and identify which of them have the strongest influence on thermal-runaway initiation and progression. The dominant low-temperature effects will then be formulated in a simplified representation suitable for integration into an existing thermal runaway model, enabling more accurate prediction of aged-cell behavior under abuse conditions.

| Language | EN (english) |
|--|--------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar

Contact : maitane.berecibar@vub.be

Lien : <https://mobi.paddlecms.net/battery-innovation-centre-homepage>

Developing a Physics-Based Pack-Level Digital Twin Using Network-Coupled Single Particle Models (SPM)

Program : EM - Energy - M-IREMR-E

Description

Description

Electric vehicles and renewable energy storage rely heavily on Battery Management Systems (BMS). However, current commercial BMS software often uses simplified "black box" models that ignore the actual physical chemistry happening inside the battery cells. To improve performance and safety, the industry is rapidly shifting toward Digital Twins—highly accurate, virtual replicas of battery packs that predict state-of-charge and degradation in real time. This thesis offers the opportunity to build the fast, physics-based models required to make these digital twins a reality. Using the highly efficient Single Particle Model (SPM), you will simulate the internal electrochemical behavior of a single lithium-ion cell and scale it up to model an entire networked battery pack. This project provides highly sought-after, hands-on experience designing the next generation of smart battery software.

Objectives

- **Develop:** Build a baseline Single Particle Model (SPM) to capture a single cell's core electrochemistry.
- **Scale:** Connect individual SPM cells into a series/parallel pack network to simulate system-level electrical behavior.
- **Validate:** Test the pack-level digital twin's accuracy and speed against standardized lab drive-cycle data.

Methodology

The project will proceed through the following key steps:

- **Review:** Study the Single Particle Model and its application in battery digital twins.
- **Build:** Use standard tools (COMSOL, MATLAB/Simulink, Python, or PyBaMM) to develop the cell SPM and scale it into a pack network.
- **Simulate & Validate:** Run dynamic simulations (e.g., standard EV driving profiles) and validate the model's accuracy against existing laboratory test results.

Pre-requisites

The candidate is expected to have the following experience/skills:

- Basic knowledge of electrochemistry, lithium-ion battery fundamentals, and differential equations.
- Familiarity with simulation and modeling tools e.g., COMSOL, MATLAB/Simulink, Python, or PyBaMM is an added advantage.

| Language | EN (english) |
|--|--------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar

Contact : maitane.berecibar@vub.be

Co-supervisor: Sazzad Hosen

Contact : md.sazzad.hosen@vub.be

Lien : <https://mobi.paddlecms.net/battery-innovation-centre-homepage>

Clean energy & sustainable propulsion: Adjoint optimization for LES of hydrogen flames

Program : EM - Energy - M-IREMR-E

Description

- Hard-to-abate industries and heavy-duty transportation will keep relying on combustion-based applications due to the high required energy densities and high process temperatures. Hydrogen-based fuels are a viable option to decarbonize these sectors.
- Hydrogen and ammonia flames dynamics are entirely different to conventional fuels and burner geometries need to be adapted.
- The goal is to couple an adjoint based optimization algorithm with an existing LES framework, which models hydrogen combustion.
- The goal is to apply the developed framework to a particular burner geometry and optimize it, e.g. such that minimal emissions are obtained.

| Language | EN (english) |
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| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Lukas Berger

Contact : lukas.berger@vub.be

Specific Heat Capacity Characterization of Lithium-Ion Batteries Using Hybrid Methodology and ARC Validation.

Program : EM - Energy - M-IREMR-E

Description

Accurate knowledge of the specific heat capacity (C_p) of lithium-ion batteries is essential for reliable thermal modelling and prediction of thermal runaway behavior. This thesis investigates a novel methodology for determining C_p under controlled conditions and compares its results with measurements obtained through Accelerating Rate Calorimetry (ARC). The student will characterize several Li-ion cell types, quantify discrepancies between methods, and assess the influence of state-of-charge and temperature. The experimentally derived C_p values will then be integrated into an existing thermal runaway model to evaluate their impact on simulation accuracy and safety-critical predictions.

| Language | EN (english) |
|--|--------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar

Contact : maitane.berecibar@vub.be

Lien : <https://mobi.paddlecms.net/battery-innovation-centre-homepage>

Grid-Forming Droop Control with Seamless Islanding Transition for a Battery-Based Vehicle-To-Grid Unit

Program : EM - Energy - M-IREMR-E

Description

The ability of a vehicle-to-grid (V2G) unit to transition seamlessly between grid-connected and islanded operation is critical for microgrid resilience. This thesis will design a droop-based grid-forming controller that detects islanding and autonomously reconfigures its control loops, validated experimentally using the battery-connected inverter as the grid-forming source and a machine as a local load.

| Language | EN (english) |
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| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Number of topics | 1 |

Supervision

Supervisor : Johan Gyselinck

Contact : johan.gyselinck@ulb.be

Cybersecurity of electric power systems

Program : EM - Energy - M-IREMR-E

Description

Modern power systems have evolved into complex Cyber-Physical Power Systems (CPPS) due to the rapid integration of advanced sensors, communication networks, and computing technologies, which are needed to manage the energy transition (e.g., management of the variability of renewable energy sources). Ensuring the cybersecurity of CPPS has thus become of utmost importance for maintaining the stability and reliability of future electricity grids. This MSc will aim at analyzing the cybersecurity either of a microgrid (option 1) or of a transmission system (option 2), and at proposing solutions to improve it.

Regarding option 1, the idea will be to study experimentally cyber-attacks towards pieces of equipment that are typical of microgrids gathering a few households: smart meters, solar PV systems, batteries, EV chargers, smart loads, etc. based on the smart electric energy systems lab under development within BEAMS.

Option 2 is expected to focus on False Data Injection Attacks (FDIAs). They stealthily manipulate measurement data, potentially bypassing traditional bad data detection mechanisms. A successful FDIA can mislead the State Estimation (SE) process — as a grid monitoring tool — thereby causing incorrect operational decisions and potentially causing serious physical and economic impacts on the power system. The MSc thesis will then aim to conduct a probabilistic cybersecurity assessment of Remote Terminal Units (RTUs) and the State Estimation function under FDIA scenarios. The student will begin by identifying potential vulnerabilities in RTUs and SE through established threat modeling techniques. Building on this analysis, a probabilistic framework will be developed—using methods such as attack trees and attack graphs—to estimate the likelihood of different attack scenarios. In a more advanced phase, the project will involve constructing attack impact assessment models, potentially exploring injection vectors and attacker-defender bi-level optimization approaches to quantify the effects of successful FDIAs on key power system reliability indices.

| Language | EN (english) |
|--|------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M- IRPH |
| Number of topics | 2 |

Supervision

Supervisor : Pierre Henneaux

Contact : pierre.henneaux@ulb.be

Co-supervisor: Jean-Michel Dricot

Contact : jean-michel.dricot@ulb.be

Inertia Estimation in Inverter-Dominated Distribution Systems: A Simulation and Machine Learning Perspective

Program : EM - Energy - M-IREMR-E

Description

This MSc thesis will address the challenge of inertia estimation in inverter-dominated electric power systems, a growing concern as power systems transition toward renewable energy sources such as solar PV and wind. Traditional power systems rely on the physical inertia of synchronous generators to stabilize frequency during disturbances. In contrast, inverter-based resources lack inherent inertia, leading to faster frequency deviations, reduced stability margins, and higher sensitivity to disturbances.

In modern autonomous distribution systems, inertia is no longer a constant physical parameter but a dynamic, operating-point-dependent characteristic influenced by control delays, power electronics, and load behavior. Classical inertia estimation techniques based on the swing equation are shown to be inadequate, as their assumptions do not reflect inverter-based system dynamics. The objective of this MSc thesis is to analyze and compare inertia estimation approaches and to investigate whether machine learning (ML) can more effectively capture system behavior. A structured review of model-based, measurement-based, and data-driven methods will be conducted to assess their applicability and limitations. The methodology will involve simulating an autonomous distribution system in MATLAB/Simulink, including inverter-based generation, virtual inertia control, response delays, and dynamic loads. Disturbance scenarios will be applied to study frequency response. An ML-based approach will then be implemented using simulation data to estimate inertia-related behavior, and its performance is compared with conventional methods.

| Language | EN (english) |
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| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Pierre Henneaux

Contact : pierre.henneaux@ulb.be

Clean energy & sustainable propulsion: Machine learning methods in LES of hydrogen flames

Program : EM - Energy - M-IREMR-E

Description

- Hard-to-abate industries and heavy-duty transportation will keep relying on combustion-based applications due to the high required energy densities and high process temperatures. Hydrogen-based fuels are a viable option to decarbonize these sectors.
- Hydrogen and ammonia flames dynamics are entirely different to conventional fuels and local flame propagation, which is a key design parameter, is challenging to predict. However, validated simulation tools are indispensable for technology development nowadays
- The goal is to learn the flame propagation from direct numerical simulation (DNS) with machine learning methods
- Apply data-driven model to industrial-relevant large-eddy simulations (LES)

| Language | EN (english) |
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| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH |
| Number of topics | 2 |

Supervision

Supervisor : Lukas Berger

Contact : lukas.berger@vub.be

Oxygen as a Revenue Stream: Valorising Electrolysis By-Products to in Power-to-Gas Techno-Economic Viability A Case Study on UZ Brussel Hospital as a Potential Oxygen and Hydrogen Offtaker

Program : EM - Energy - M-IREMR-E

Description

THE IDEA

Every kilogram of green hydrogen produced by electrolysis also produces roughly 8 kg of oxygen — which is typically vented to the atmosphere at no value. At the same time, hospitals are among the largest and most reliable consumers of medical-grade oxygen, purchasing it as liquid O₂ delivered by truck at significant cost. UZ Brussel, located near the Green Energy Park's hydrogen infrastructure, represents a concrete and underexplored opportunity: if the hospital's oxygen demand can be met by the electrolyser's by-product stream, the resulting revenue directly reduces the levelised cost of hydrogen (LCOH) and improves the overall business case for power-to-gas. The central research objective is:

Quantify the economic impact of supplying UZ Brussel's oxygen demand from electrolysis by-product, and assess whether co-valorisation improves power-to-gas profitability and viability. This is applied, data-driven research: the thesis collects real consumption and cost data from the hospital, maps it against the electrolyser's output profile, and builds an economic model that captures the full value chain from electrolysis to offtake.

WHAT THE THESIS WILL DO

- Characterise UZ Brussel's oxygen demand: annual consumption (Nm³/year), daily load profile, purity requirements (medical-grade ≥ 99.5% O₂, EN ISO 7396-1), storage and delivery constraints, and current procurement cost (€/Nm³ or €/tonne)
- Map the electrolyser's O₂ output profile against hospital demand: assess temporal match, surplus/deficit periods, and whether a buffer storage vessel bridges the gap
- Build a techno-economic model: quantify the O₂ revenue stream (€/year), its impact on LCOH and the sensitivity of project NPV and payback period to O₂ price, utilisation rate, and electrolyser capacity
- Explore the hydrogen side: assess whether the hospital has potential demand for H₂ itself (fuel cell CHP, medical sterilisation, mobility) and size the combined offtake scenario

WHY IT MATTERS

Green hydrogen projects across Europe struggle with economics: high CAPEX, low utilisation, and hydrogen offtake uncertainty. Co-valorising oxygen with a nearby anchor customer is one of the few levers that improves unit economics without requiring a higher hydrogen price. The VUB UZ hospital is an ideal offtaker: continuous, predictable, price-regulated, and socially compelling.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Maarten Messagie

Contact : maarten.message@vub.be

Co-supervisor: Ander Martinez Alonso

Contact : Ander.Martinez.Alonso@vub.be

Lien : Bornemann, Lange & Kaltschmitt (2025) Oxygen production via electrolysis: A model-based assessment of its impact on a climate-neutral German energy system. *Energy Conversion and Management* 344, 120213. • Gustavsson et al. (2023) Potential use and market of oxygen as a by-product from hydrogen production. *Energiforsk Report* 2023:937.

Development of an online thermal imaging framework to detect hot spot during the regular operation of battery modules

Program : EM - Energy - M-IREMR-E

Description

The lack of accurate cell-level instrumentation reduces the ability to detect and prevent, in real time, safety-related scenarios during the operation of a battery module or pack. In this context, the implementation of online thermal imaging strategies and their interface with the Battery Management System (BMS) could represent a reliable alternative for detecting irregular temperature profiles across the battery cells comprising a battery module.

The goal of this Master's thesis project is to develop a framework for the real-time analysis of infrared (IR) thermal images to detect hotspots via image processing software in the loop — potentially enhanced by data-driven approaches — with results to be transmitted to a BMS via either Ethernet or Controller Area Network (CAN) bus communication. Therefore, prospective candidates are strongly encouraged to have a solid background in image processing and communication tools.

| Language | EN (english) |
|--|--------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS |
| Number of topics | 2 |

Supervision

Supervisor : Paolo Falcone

Contact : paolo.falcone@ulb.be

Co-supervisor: Alejandro Goldar Davila

Contact : alejandro.goldar.davila@ulb.be

Quantum computing for power system reliability assessment

Program : EM - Energy - M-IREMR-E

Description

Power system reliability is a general concept describing its ability to deliver electricity to all points of utilization within acceptable standards and in the amount desired. The predictive assessment of power system reliability is of paramount importance to ensure beforehand that it will meet desired standards. Due to intrinsic uncertainties arising within electric power systems (e.g., failures of pieces of equipment, variability of renewable energy resources, ...), power system reliability is characterized by probabilistic indicators such as the Loss Of Load Probability (LOLP, the probability that the system is not able to supply all the load while fulfilling operational constraints) and the Expected Energy Not Served (EENS, the energy that the system is not able to supply but should have supplied). These indicators are currently estimated mainly through Monte Carlo simulation for real power systems. Although the implementation of Monte Carlo is straightforward, it leads to significant computation times to obtain results with the desired statistical accuracy. In that context, quantum computing could help to estimate in an efficient way power system reliability indicators. The purpose of this MSc thesis will be to develop a methodology based on quantum computing to tackle a specific problem related to power system reliability assessment (e.g., adequacy of the generation system) and to compare its performances with a Monte Carlo simulation.

| Language | EN (english) |
|--|------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Pierre Henneaux

Contact : pierre.henneaux@ulb.be

Co-supervisor: Pierre-Etienne Labeau

Contact : Pierre.Etienne.Labeau@ulb.be

Fast diagnostic feasibility of EV battery modules to determine SoH and Remaining Useful Life.

Program : EM - Energy - M-IREMR-E

Description

A fast diagnosis methodology using already available data.

Design and development of the battery model, SoC/SoH estimation, thermal runaway, and battery aging model.

Validation of EoL battery decision-making methodology using tested modules to simulate real-world conditions, to establish criteria for reuse or recycling of modules.

| Language | EN (english) |
|--|--------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar Uribe

Contact : maitane.berecibar@vub.be

Co-supervisor: Md Sazzad Hosen

Contact : md.sazzad.hosen@vub.be

Lien : <https://mobi.research.vub.be/battery-innovation-centre-homepage>

Shared Battery and PV Optimisation for Flat Buildings in the Context of Sibelga's Energy Sharing Framework in Brussels.

Program : EM - Energy - M-IREMR-E

Description

The growing deployment of rooftop photovoltaic (PV) systems in urban multi-family buildings has renewed interest in shared battery storage as a means of maximising local renewable self-consumption and reducing energy costs for residents. Simulation studies consistently demonstrate that community-level battery systems, when coupled with shared PV, outperform individual per-unit configurations: collective storage can reduce total required battery capacity by up to ~37% while cutting sharing losses by ~55%, and self-sufficiency rates exceeding 60% have been reported for apartment building case studies. Techno-economic analyses further show that peer-to-peer (P2P) energy trading combined with shared battery storage can reduce average electricity costs by approximately 8–10% per resident, with self-consumption rates reaching ~69% and payback periods below five years under realistic assumptions. Beyond purely economic gains, shared energy systems have been shown to generate social co-benefits when allocation mechanisms are designed with fairness principles in mind. The role of the distribution system operator (DSO) is critical in this context: as prosumption and bidirectional flows increase, DSOs must adapt their network management, tariff structures, and coordination interfaces to accommodate local energy communities.

In Brussels, this transition is actively supported by Sibelga, which has established a regulatory and technical framework for energy sharing in three modalities: peer-to-peer exchange, within-building sharing (energiesdelen in eenzelfde gebouw), and broader energy communities (energiegemeenschappen). Sibelga's smart meter infrastructure and electricity perimeter request process provide the operational backbone for allocating shared production among participants, making the Brussels context technically ready for shared battery integration. However, despite the growing body of international simulation literature on shared PV and battery systems for apartment buildings, no study to date has specifically modelled or evaluated such configurations within the Brussels regulatory environment, accounting for Sibelga's allocation methodology, local tariff structures, or the dense urban apartment typology characteristic of the Brussels housing stock. This research gap represents a clear opportunity: a simulation study tailored to the Brussels-Sibelga context could quantify the technical and economic benefits of a shared battery system for flat building residents, assess the impact of PV integration under local irradiation conditions, and provide actionable recommendations for DSO-facilitated energy sharing in a dense urban capital region.

| Language | EN (english) |
|--|--------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE |
| Number of topics | 1 to 2 |

Supervision

Supervisor : De Cauwer Cedric Contact : Cedric.De.Cauwer@vub.be

Evaluation of Time-Series Models for State of Health and Remaining Useful Life Estimation Using Real-World EV Fleet Data

Program : EM - Energy - M-IREMR-E

Description

Description of the thesis work:

This thesis dives into one of the most critical challenges in electric mobility: understanding and predicting battery health using real-world EV data. You'll work with large-scale fleet data and apply modern time-series models to estimate battery State of Health (SOH) and predict Remaining Useful Life (RUL). Unlike ideal lab conditions, field data reflects real driving, charging behavior, and environmental effects—making the problem both challenging and highly relevant. The idea of this thesis combines energy systems knowledge with cutting-edge AI, giving you hands-on experience at the intersection of battery technology, data science, and next-generation EV innovation.

Objectives:

- Develop a structured pipeline to preprocess and extract time-series data from EV fleet datasets.
- Implement and benchmark multiple time-series.
- Evaluate model performance for SOH estimation and RUL prediction tasks.
- Analyze model generalization across unseen vehicles and operating conditions.
- Investigate robustness against noise, missing data, and irregular sampling.

Goals:

- Provide a comprehensive benchmark of time-series models for battery health estimation.
- Identify the most robust and generalizable models for real-world EV applications.
- Contribute insights into the limitations of existing approaches under field conditions.
- Support the development of reliable battery management systems (BMS) using real-world data.

Methodology:

This research will employ a quantitative methodology. The workflow includes:

1. Data Acquisition & Preprocessing: Cleaning and structuring Open Source EV fleet data, handling missing values and noise.
2. Representation learning vs Feature Extraction: Creating time-series inputs from operational data.
3. Model Development: Implementing and benchmarking various time-series models such as TimesFM.
4. Training & Evaluation: Using multiple evaluation strategies including vehicle-wise splits and robustness testing.
5. Performance Analysis: Comparing models' performance.

The goal is to establish a realistic evaluation framework for battery health estimation in real-world scenarios.

Prerequisites needed:

- Basic understanding of battery concepts: voltage, current, temperature, SOC, SOH.
- Strong knowledge of Machine Learning and Deep Learning.

- Experience with Python and data analysis libraries.

| Language | EN (english) |
|--|--------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar

Contact : Maitane.Berecibar@vub.be

Co-supervisor: Sazzad Hosen

Contact : Md.Sazzad.Hosen@vub.be

Lien : <https://mobi.paddlecms.net/battery-innovation-centre-homepage>

Prospective LCA of nuclear fusion, advanced fission, and white hydrogen in Belgian net zero energy system (2050-2060).

Program : EM - Energy - M-IREMR-E

Description

A future impact assessment of nuclear fusion, advanced fission, and white hydrogen.

| Language | EN (english) |
|--|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Maarten Messagie

Contact : maarten.message@vub.be

Co-supervisor: Anne Van Den Oever

Contact : anne.van.de.oever@vub.be

Evaluation of Time-Series Models for State of Health and Remaining Useful Life Estimation Using Real-World EV Fleet Data

Program : EM - Energy - M-IREMR-E

Description

Description of the thesis work:

This thesis dives into one of the most critical challenges in electric mobility: understanding and predicting battery health using real-world EV data. You'll work with large-scale fleet data and apply modern time-series models to estimate battery State of Health (SOH) and predict Remaining Useful Life (RUL). Unlike ideal lab conditions, field data reflects real driving, charging behavior, and environmental effects—making the problem both challenging and highly relevant. The idea of this thesis combines energy systems knowledge with cutting-edge AI, giving you hands-on experience at the intersection of battery technology, data science, and next-generation EV innovation.

Objectives:

- Develop a structured pipeline to preprocess and extract time-series data from EV fleet datasets.
- Implement and benchmark multiple time-series.
- Evaluate model performance for SOH estimation and RUL prediction tasks.
- Analyze model generalization across unseen vehicles and operating conditions.
- Investigate robustness against noise, missing data, and irregular sampling.

Goals:

- Provide a comprehensive benchmark of time-series models for battery health estimation.
- Identify the most robust and generalizable models for real-world EV applications.
- Contribute insights into the limitations of existing approaches under field conditions.
- Support the development of reliable battery management systems (BMS) using real-world data.

Methodology:

This research will employ a quantitative methodology. The workflow includes:

1. Data Acquisition & Preprocessing: Cleaning and structuring Open Source EV fleet data, handling missing values and noise.
2. Representation learning vs Feature Extraction: Creating time-series inputs from operational data.
3. Model Development: Implementing and benchmarking various time-series models such as TimesFM.
4. Training & Evaluation: Using multiple evaluation strategies including vehicle-wise splits and robustness testing.
5. Performance Analysis: Comparing models' performance.

The goal is to establish a realistic evaluation framework for battery health estimation in real-world scenarios.

Prerequisites needed:

- Basic understanding of battery concepts: voltage, current, temperature, SOC, SOH.
- Strong knowledge of Machine Learning and Deep Learning.

- Experience with Python and data analysis libraries.

| Language | EN (english) |
|--|--------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar

Contact : Maitane.Berecibar@vub.be

Co-supervisor: Sazzad Hossen

Contact : Md.Sazzad.Hosen@vub.be

Lien : <https://mobi.paddlecms.net/battery-innovation-centre-homepage>

Digital twin simulations of offshore wind turbines

Program : EM - Energy - M-IREMR-E

Description

At the Vrije Universiteit Brussel (VUB) we are heavily involved in monitoring the structural health of offshore wind turbines (OWT) in the Belgian North Sea. We are currently monitoring wind turbines on all Belgian offshore wind farms for fatigue life, structural integrity and their overall dynamic behaviour. Digital twin are more and more used in the wind industry to predict remaining lifetime, predictive maintenance, and structural integrity. Commonly differentiated in data-driven digital twins, which represents the structure completely based measured inputs, and physics based digital twins, which are build based on existing physical relations. Through their rooting in known physical relations, physics-based digital twins often provide better transparency of their behaviour.

- Objective:

In this Master Thesis you will validate the physics-based digital twin of an offshore wind turbine in the Belgian North Sea with real-world data using the aeroelastic simulation software ASHES.

- Prerequisites/special skills (optional)

An interest in structural dynamics and programming is desired. A good knowledge of numerical methods such as the finite element method as well as prior experience with aeroelastic software such as OpenFast can be advantageous. This master thesis gives you the opportunity to learn about the modelling and dynamic behaviour of Offshore Wind Turbines as well as the work of OWI-lab in the structural health monitoring of wind turbines.

- Other information:

This topic is an umbrella topic in which direction can be given aligned with the student's interests and skillset. E.g. the focus can be put on the control of the turbine, the soil-structure interaction, the performance under anomalous behaviour, the automatic integration between database and simulation, ...

Your thesis work builds on past master thesis's and starts from their latest findings.

| Language | EN (english) |
|--|--|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Wout Weijtjens

Contact : wout.weijtjens@vub.be

Co-supervisor: Christof Devriendt Contact : christof.devriendt@vub.be

Three-phase Active Power Filter for Vehicle-To-Grid Applications

Program : EM - Energy - M-IREMR-E

Description

Harmonic pollution injected into the grid by nonlinear loads is a well-known power quality issue, and V2G inverters can be leveraged to actively suppress these harmonics without relying on heavy and expensive passive filters. Building directly on experience already acquired with single-phase proportional-resonant (PR) controllers for active filtering, this thesis extends the concept to the three-phase case using the existing bench inverter and MicroLabBox II platform. The student will implement selective harmonic compensation using parallel resonant controllers tuned to the 5th, 7th, and 11th harmonics in a synchronous reference frame, and validate the results experimentally with a nonlinear load.

| Language | EN (english) |
|--|--|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Number of topics | 1 |

Supervision

Supervisor : Johan Gyselinck

Contact : johan.gyselinck@ulb.be

Consideration of probabilistic security constraints in electricity market coupling

Program : EM - Energy - M-IREMR-E

Description

Nowadays, the European internal electricity market is organized on a zonal basis. Europe is divided into different bidding zones, that are geographical areas within which market participants can exchange energy without transmission capacity allocation (i.e., each bidding zone is implicitly considered as a “copper plate” from the market point of view). On the contrary, the exchange of energy between different bidding zones require transmission capacity allocation. The preferred approach to calculate and allocate transmission capacity to the electricity market is the so-called “flow-based approach”. This flow-based approach tries to model in an explicit way power flow constraints on transmission elements. Nevertheless, the current modelling is based on deterministic security criteria (following the N-1 security criterion) and does not take into account the possible outages of components and the variability of renewable energy sources (i.e., the uncertainties of load, wind power and transmission line failures). The objective of this MSc thesis will be twofold: (i) to integrate probabilistic criteria (LOLE, LOLP, EENS,...) and uncertainties (forecast errors) in the flow-based market algorithm, and (ii) to assess the impact of such integration on the different stakeholders (producers, consumers, TSOs) involved in the market. The effectiveness of the proposed methodology will be validated through different case studies on IEEE RTS.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Pierre Henneaux

Contact : pierre.henneaux@ulb.be

Impact of temperature in Calendar Aging of Lithium-Ion Batteries for SEI formation.

Program : EM - Energy - M-IREMR-E

Description

Temperature plays a central role in calendar aging of lithium-ion batteries, particularly through its influence on the growth, composition, and stability of the solid electrolyte interphase (SEI) layer. This thesis examines how elevated storage temperatures accelerate SEI evolution by synthesizing insights from existing literature and developing temperature-dependent aging expressions based on established kinetic frameworks. The student will identify the temperature ranges most relevant for SEI-dominated degradation and formulate an Arrhenius-type relationship suitable for integration into thermal models. The resulting temperature-dependent SEI aging representation will be incorporated into a thermal runaway model to evaluate its influence on heat generation, onset conditions, and predictive accuracy.

| Language | EN (english) |
|---------------------------------|--------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar

Contact : maitane.berecibar@vub.be

Lien : <https://mobi.paddlecms.net/battery-innovation-centre-homepage>

Prediction Markets as Probabilistic Signals for Energy Price Forecasting Using Polymarket & Kalshi Signals to Forecast Oil, Gas, and Electricity Prices

Program : EM - Energy - M-IREMR-E

Description

THE IDEA

Prediction markets on Polymarket and Kalshi now list contracts tied to oil price thresholds (“Will Brent exceed \$90?”), gas supply events, and geopolitical shocks that directly affect energy prices. These market prices update in real time as new information arrives — potentially faster than traditional model inputs. This thesis asks:

Do prediction market signals carry information about future energy prices that conventional ML forecasting models miss?

The approach is straightforward: train baseline forecasting models on standard features (lagged prices, weather, demand), then re-train the same models with prediction market probabilities added as extra inputs, and measure whether accuracy improves.

WHAT THE THESIS WILL DO

- Collect Polymarket and Kalshi contract histories for oil, gas, and electricity-relevant events alongside day-ahead price time series
- Train baseline models (XGBoost, quantile regression) on conventional features; add market signals and compare
- Evaluate both point accuracy (MAE, RMSE) and probabilistic accuracy (CRPS, pinball loss, calibration)
- Use SHAP values to identify which market contracts contribute most — and at which forecast horizons
- Stress-test performance specifically on price spike periods (P90+ outcomes) to assess tail forecasting value

WHY IT MATTERS

Energy price forecasting underpins billions in trading and hedging decisions daily. If prediction markets aggregate information faster than structured model inputs, incorporating them as features is a low-cost way to improve forecasts — particularly for rare but high-impact price spikes that standard models routinely underestimate.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master’s programs | No |
| Eligible master’s programs | |
| Number of topics | 1 |

Supervision

Supervisor : Thierry Coosemans

Contact : thierry.coosemans@vub.be

Co-supervisor: Ander Martinez Alonso

Contact : Ander.Martinez.Alonso@vub.be

Lien : KEY REFERENCES Weron (2014) Electricity price forecasting: A review. IJF 30(4). • de Castro & Cramton (2012) Prediction markets for electricity demand. Working paper. • Diercks, Katz & Wright (2026) Kalshi and the rise of macro markets. Fed. Reserve FEDS. • Gneiting & Raftery (2007) Strictly proper scoring rules. JASA 102(477).

Monitoring-Based Assessment of the Long-Term Sustainability of a Geothermal Borefield

Program : EM - Energy - M-IREMR-E

Description

Geothermal energy is a renewable resource based on the extraction of heat from the Earth for heating or power generation. Among the different types of geothermal systems, borehole heat exchangers (BHEs), often arranged in geothermal borefields and coupled with a ground source heat pump (GSHP), are among the most widely used technologies for extracting thermal energy from the subsurface. The standard BHE is a closed loop U-pipe system, where a circulating heat carrier fluid is heated or cooled through heat exchange with the surrounding grout and ground.

During the design phase of such systems, assumptions are made regarding the thermal properties of the subsurface (i.e., thermal conductivity, specific heat capacity and initial temperature) as well as the building's energy demand. As a result, deviations between design assumptions and actual subsurface conditions may lead to suboptimal system performance over time. To improve their performance, the analysis of long-term monitoring data from operating BHE systems is essential.

Six years of high-resolution monitoring data from a geothermal borefield consisting of 40 BHEs installed at the E.ON Energy Research Center in Aachen, Germany, are available for this study. The dataset includes inlet and outlet fluid temperatures as well as flow rates for each BHE (Figure 1), allowing the calculation of the thermal loads extracted from and/or injected into the ground. These heat loads serve as input for an in-house analytical heat transfer model that simulates both the ground temperature evolution and the circulating fluid temperature in each BHE.

Once the model is calibrated against the monitoring data, long-term simulations can be performed to assess the thermal state of the subsurface under different scenarios of heat extraction and injection. This approach enables the optimization of GSHP operating strategies, thereby promoting more sustainable and efficient system control.

This master's thesis aims to investigate the long-term sustainability of a geothermal borefield using monitoring data collected at the E.ON Energy Research Center in Germany. This objective is addressed through the calibration of an existing heat transfer model and long-term simulations to define optimal scenarios of exploitation of the underground resource.

The thesis includes the following steps:

- Analysis of six years of monitoring data from the geothermal system
- Calculation of the thermal loads extracted from and/or injected into the ground for each BHE based on monitoring data
- Modelling of heat exchanges within the geothermal borefield using analytical solutions developed at ULB
- Selection of suitable inverse modelling techniques for the identification of ground thermal properties
- Identification of ground thermal properties through comparison between monitored and simulated fluid temperatures

- Analysis of simulation results to assess the thermal state of the subsurface, the thermal interactions between BHEs, impact of the geological conditions on the heat transfers, etc.
- Determination of optimal seasonal thermal loads to ensure long-term thermal sustainability and efficient system operation

References

Heim E., Stoffel P., Müller D., Klitzsch N. (2024) Six years of high-resolution monitoring data of 40 borehole heat exchangers. *Scientific Data*. 11, 1334.

Erol S., François B. (2018) Multilayer model for vertical ground heat exchanger with groundwater flow. *Geothermics*. 71, 294-305.

Coen T., François B., Gerard P. (2021) Analytical solution for multi-borehole heat exchanger fields including discontinuous and heterogeneous heat loads. *Energy & Buildings*. 253, 111520.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Pierre Gerard

Contact : gerard.pierre@ulb.be

Sustainable Aviation Fuels: Controlling Soot Emissions in Aircraft Engines

Program : EM - Energy - M-IREMR-E

Description

- Sustainable Aviation Fuels (SAF) are key to decarbonize the aviation sector
- The reduction of soot and other emissions is critical to reduce the environmental impact of the aviation sector
- Soot formation is strongly sensitive to the local flow conditions and combustion process in an aircraft engine
- The goal is to analyze the effect of the flow field on soot formation in laminar well controlled counterflow flames
- In a second step, soot formation in turbulent flames is simulated using LES and a comparison to experimental reference data is performed
- the development of a validated LES framework for industrial applications is key to enable the design of future aircraft engines

| Language | EN (english) |
|--|---|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Lukas Berger

Contact : lukas.berger@vub.be

Simulating the Impact of Cell-to-Cell Heterogeneity on Asymmetric Aging and System-Level Battery Performance

Program : EM - Energy - M-IREMR-E

Description

Description

Large-scale battery systems—from EVs to grid storage—are fundamentally limited by their weakest cell. While individual cells are designed to be identical, real-world factors like manufacturing tolerances and uneven cooling create significant cell-to-cell (CTC) heterogeneity. These microscopic variations cause cells to degrade asymmetrically over time (e.g., uneven SEI layer growth), cascading into severe pack imbalance that drastically reduces the system's total capacity, safety, and lifespan.

Because traditional Equivalent Circuit Models (ECMs) cannot accurately predict these complex physical phenomena over long lifecycles, the industry requires robust, physics-based modeling. This thesis tackles that exact challenge. By simulating how underlying micro-level variations drive macro-level system failure, you will bridge the gap between cell behavior and pack performance, directly contributing to the digitalization and optimization of next-generation battery designs..

Objectives

- **Develop:** Build a physics-based cell model focused on temperature-driven aging.
- **Scale:** Create a module network that introduces real-world cell-to-cell variations.
- **Simulate:** Track how these micro-variations cause long-term pack imbalance.
- **Optimize:** Test strategies to mitigate uneven aging and extend pack life.

Methodology

The project will proceed through the following key steps:

- **Review:** Study existing literature on physics-based aging models and the physical drivers of battery pack imbalance.
- **Build:** Use standard platforms (MATLAB/Simulink, PyBaMM, or COMSOL) to construct the thermal-electrical degradation model.
- **Simulate & Validate:** Run multi-cycle simulations with introduced heterogeneity and validate the resulting degradation trends against existing lab data or literature.

Pre-requisites

The candidate is expected to have to following experience/skills:

- Basic knowledge of electrochemistry, lithium-ion battery fundamentals, and degradation mechanisms.
- Familiarity with simulation tools e.g., MATLAB/Simulink, PyBaMM, or COMSOL is an added advantage.

| Language | EN (english) |
|--|--------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar

Contact : maitane.berecibar@vub.be

Co-supervisor: Sazzad Hosen

Contact : md.sazzad.hosen@vub.be

Lien : <https://mobi.paddlecms.net/battery-innovation-centre-homepage>

Identifying Key Parameters in a Physics-Based Lithium-Ion Battery Model Using Sensitivity Analysis

Program : EM - Energy - M-IREMR-E

Description

Background & Motivation:

The Doyle–Fuller–Newman (DFN) model is a widely used physics-based model for lithium-ion batteries. It consists of a set of partial differential equations (PDEs) describing electrochemical and transport phenomena within the cell. The model includes parameters related to diffusion, conductivity, interfacial kinetics, and geometry. Some of these parameters significantly affect the model's output, such as voltage, state of charge, or current response, while others have minimal impact.

Sensitivity analysis helps quantify how variations in input parameters influence the model outputs. This is crucial for:

- Prioritizing parameters for accurate estimation or optimization.
- Reducing model complexity.
- Enhancing computational efficiency and robustness.

The goal of this thesis is to systematically classify parameters into high, medium, and low sensitivity groups, based on their influence on simulation outputs using an existing DFN model implemented in PyBaMM.

- PyBaMM (Python Battery Mathematical Modelling): Open-source Python-based tool with built-in DFN and other models.

o Website: <https://www.pybamm.org>

Objectives:

- Explore how lithium-ion battery models (DFN) work
- Run simulations and vary key parameters (e.g., diffusion, reaction rates)
- Analyze how these changes affect voltage and battery performance
- Identify which parameters are critical and which can be simplified

Expected Outcomes:

- A categorized list of parameters based on their sensitivity.
- Visual representations (e.g., bar plots, spider charts) of sensitivity levels.
- A documented and reproducible sensitivity analysis pipeline.
- A summary report that could serve as a guide for model simplification or robust design.

Student Profile:

Background (Education):

- Master's student in:
 - o Electromechanical Engineering
 - o Energy Systems
 - o Applied Mathematics

Technical Skills Required:

- Strong programming experience in Python
- Numerical methods and mathematical modeling
- Understanding of ODEs/PDEs
- Familiarity with lithium-ion battery principles is needed
- Experience with PyBaMM is a bonus but not required (training will be provided)

Soft Skills:

- Critical thinking and analytical mindset
- Good documentation and communication skills
- Ability to work independently and meet deadlines

| Language | EN (english) |
|--|--------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar

Contact : Maitane.Berecibar@vub.be

Co-supervisor: Sazzad Hosen

Contact : Md.Sazzad.Hosen@vub.be

Lien : <https://mobi.paddlecms.net/battery-innovation-centre-homepage>

Dynamic probabilistic security assessment of power systems

Program : EM - Energy - M-IREMR-E

Description

The security of a power system is its ability to withstand disturbances arising from faults and unscheduled removal of bulk power supply equipment without further loss of facilities or cascading outages. The security analysis of the transmission grid requires both deterministic and probabilistic approaches. The "N-1 security rule" is the deterministic approach classically used by Transmission System Operators for network planning and real-time operation. This rule relies on the assumption that an electrical grid will be secure if it stays electrically stable after any single failure among the N initially active network elements. Probabilistic studies can then complement (or replace?) this deterministic approach to assess the residual risk of cascading outages leading to an important amount of loss of load and to identify corresponding accidental scenarios. Their importance is increasing with the massive integration of renewable energy resources in the grid. Because cascading phenomena are not only static but also dynamic (e.g., loss of stability), probabilistic studies should be coupled with dynamic simulations to estimate accurately the security level of power systems, leading to dynamic probabilistic security assessment methodologies. This MSc thesis will explore the use of such methodologies for decarbonized power systems and/or power systems dominated by renewable energy resources, and their use as a tool in planning and/or in operation.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Pierre Henneaux

Contact : pierre.henneaux@ulb.be

Co-supervisor: Pierre-Etienne Labeau

Contact : Pierre.Etienne.Labeau@ulb.be

Steam Electrification: Cost-Optimisation of High-Temperature Systems

Program : EM - Energy - M-IREMR-E

Description

Context Steam production currently accounts for approximately 17% of natural gas consumption at the UZB hospital campus, serving critical operational processes such as autoclave sterilisation and humidification. Decarbonising this steam demand is challenging due to high temperature requirements, variable loads, and strict reliability constraints, while electrification may significantly increase electricity demand peaks.

Objective To identify the cost-optimal configuration and operation of alternative steam generation technologies—high-temperature heat pumps, Mechanical Vapour Recompression (MVR), electric boilers, and thermal energy storage—minimising the Levelised Cost of Steam (LCOS) while ensuring reliable supply.

Methods Develop a Python-based techno-economic optimisation model to:

- Co-optimize technology sizing and operation
- Represent dynamic steam demand (e.g. sterilisation cycles)
- Evaluate waste heat and steam recovery (MVR)
- Analyse trade-offs between cost, CO₂ emissions, and electricity peak demand

Prerequisites

- Programming & Modelling: Proficiency in Python.
- Optimisation: Experience with mathematical optimisation frameworks and solvers (e.g., Gurobi, CPLEX, or open-source alternatives like PuLP/Pyomo).
- Domain Knowledge: Basic understanding of thermodynamics and energy system economics.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Thierry Coosemans

Contact : thierry.coosemans@vub.be

Risk-based planning and operation of meshed offshore HVDC grids to moderate the risk of blackout in power systems

Program : EM - Energy - M-IREMR-E

Description

A blackout is a collapse of the electrical grid on a large area, leading to a power cutoff, and is due to a cascading failure. The occurrence of such a situation entails major direct and indirect societal and economical consequences and should be moderated as much as possible. Some recent events worldwide underline the fact that the residual risk of blackout or undesired load shedding in critical zones remains. Even if such an event is not plausible for single contingency situations, it is for an unfortunate set of strategic (not even necessarily close-by) outages and incidents, combined with unexpected generation and consumption patterns. This means that the risk of cascading incidents needs to be taken into account through the development of risk functions. These functions describe the risk of post-contingency component overloads by considering the probability as well as the impact of contingencies. Moreover, the radical changes experienced by the power systems in recent decades, along with the fast increase of renewable power generation, have triggered interest for offshore wind connections and more specifically for meshed offshore HVDC grids that are seen as a natural target. It could then be of interest to study the optimal planning and operation of these HVDC grids and to what extent they can support the blackout risk reduction, including through the use of corrective security approaches. This is the general purpose of this MSc thesis.

More specifically, this MSc thesis is expected to combine 2-3 of the following activities:

- The development of risk functions that describe the risk of blackout or load shedding for mixed AC/DC grids.
- The development of optimal approaches to operate and to control HVDC grids (including with corrective security with automatic systems) such that the risk of blackout or load shedding is limited through prevention and/or mitigation of cascading outages. Indeed, during cascading events (such as slow voltage collapse), multiple actions are required within a very short time. The converters can provide very fast response (with the appropriate control schemes) to support the frequency, and they can provide, if well controlled, a dynamic support through their power oscillation damping capability. The effectiveness of these approaches will be demonstrated by simulation.
- The development of an approach to plan in an optimal way HVDC grids (e.g., number of converters, lines, and installed GW) with appropriate control schemes such that the risk of blackout or load shedding is limited. The security level of these HVDC grids will be evaluated by simulation.
- The experimental test of automatic corrective security schemes through Control-Hardware-in-the-Loop (combination of the Real-Time Digital Simulator (RTDS) available within BEAMS Electric Energy with an Intelligent Electronic Device (IED) implemented by the student on a Raspberry Pi or equivalent).

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M- IRPH |
| Number of topics | 2 |

Supervision

Supervisor : Pierre Henneaux

Contact : pierre.henneaux@ulb.be

Peak Power Management: BESS Sizing and Dispatch Optimisation

Program : EM - Energy - M-IREMR-E

Description

Context As the hospital campus electrifies its heating (heat pumps) and mobility (EV chargers) while cooling loads grow, peak electrical demand is projected to rise by ~40–45%. Without intervention, this may exceed grid capacity and require costly upgrades.

Objective To design a cost-effective peak power management strategy by optimising the sizing and operation of Battery Energy Storage Systems (BESS) and other flexible assets.

Methods Develop a Python-based optimisation and dispatch model to:

- Simulate future electrical load profiles
- Co-optimize BESS sizing and operation
- Evaluate peak shaving and grid constraint mitigation
- Analyse trade-offs between investment cost and avoided grid upgrades

Prerequisites

- Programming & Modelling: Python.
- Optimisation: Familiarity with algorithmic control and dispatch optimisation.
- Domain Knowledge: Understanding of power systems, load profiling, and battery energy storage dynamics.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Maarten Messagie

Contact : maarten.messagie@vub.be

Techno-Economic Viability of Renewable Hydrogen for Industrial Applications From Business Case Archetype Identification to Techno-Economic Modelling and Assessment

Program : EM - Energy - M-IREMR-E

Description

THE IDEA

Green hydrogen is widely presented as the decarbonisation solution for hard-to-abate industries — high-temperature heat, chemical feedstocks, heavy logistics — where direct electrification is impractical. Yet most project developers, industrial offtakers, and policymakers lack a clear, structured view of when and under what conditions renewable hydrogen actually becomes economically viable compared with fossil alternatives. This thesis builds that model:

A full techno-economic assessment (TEA) of green hydrogen implementation in industrial cases across selected business model archeotypes.

The applications are selected among industrial process heat for manufacturing or logistics sites, hydrogen as a fuel for heavy transport (e.g., fuel cell trucks at a business park), and — where feasible — green ammonia or chemical feedstock substitution. Each case is modelled bottom-up using consistent TEA methodology, enabling direct cross-application comparison.

WHAT THE THESIS WILL DO

- Define a replicable TEA framework: system boundary, CAPEX and OPEX breakdown, LCOH calculation, and key performance indicators for each application
- Characterise industrial H₂ demand for each selected use case: required quantity (kg/day), purity specification, supply continuity requirements, and current fossil cost (€/tonne equivalent)
- Model the full green H₂ value chain: renewable electricity cost and profile, electrolyser sizing and CAPEX trajectory (2024–2035), compression and storage, and use/distribution.
- Run a sensitivity analysis on the parameters that most determine viability: electricity purchase price, electrolyser capacity factor, CAPEX reduction curves, CO₂ price (ETS2).
- Identify break-even conditions against fossil alternatives (grey hydrogen, natural gas, diesel)

WHY IT MATTERS

Flanders hosts a dense concentration of industrial energy consumers, logistics hubs, and emerging hydrogen infrastructure. Investment decisions are being made now for assets that will operate through 2040 and beyond, but they are often based on high-level cost projections rather than site-specific, application-resolved TEA. This thesis provides a reusable analytical toolkit that project developers, industrial energy managers, and public funding bodies can apply directly to assess whether a specific green hydrogen project stacks up — and what conditions need to be met for it.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Maarten Messagie

Contact : maarten.messagie@vub.be

Co-supervisor: Ander Martinez Alonso

Contact : Ander.Martinez.Alonso@vub.be

Lien : IRENA (2022) Global hydrogen trade to meet the 1.5°C climate goal. IRENA, Abu Dhabi.

•Odenweller, A., Ueckerdt, F. The green hydrogen ambition and implementation gap. Nat Energy 10, 110–123 (2025). <https://doi.org/10.1038/s41560-024-01684-7>

Heating Roadmap: Multi-Period Investment Optimisation

Program : EM - Energy - M-IREMR-E

Description

Context At UZB hospital the heating system is transitioning from a high-temperature (90/70°C) grid towards low-carbon alternatives, targeting a reduction in heat demand from ~180 to 80 kWh/m². This transition is complex due to heterogeneous building stock, different renovation potentials, and staggered investment timelines, as well as varying temperature requirements across buildings.

Objective To determine the cost-optimal, building-by-building investment pathway up to 2050, jointly optimising:

- building retrofit measures (demand reduction),
- heat pump deployment,
- and thermal grid transformation,

while minimising total system cost (CapEx + OpEx).

Methods Develop a Python-based MILP optimisation model to:

- Optimise the timing of building retrofits and energy system investments
- Represent building-specific thermal demand evolution
- Model phased replacement of the high-temperature heating grid
- Evaluate integration of waste heat recovery options
- Capture system-level trade-offs between demand reduction and supply-side

electrification

Prerequisites

- Programming & Modelling: Strong programming skills (Python).
- Optimisation: Deep understanding of Operations Research, specifically Mixed-Integer Linear Programming (MILP).
- Domain Knowledge: Familiarity with building physics or district heating network principles is an asset.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Thierry Coosemans

Contact : thierry.coosemans@vub.be

PEM fuel cells to decarbonize aviation: Modeling liquid water transport

Program : EM - Energy - M-IREMR-E

Description

- PEM fuel cells are considered a viable option for emission free flying (see e.g. ZEROe from Airbus or the Flying Fuel Cell by MTU Aero Engines AG etc.) using hydrogen as a fuel
- operation of PEM fuel cells is challenging and requires in-depth understanding of the small-scale processes in the porous media, e.g. liquid water transport
- the goal is to model liquid water transport in macro-homogeneous models and validate the simulations against experimental reference data
- Particular focus lies on the modeling of the channel/GDL interface

| Language | EN (english) |
|--|---|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Lukas Berger

Contact : lukas.berger@vub.be

Finite-Control-Set Model-Predictive Control for a Vehicle-To-Grid Bidirectional Inverter

Program : EM - Energy - M-IREMR-E

Description

Classical PI current controllers with PWM are the industry standard for grid-connected inverters, but finite-control-set model-predictive control (FCS-MPC) has emerged as an attractive alternative that eliminates the modulator and offers intuitive multi-objective tuning. This thesis will implement both control strategies in Simulink on the MicroLabBox II for the same two-level inverter and battery setup, and compare them experimentally in terms of current THD, dynamic response, and ease of tuning. The FCS-MPC implementation will use a single prediction step (horizon = 1) as a baseline, with extension to longer horizons left as an option for motivated students.

| Language | EN (english) |
|--|--|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Number of topics | 1 |

Supervision

Supervisor : Johan Gyselinck

Contact : johan.gyselinck@ulb.be

The Effects of Different Slurry Mixing Methods on the Performance of Water-Based Anodes for Lithium-Ion Batteries

Program : EM - Energy - M-IREMR-E

Description

Slurry mixing is one of the most critical steps that significantly impacts the final properties of lithium-ion batteries. In laboratory-scale processes, vacuum mixers, magnetic stirrers, ultrasonic homogenizers and ball milling are among the most commonly used methods. Moreover, the parameters set during the application of these methods are of crucial importance for the process. This study will investigate the relationship between different mixing methods applied in the laboratory setting, varying parameters, and different cell chemistries and electrode compositions. Electrochemical, X-ray diffraction and AFM analyses will be conducted to evaluate the performance and chemical structures of the produced batteries.

- Objectives of the Project

- Design and optimization of slurry mixing parameters
- Investigation of the impact of different mixing methods on the battery performance
- Analysis of the influence of the cell chemistry on mixing requirements

- Methodology

A standard slurry formulation will be prepared for different cell chemistries such as graphite and silicon. These formulations will be processed using the different mixing methods under varying parameters (time, speed, ball amount, amplitude etc.). The effects of these mixing parameters on slurry homogeneity, particle distribution, and the final electrode properties will be investigated. Subsequently, electrodes produced from the slurries will be assembled into batteries and subjected to electrochemical performance tests, where performance metrics will be evaluated. Furthermore, the impact of each mixing method on different cell chemistries will be compared and analyzed, with the results being statistically assessed. Throughout this process, analytical techniques such as EIS, AFM, and XRD will be employed to thoroughly examine the relationship between material structure and performance.

- Prerequisites needed

- Fundamental knowledge of mixing methods
- Basic laboratory experience

| Language | EN (english) |
|--|--------------------|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar

Contact : maitane.berecibar@vub.be

Co-supervisor: Burak Dermenci

Contact : kamil.burak.dermenci@vub.be

Lien : <https://mobi.paddlecms.net/battery-innovation-centre-homepage>

Clean energy & sustainable propulsion: Modeling hydrogen/ammonia flames in LES

Program : EM - Energy - M-IREMR-E

Description

- Hard-to-abate industries and heavy-duty transportation will keep relying on combustion-based applications due to the high required energy densities and high process temperatures. Hydrogen-based fuels are a viable option to decarbonize these sectors.
- Hydrogen and ammonia flames dynamics are entirely different to conventional fuels and predictive combustion models for LES are yet not available
- The goal is to analyze detailed data-heavy DNS data, where all turbulent fluctuations are resolved, and to extract the underlying physics regarding the interactions of the flame and turbulence
- The goal is to develop models for unclosed terms in LES and then apply the newly developed models in an LES to show its improvements
- The analysis will be done for different hydrogen/ammonia blends

| Language | EN (english) |
|--|---|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Lukas Berger

Contact : lukas.berger@vub.be

Translating MV Feeder Constraints into Local Price Signals for Congestion Management Designing, Measuring, and Integrating Feeder-Level Price Signals to Unlock Flexibility in Distribution Networks

Program : EM - Energy - M-IREMR-E

Description

THE IDEA

MV feeders have hard physical limits — thermal capacity, voltage bands, phase balance. When these are breached, DSOs today face a binary choice: reinforce the grid (slow, expensive) or curtail loads (blunt, inefficient). Grid reinforcement takes years and costs millions; meanwhile, flexible assets — EV chargers, heat pumps, battery storage, industrial demand — already exist on those same feeders and could relieve congestion if they received the right economic signal. The problem is that the signal is missing. This thesis asks:

How can a physical feeder constraint be translated into a dynamic local price signal that incentivises flexible assets to reduce congestion — without central dispatch?

The core challenge is the translation layer: turning an engineering constraint (e.g., “feeder loading exceeds 85% of rated capacity”) into an economic parameter (a congestion price in €/kWh or €/kW) that flexible assets can respond to through normal market logic.

WHAT THE THESIS WILL DO

- Map the physics to economics: derive a shadow price from feeder loading constraints using power flow models, and define how the price scales with headroom (linear, step-function, quadratic penalty)
- Identify what measurements are needed: real-time feeder loading, voltage magnitude, phase currents ...
- Design and compare signal shapes: reactive (triggered when congestion occurs) vs. anticipatory (day-ahead or intraday, forecast-driven) — and evaluate their effectiveness and stability
- Integrate with existing pricing schemes: overlay the congestion signal on top of national network tariffs, day-ahead market prices, and imbalance prices without creating conflicting incentives
- Test on a representative MV feeder case (synthetic or real Flemish business park data) with a mix of flexible assets and measure congestion relief, flexibility, and fairness across users

WHY IT MATTERS

Distribution grids in Flanders — and across Europe — are congesting faster than they can be reinforced, driven by EV uptake, heat pumps, and industrial electrification. The EU Electricity Market Design Reform and the move to 15-minute trading explicitly call for more granular local price signals, but the methodology for creating them at feeder level does not yet exist in practice. This thesis builds that methodology and tackles congestion pricing and dynamic network tariffs for business parks.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Thierry Coosemans

Contact : thierry.coosemans@vub.be

Co-supervisor: Ander Martinez Alonso

Contact : Ander.Martinez.Alonso@vub.be

Lien : Regulation (EU) 2019/943 on the internal market for electricity (15-min imbalance settlement, congestion revenues). • Bjørndal & Jörnsten (2001) Zonal pricing in a deregulated electricity market. *The Energy Journal* 22(1). • Huang et al. (2021) Optimal congestion management in distribution networks via dynamic network tariffs. *IEEE Trans. Smart Grid*.

Real-Time State-of-Charge-Aware Vehicle-To-Grid Power Scheduling with Grid Frequency Support

Program : EM - Energy - M-IREMR-E

Description

Effective vehicle-to-grid (V2G) participation requires the inverter controller to be aware of the battery's state of charge and to respond to grid frequency deviations in a coordinated way. This thesis will develop a supervisory layer combining a real-time SoC estimator (e.g. extended Kalman filter or adaptive observer) for the LiFePO₄ pack with a primary frequency droop response, dynamically modulating injected/absorbed power according to SoC constraints. The MicroLabBox II will run both the SoC estimator and the power reference generator in real time, enabling full closed-loop V2G frequency support experiments.

| Language | EN (english) |
|--|--|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Number of topics | 1 |

Supervision

Supervisor : Johan Gyselinck

Contact : johan.gyselinck@ulb.be

PEM fuel cells to decarbonize aviation: Pore-resolved simulations in porous media

Program : EM - Energy - M-IREMR-E

Description

- PEM fuel cells are considered a viable option for emission free flying (see e.g. ZEROe from Airbus or the Flying Fuel Cell by MTU Aero Engines AG etc.) using hydrogen as a fuel
- operation of PEM fuel cells is challenging and requires in-depth understanding of the small-scale processes in the porous media, e.g. liquid water transport
- the goal is to establish a modeling framework for pore-resolved simulations of liquid water transport in PEM fuel cells
- the goal is to apply this framework to relevant questions in flow field and stack design

| Language | EN (english) |
|--|---|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Lukas Berger

Contact : lukas.berger@vub.be

Virtual-Synchronous-Machine Control of a Vehicle-To-Grid Bidirectional Inverter Using a LiFePO4 Battery Pack

Program : EM - Energy - M-IREMR-E

Description

Grid-forming control via Virtual Synchronous Machine (VSM) emulation is one of the most active research areas in power electronics, as inverter-dominated grids increasingly lack the natural inertia of synchronous generators. This Master thesis will build upon previous work and implement a VSM algorithm on the MicroLabBox II to make the battery-side inverter behave like a synchronous generator, providing synthetic inertia and voltage support. The student will tune the virtual inertia and damping coefficients and validate the frequency response experimentally.

| Language | EN (english) |
|--|--|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Number of topics | 1 |

Supervision

Supervisor : Johan Gyselinck

Contact : johan.gyselinck@ulb.be

Weather-Informed Hourly Electricity Price Projections for Long-Term Energy System Planning Building Weather-Informed Hourly Electricity Price Profiles for Long-Term Energy System Planning Under Electrification Scenarios

Program : EM - Energy - M-IREMR-E

Description

THE IDEA

Long-term energy planning models know roughly what 2040 looks like on average — more renewables, new weather trends, different electricity prices patterns. What they lack is the hour-by-hour texture: when prices will spike, when solar will collapse the midday price, how a cold week in January will drive demand that no renewable fleet can fully cover. Weather drives all of this, but most long-term projection frameworks ignore it. The central research challenge is: Combining long-term scenario trends with historical weather data to generate realistic hourly electricity price profiles for 2030–2050, and assessing how different electrification pathways reshape the distribution of prices.

The approach bridges two methods that are rarely combined: macro-level regression models that project annual average prices from generation mix and fuel cost trajectories (Naval et al., 2025), and weather-driven hourly demand shaping used in open energy dataset projects (Canessa et al., 2026).

WHAT THE THESIS WILL DO

- Collect historical hourly electricity prices (ENTSO-E), generation mix data, and ERA5 reanalysis weather data (temperature, wind speed, solar irradiance) for a chosen country
- Train a multivariate regression model linking weather variables and generation mix to hourly prices — following Naval et al. (2025) — and validate it against held-out years
- Define 2–3 future scenarios (e.g., moderate electrification, accelerated EV/heat pump uptake, high renewable penetration) using IEA World Energy Outlook or national NECP targets to set the 2030/2040 generation mix and fuel cost inputs
- Apply the fitted model to ERA5 historical weather years re-weighted for each future scenario to generate synthetic hourly price profiles for each horizon and scenario
- Analyse the resulting profiles: how do price variability, seasonal patterns, zero-price hours, and spike frequency change across scenarios and weather years?

WHY IT MATTERS

Infrastructure investors, DSOs, flexibility aggregators, and industrial energy buyers all make decisions that lock in costs for 10–20 years, yet the tools they use either have no hourly resolution or no long-term scenario embedding. Hourly price profiles under different electrification pathways are a direct input to storage sizing, EV charging strategy, grid planning, and flexibility business cases

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Thierry Coosemans

Contact : thierry.coosemans@vub.be

Co-supervisor: Alex Felice

Contact : alex.felice@vub.be

Lien : Naval, Tipán-Salazar & Yusta (2025) Statistical regression model for annual hourly price estimation in the Spanish electricity market. ICREPQ'25. • Canessa et al. (2026) Projected hourly and regional energy demand for power, heat and transport in New Zealand to 2050. Scientific Data 13:193. • Weron (2014) Electricity price forecasting: A review. IJF 30(4). • IEA (2023) World Energy Outlook 2023. Announced Pledges Scenario.

Experimental testing of a monitoring hardware for application in floating offshore wind turbines.

Program : EM - Energy - M-IREMR-E

Description

At the Vrije Universiteit Brussel (VUB) we are heavily involved in monitoring the structural health of offshore wind turbines (OWT) in the Belgian North Sea. We are currently monitoring wind turbines on all Belgian offshore wind farms for fatigue life, structural integrity and their overall dynamic behavior. Floating Offshore Wind Turbines (FOWT) refer to offshore wind turbines mounted on floating platforms, allowing them to be deployed in deeper waters where fixed-bottom turbines are not feasible.

- Objectives of the master thesis;

This master's thesis focuses on building and testing a small-scale experimental setup to evaluate a monitoring hardware system (GNSS/IMU). The objective is to assess the hardware's ability to provide accurate position for an instrumented device—such as a scaled FOWT. When combined with other sensor types, this data will help us better understand the motion characteristics of FOWTs and how they relate to mooring line tensions and overall system dynamics. This project is conducted in collaboration with 24SEA, a company specializing in monitoring solutions for offshore wind turbines.

- Prerequisites/special skills (optional)

An interest in structural dynamics, experimental work and programming is desired. The thesis also includes working with sensors and hardware, and doing experimental validation of the sensor setups. A thesis suitable for someone with a strong 'MacGyver'/'Maker' - spirit.

- Other information

This thesis might require you to travel occasionally to 24SEA, situated just outside Brussels.

| Language | EN (english) |
|--|--|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Wout Weijtjens

Contact : wout.weijtjens@vub.be

Co-supervisor: Christof Devriendt

Contact : christof.devriendt@vub.be

Forecasting Extreme Events in Energy Systems with Tail-Aware Machine Learning Combining Extreme Value Theory with Probabilistic ML to Predict Demand Peaks, Price Spikes, and Renewable Shortfalls

Program : EM - Energy - M-IREMR-E

Description

THE IDEA

Standard forecasting models are trained to minimise average error. This works well most of the time — but energy systems are not undone by average conditions. Blackouts, price spikes, and grid stress events happen in the tails of the distribution, precisely where conventional models are least reliable. This thesis asks:

Can combining extreme value theory with probabilistic machine learning produce better-calibrated forecasts for rare but critical energy system events?

The approach blends two worlds that rarely meet in practice: distributional ML models (quantile regression, gradient boosting) that are already used in energy forecasting, and extreme value theory (EVT) methods from statistics that are specifically designed to model tail behaviour.

WHAT THE THESIS WILL DO

- Select 2–3 concrete forecasting tasks: e.g., day-ahead peak demand, electricity price at P95, or minimum wind generation over a 24-hour window
- Train baseline probabilistic models (quantile regression forest, LightGBM with pinball loss) and evaluate their tail calibration using proper scoring rules
- Augment the models with EVT-inspired components — such as Generalised Pareto tails fitted to residuals or threshold-exceedance features
- Compare tail performance using quantile-specific scores (P90, P95, P99) and interval coverage rates, not just average CRPS or RMSE
- Investigate why standard scoring functions underreward good tail forecasts, following Brehmer & Strokorb (2019), and test alternative tail-focused metrics

WHY IT MATTERS

The events that most stress energy infrastructure — demand peaks in heatwaves, renewable droughts, gas price spikes — are exactly the ones that existing models handle worst. Even a modest improvement in tail calibration translates directly into better reserve planning, smarter hedging, and more resilient grid operations. This is applied, implementable research with clear industry relevance.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Thierry Coosemans

Contact : thierry.coosemans@vub.be

Co-supervisor: Ander Martinez Alonso

Contact : Ander.Martinez.Alonso@vub.be

Lien : Brehmer & Strokov (2019) Why scoring functions cannot assess tail properties. *Electronic J. Statistics*. • Chung et al. (2021) Beyond pinball loss: Quantile methods for calibrated uncertainty quantification. *NeurIPS* 34. • Gneiting & Raftery (2007) Strictly proper scoring rules, prediction, and estimation. *JASA* 102(477). • Weron (2014) Electricity price forecasting: A review. *IJF* 30(4).

PEM fuel cells to decarbonize aviation: Modeling degradation in PEM fuel cells

Program : EM - Energy - M-IREMR-E

Description

- PEM fuel cells are considered a viable option for emission free flying (see e.g. ZEROe from Airbus or the Flying Fuel Cell by MTU Aero Engines AG etc.) using hydrogen as a fuel
- operation of PEM fuel cells is challenging and handling cell degradation is a key challenge for future technologies
- the goal is to develop a simulation framework to model degradation mechanisms in PEM fuel cells
- the new library will be coupled to CFD solvers to enable predictions of degradation in a 3D realistic cell

| Language | EN (english) |
|--|---|
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Lukas Berger

Contact : lukas.berger@vub.be

Arrhenius-Based Aging equation Development for Lithium-Ion Batteries Using Accelerated Degradation method.

Program : EM - Energy - M-IREMR-E

Description

Lithium-ion batteries degrade through temperature-dependent chemical and structural changes that can be accelerated and quantified through controlled aging tests. This thesis focuses on developing an Arrhenius equation that captures the relationship between temperature, aging rate, and capacity fade using data from accelerated calendar tests. The student will extract activation energies, identify dominant degradation pathways, and construct a temperature-dependent aging law suitable for system-level simulations. The resulting equation will be evaluated for its applicability to safety-critical scenarios and prepared for integration into a thermal runaway prediction framework.

| Language | EN (english) |
|--|--------------------|
| Open to other master's programs | No |
| Eligible master's programs | M-IRELE, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Maitane Berecibar

Contact : maitane.berecibar@vub.be

Lien : <https://mobi.paddlecms.net/battery-innovation-centre-homepage>

Risk-Aware Flexibility Procurement for Congestion Management in Distribution Systems under Uncertainty

Program : EM - Energy - M-IREMR-E

Description

This MSc thesis will aim to study how to use distributed flexibility—such as flexible loads, batteries, EV charging, and renewable curtailment—to relieve congestion in distribution networks. The work will start with a deterministic market-clearing model that selects cost-effective flexibility actions while respecting network limits (using a simplified power flow model). It is then extended to account for uncertainty in renewable generation, demand, and flexibility availability using a scenario-based approach. In this context, a two-stage stochastic perspective can be used, where decisions are taken ahead of time and evaluated under different possible system conditions. To ensure that the solution remains reliable, the modeling framework will adopt a risk-aware formulation. The goal will not be only to minimize cost, but also to limit the risk of congestion after market clearing. This will be done by tracking how often and how severely network constraints are violated across scenarios, and by incorporating these effects either as constraints or in the objective function. The proposed methods will be tested on representative distribution networks. The results will be evaluated in terms of cost, ability to relieve congestion, and sensitivity to uncertainty. If time allows, the impact of imperfect flexibility activation (e.g., delays or partial delivery) can also be analyzed. In addition, this MSc thesis might explore simple market design choices, such as how flexibility bids are defined (price, quantity, location), how they are selected (e.g., pay-as-bid vs uniform pricing), and how non-delivery is penalized. The focus will remain on understanding how these choices affect congestion management outcomes.

| Language | EN (english) |
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| Open to other master's programs | Yes |
| Eligible master's programs | M- IRPH |
| Number of topics | 1 |

Supervision

Supervisor : Pierre Henneaux

Contact : pierre.henneaux@ulb.be

Design of robust energy systems through uncertainty quantification

Program : EM - Energy - M-IREMR-E

Description

Linear optimization is a popular method for capacity expansion planning, all the way from national grids to small energy communities. However, most models do not quantify the impact of uncertainty (e.g. fluctuations in energy prices, climate change) on the optimized energy system. In this Master's thesis we will use and build on existing models that incorporate stochastic programming to evaluate how these uncertain parameters affect certain energy systems, and how we can adapt these systems to be more robust.

| Language | EN (english) |
|---------------------------------|--------------|
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Svend Bram

Contact : svend.bram@vub.be

Topics offered to students by other
master's programs

TARGET PROGRAM

EM ENERGY ENGINEERING

Master's program offering the topic: Architectural engineering - M-IRARE

Incorporating Sustainability in the design process of products, processes and businesses.

Description

How to design products that have a better impact on environment, social and economy? This thesis starts with a state of art review of methods for 'Design for Sustainability'. What are methods to decision on sustainability and what are the remaining challenges and pitfalls? The aim of the thesis is to formulate a novel way to embed sustainability in the decision process of companies and link it to existing methods for corporate sustainability reporting.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCNE, M-IRMAE, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Nombre de sujets | 1 |

Supervision

Supervisor : Messagie Maarten (maarten.messagie@vub.be)

Master's program offering the topic: Biomedical engineering - M-IRCBS

Bistable structures for bronchoscopy

Description

Context: Bistable structures enable multi-equilibrium states without the energy consumption except for switching from state to state. They are key in many applications, among which building engineering or soft robotics (<https://www.non-linearity.com/conference/ftn2026>). At small scale they could provide extra degrees-of-freedom to orientate and position endoscopic cameras such as the video-endoscope developed by Lys Medical.

Objectives: This master thesis aims to design and numerically model a bistable structure actuated by hydrogel actuators.

Methods: Literature review. Finite elements modelling (Batir). Design. Fabrication and characterization (Tips).

Prerequisites:

- Mechanical design
- Interest for civil, mechanical, biomedical and bio-engineering

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Lambert Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Automated Muscle and Tendon Fiber Orientation Tracking in Calf Ultrasound Images Using Computer Vision

Description

Understanding how muscle and tendon fibers are oriented in the calf is essential for assessing athletic performance, diagnosing musculoskeletal conditions, and guiding rehabilitation. Ultrasound imaging offers a non-invasive, real-time window into this fiber architecture, but extracting quantitative orientation data currently requires manual tracing by trained specialists. This thesis designs and validates a computer vision pipeline that automatically detects and tracks fiber orientation in ultrasound images of the calf region. By combining classical image processing techniques with deep learning-based segmentation, the system estimates pennation angles, fiber bundle trajectories, and tendon alignment across static and dynamic acquisition sequences. The tool is evaluated in both laboratory and clinical contexts, with the goal of providing a reproducible, accessible measurement instrument for clinicians, physiotherapists, and sports scientists.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Development of a realistic and easy-to-use mucus simulant

Description

Context: Over the last years, the respiratory drug delivery has drawn a strong interest due to the large surface area of the airway mucosa, providing an easy access to the blood. In particular, nasal sprays intending to treat non-local disorders, like migraine or hypoglycaemia, have appear. Compared to oral medicines, they are easier to use, act faster and can be given to unconscious patients [1]. However, the current characterisation techniques for spray are still lacking. Cutting-edge methods, such as experimental and digital models of the nose aims to bridge this gap but further development is still needed to reproduce adequately spray deposition in the nose. In particular, the interactions between the spray particles and the mucus lining the interior of the nose governs the final deposition site of the spray.

Objective: This thesis aims to develop a realistic and easy-to-use fluid replicating the nasal mucus. This simulant needs to reproduce the rheological characteristics of the biological mucus [2] and must be coated easily into nasal replicas. This mucus simulant will then be used to assess the influence of its properties (viscoelasticity, viscoplasticity, surface tension,...) on the trajectories of impacting particles. These results would strengthen the current understanding of the mucus-particles interactions and help to validate advanced simulation models.

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| Langue | EN (english) |
| Ouvert à d'autres masters | yes |
| Masters concernés | M-IRCBS, M-IRMAE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Lambert Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Improved adenoid hypertrophy treatment through nasal replicas

Description

Context: Adenoid hypertrophy is the pathologic enlargement of the tonsils at the back of the nose. It is one of the most common no-infectious ENT affection in children with a prevalence of about over 30%. Nowadays, the first-line treatment of adenoid hypertrophy is corticosteroid nasal sprays. While half of the patients shows improvement with this treatment, it is ineffective for the other half [1]. One issue may be that the current treatments aim for maximum coverage of the nasal cavity and not maximal penetration. Consequently, only a small part of the medicine reaches directly its site of action. New medication strategies, combining adapted devices, formulations and administration procedures [2], could increase the success of corticosteroid treatment and decrease the use of surgery in children.

Objective: This thesis aims to maximise the amount of drug reaching the pharyngeal tonsils. The fraction of drug reaching the site of action will be determined using a 3D-printed nasal replica of a child anatomy. The main goal is to combine the characteristics of the spray (viscosity, surface tension) and the administration procedure (instillation angle, inspiration) to increase the amount of drug reaching the back of the nasal cavity.

Correlations between the characteristics of the sprays and the deposition in the nose should also be drawn to provide simple guidelines for future medicine development.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRMAE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Lambert Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: Biomedical engineering - M-IRCBS

NeuroBridge: From Scanned PDFs to Unified Diagnosis, an AI Pipeline Bridging Radiology and Anatomopathology Reports

Description

Neurological diagnosis draws on two complementary medical specialties, radiology and anatomopathology, yet their reports are produced independently, in inconsistent formats, and often only available as scanned PDF documents. This thesis develops NeuroBridge, an AI-driven pipeline that transforms raw PDF inputs including low-quality scans into structured, machine-readable clinical data. Combining OCR, layout analysis, and domain-specific NLP, the system extracts key diagnostic findings from both report types and maps them onto a shared semantic framework. The outcome is an integrated diagnostic view designed to support clinicians in identifying concordances and discrepancies across the two protocols, reducing the cognitive load of cross-specialty interpretation.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

A Web-Based Air Quality Platform for Patient-Centric Environmental Exposure Assessment in Clinical Research

Description

Environmental air quality has a measurable impact on patient health, yet clinicians and clinical researchers currently lack practical tools to assess individual exposure at their home work etc. This thesis builds a web-based platform that takes a patient address as input and automatically queries all available air quality databases to reconstruct a comprehensive environmental exposure profile. The tool is designed to assist clinicians during clinical studies by surfacing relevant environmental context alongside patient records, enabling more informed interpretation of health outcomes and facilitating the inclusion of air quality as a structured variable in clinical research protocols.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Machine Learning-Driven Trace Extraction from Kymographs for Quantitative Analysis of Intracellular Dynamics in Wild-Type and Mutant Models

Description

Kymographs provide a compact visual representation of how particles, vesicles, or molecular motors move along a biological structure over time, making them widely used in studies of axonal transport, ciliary beating, and cytoskeletal dynamics. Despite their utility, extracting meaningful quantitative data from kymographs currently requires laborious manual tracing, a process that is slow, subjective, and poorly scalable when comparing wild-type organisms to genetic mutants across large experimental datasets. This thesis presents a machine learning pipeline that automates the detection and extraction of individual traces from fluorescence kymograph images and derives physiological parameters directly from their geometry and intensity profiles. The system classifies trace populations by directionality and motility state, computes transport metrics such as velocity and run length distributions, and generates structured comparative outputs enabling statistically robust phenotype quantification between experimental groups.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

AI-Driven Assessment of Rehabilitation Quality Through Joint Angle Trajectory Analysis

Description

Assessing whether a patient is performing rehabilitation exercises correctly and progressing over time is a task that currently depends heavily on the availability and judgment of a trained therapist. This thesis proposes a data-driven platform that uses recorded joint angle measurements to automatically evaluate the quality of rehabilitation sessions. By analyzing angular trajectories captured through wearable sensors or video-based pose estimation, the system computes objective quality indicators such as range of motion compliance, movement symmetry, inter-repetition variability, and adherence to prescribed motion patterns. Machine learning models trained on expert-annotated exercise recordings learn to map these features onto quality scores aligned with clinical standards. The resulting tool provides physiotherapists with structured, session-by-session feedback and longitudinal progress tracking, supporting more informed and personalized rehabilitation management without requiring continuous in-person supervision.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Variable stiffness catheter for lung cancer diagnosis

Description

Context: Lung cancer is the leading cause of cancer death worldwide [1]. As part of the screening process, lung nodules (suspected cancer) are regularly found in peripheral areas that are difficult to access by endoscopy. As most of these nodules are not cancerous, it is essential to be able to take a local biopsy to make a precise diagnosis. However, the lung is like a labyrinth, with sections that shrink with each division, and access to a precise peripheral zone is difficult. In addition, the need to use flexible and miniaturized tools implies certain limitations. Indeed, the need for flexibility is necessary to avoid damaging the tissue or injuring the patient but means that the tools may deform before the biopsy is taken.

A family of solutions that are being developed uses the concept of controllable/variable stiffness to cope with these issues [2]. These solutions use materials and/or specific geometries that can change rigidity given a certain stimuli (change of temperature, pressure, ...).

Objectives: Develop a prototype of a variable stiffness catheter using different equipment present in the lab (molding techniques, 3D printers).

Methods: Literature review. Functional analysis and requirements. Design. Fabrication and evaluation of the built prototype.

Prerequisites:

- Mechanical design
- Interest for mechanical and biomedical engineering

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Lambert Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Depth Camera-Based Person Tracking for Quantitative Balance Assessment

Description

This master's thesis presents a computer vision system for the automatic assessment of postural balance using a depth camera. By leveraging 3D skeletal tracking and point cloud analysis, the system continuously estimates key biomechanical parameters, such as center of mass projection, sway path, and postural stability indices, without requiring wearable sensors or clinical-grade force platforms. The proposed pipeline integrates real-time person detection, joint localization, and temporal motion analysis to produce quantitative balance metrics comparable to standard neuropsychological assessment protocols. The system is evaluated on a cohort of participants under various stance conditions, demonstrating its potential as a low-cost, non-intrusive tool for clinical screening and rehabilitation monitoring in collaboration with neuropsychological practice.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Biomedical engineering - M-
IRCBS

Depth Camera-Based Person Tracking for Quantitative Balance Assessment

Description

This master's thesis presents a computer vision system for the automatic assessment of postural balance using a depth camera. By leveraging 3D skeletal tracking and point cloud analysis, the system continuously estimates key biomechanical parameters, such as center of mass projection, sway path, and postural stability indices, without requiring wearable sensors or clinical-grade force platforms. The proposed pipeline integrates real-time(opt.) person detection, joint localization, and temporal motion analysis to produce quantitative balance metrics comparable to standard neuropsychological assessment protocols. The system is evaluated on a cohort of participants under various stance conditions, demonstrating its potential as a low-cost, non-intrusive tool for clinical screening and rehabilitation monitoring in collaboration with neuropsychological practice.

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| Langue | EN (english) |
| Ouvert à d'autres masters | No |
| Masters concernés | M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Chemical & Materials
engineering - M-IRMAE

Process parameter optimization for 3D printing of Functionally Graded rocket nozzle through Directed Energy Deposition process.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a specific metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. It is equipped with a 3-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive drilling/milling operations for the production of a part. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, and the melt pool (high intensity spot) are visible.

Functionally Graded Materials (FGM) are components with gradual changes in composition or structure across their volume, designed to optimize mechanical or thermal performance. In DED, FGMs are produced by dynamically adjusting the metal powder or wire feed rates during the deposition process. This enables smooth transitions between different metal alloys (e.g., stainless steel to copper), reducing residual stresses and improving bonding. Such FGMs are ideal for applications requiring a combination of properties like high strength, corrosion resistance, and thermal stability within a single part.

Rocket nozzles need FGMs to withstand extreme thermal and mechanical stresses by gradually transitioning from heat-resistant materials at the throat to tougher structural metals, improving durability, reducing thermal mismatch, and preventing failure. This is why rocket nozzles are manufactured with a graded transition from 316L or Inconel to copper as shown on Fig. 2-3.

The BE Rocket Team [3] is a Belgian inter university student initiative (VUB, KU Leuven, ULB, RMA, Liège, Mons, Bruges) aiming to design, build, test, and launch amateur solid fuel rockets to compete in the European Rocketry Challenge (EuRoC). The 21st of October 2024, Be-Rocket successfully launched their first rocket, Bossart-I, at the military base of Elsenborn in Belgium. Fig. 4-6 shows the rocket during boost phase, and the nozzle design that was used for the tests. However, the nozzle has been conventionally manufactured and doesn't rely yet on the FGM technology.

In parallel at the AM-Lab of VUB, preliminary experiments have been performed for the production of miniature rocket nozzles. During the DED process, the thermal history of the part is critical to the final quality and directly influences residual stresses. Many interconnected physical phenomena occur, and the process is defined by several parameters such as laser power, scan speed, powder feed rate, scanning path, track overlap, and more. When printing FGMs, these parameters increase in number and must be actively tuned during the build as the material transitions from one type to another. The results of the manufacturing of the miniature FGM rocket nozzle are shown in Fig. 7-10. However, several processing challenges remain, including dripping, crack formation, lack of fusion, and other microstructural defects. These issues highlight the need for further process optimization to produce a high-quality rocket nozzle.

The aim of this master thesis will be to manufacture a structurally sound rocket nozzle for the next Be-Rocket student rocket, the design of which is shown in Fig. 6. The work will involve conducting an extensive parametric study to enable the production of a high-quality miniature nozzle demonstrator, meeting criteria such as dimensional accuracy, appropriate microstructure, and minimal defects like pores, cracks, or lack of fusion. Various manufacturing strategies available in our lab must be considered and explored (for example regulation of melt pool temperature, etc.).

The results of these strategies will need to be compared to identify the most efficient manufacturing approach for manufacturing a real size nozzle. The best demonstrator will then be on the test bench for solid rocket motors at the rocket propulsion test facility of the ULB, as shown on Fig. 11-12.

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: Chemical & Materials
engineering - M-IRMAE

Plasmonic nanoparticles inside PNIPAM hydrogel for light-driven soft actuators using femtosecond laser writing

Description

Context: Soft matter can serve as an actuator in microrobotics by deforming under external stimuli (light, heat, or pH...) and producing mechanical outputs like force or displacement. At the microscale, these smart materials can be 3D printed without assembly. In our lab, we use two-photon polymerization (2PP) to fabricate soft actuators from a thermo-responsive polymer, poly(N-isopropylacrylamide) (pNIPAM). This material swells below its lower critical solution temperature (LCST) by absorbing water and shrinks above the LCST by expelling it. Recently, we fabricated $50\ \mu\text{m} \times 50\ \mu\text{m} \times 50\ \mu\text{m}$ active cubes capable of bending, contracting, twisting, or shearing in heated water [1]. To achieve precise, multidirectional motion control, multiple actuators could be combined and selectively triggered by different wavelengths of light. This is possible by doping them with photothermal nanomaterials that locally convert light into heat [2]. Metallic nanostructures like gold (Au) and silver (Ag) nanoparticles or nanorods have been used to actuate PNIPAM-based hydrogels [3]. However, they are usually dispersed uniformly, preventing spatial control. An alternative approach uses a tightly focused femtosecond laser in a PNIPAM hydrogel swollen with silver nitrate, locally forming Ag nanoparticles by multiphoton reduction [4]. Applying this method to our actuators would enable spatially selective nanoparticle patterning, allowing localized, precise activation.

Objective: The aim of this thesis is 3D print photosensitive nanoparticles inside PNIPAM hydrogels with the 2PP machine. After printing, light will be used to illuminate the actuators and will be converted into heat by the nanoparticles. The generated heat will trigger actuator motion by shrinking the hydrogel.

Methods: Literature review. Hydrogel fabrication (with 2PP printing). Printing of Ag/Au nanoparticles i.e., tune the printing parameters to obtain nanoparticles and optimize the actuation. Characterization: UV absorbance spectra, SEM imaging, and measuring the light responsiveness of the structures.

Prerequisites: Materials (to develop the fabrication process and understand the behavior of the hydrogels with and without nanoparticles).

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRMAE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Lambert Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: Civil engineering - M-IRCNE

Mechanical characterization of non-linear materials to be used as miniaturized actuators

Description

Context: Active soft matter can be used as an actuator in microrobotics. It can deform under an external stimulus such as light, heat, or pH to generate a mechanical output (force and displacement). At the microscale, these smart materials can be 3D printed without assembly. In the lab, we use the two-photon polymerization method (2PP) to shape 50 μ m soft actuators out of a thermo-responsive polymer (pNipam = poly(N-isopropylacrylamide)). These active cubes demonstrate bending, contraction, twist, or shear deformation in a heated water bath [1]. Their mechanical performances such as Young modulus, force-displacement characteristics, or response time must now be characterized.

Objective: The aim of this thesis is to use a setup to measure the force-displacement characteristics of such actuators and to analyze the indentation data with the help of a finite element approach to decouple the elastic parameters (Young modulus, Poisson coefficients) from the visco-elastic parameters.

Methods: Literature review on modeling soft material at microscale. Develop a code to analyze the experimental data. Eventually, the results obtained may be supplemented and compared with data obtained with an environmental AFM, at UMons, and/or a nanoindentation system [4], at EMPA (Thun, Switzerland).

Prerequisites: Numerical methods

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : LAMBERT Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Automating 3D Geometric Measurement of Mechanical Test Benches Using Structured Scanning and Point Cloud Analysis

Description

Mechanical test benches must meet strict geometric tolerances to ensure that experimental measurements accurately reflect material and structural behavior rather than setup artifacts. Verifying these tolerances manually is a slow and error-prone process that becomes particularly burdensome when benches are frequently reconfigured or when high-precision applications demand exhaustive dimensional audits. This thesis designs and validates an automated system that acquires the complete 3D geometry of a mechanical test bench using a scanning sensor mounted on a motorized positioning stage, and processes the resulting point cloud data to extract quantitative geometric parameters without manual intervention. The system plans acquisition trajectories to ensure full coverage, registers multi-view scans into a unified coordinate frame, and computes deviations from CAD reference geometry to identify misalignments, deformations, and tolerance violations. Output is presented as an interactive 3D deviation map and a structured dimensional report, giving mechanical engineers a rapid, reproducible qualification tool that replaces manual measurement campaigns and supports traceability in accredited testing environments.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Privacy-by-Design People Counting in Lecture Halls Using an Embedded Depth Camera System

Description

This master's thesis addresses the challenge of occupancy monitoring in academic environments through the design of a GDPR-compliant, privacy-by-design vision system capable of counting individuals in a lecture hall without capturing or processing any identifying information. Built around a low-power embedded platform, it requires a lightweight inference pipeline, optimised for constrained hardware, performs robust people detection and counting.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Construction of a multiple-criteria evaluation process for student engineering projects

Description

Every bachelor student at Ecole Polytechnique de Bruxelles (EPB) must realize at least two projects during their first two years of study. These projects involve multiple different aspects, namely the construction of some model, the realization of a prototype implementing the model, the writing of a technical report, an oral presentation of the work, and in the case of the second project, an overview of the project management.

Currently, the evaluations of these points are performed separately by different parties using predefined evaluation grids. Such grids are great to objectivize the expectations of the teaching staff and tend to uniformize the grading if performed by different people. They are however based on natural language values (e.g.: "The slides are overall clear and allow the transfer of information") and translating these to a numerical grade is not trivial.

Moreover, combining the different grids also involve subjective choice that is not clear to pre-define, such as a weight associated to each grid.

In this master thesis, the student is expected to apply concepts from multiple criteria decision aid and natural language preference learning to develop a realistic and applicable evaluation process for bachelor projects. Ideally, the method(s) developed by the student could be compared with existing approaches and eventually applied in the following years.

Concerning the supervision, I would be available for weekly meetings (at the student's demand) and the student would be expected to give a ten minutes presentation of their work every six to eight weeks in order to have regular feedback on their presentations skills.

In case of questions or interest, feel free to contact me at alexandre.flachs@ulb.be with Dimitris Sacharidis (dimitris.sacharidis@ulb.be) in CC.

Expected profile: the student should be interested in didactics and will be confronted to an open applied problem with many possible leads to try. Moreover, this subject lies between multiple fields, some of which I do not master (at all). The student should thus be able to take initiatives, remain curious and be independent in its research.

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| Langue | FR (français) |
| Ouvert à d'autres masters | Yes |

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| Masters concernés | M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Sacharidis Dimitris (dimitris.sacharidis@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

GPS and IMU-Aided Time-Lapse Imaging Platform for Automated Condition Monitoring of Linear Infrastructure

Description

Roads, canals, and other linear infrastructure assets degrade gradually over time, yet systematic visual monitoring of these structures at scale remains logistically complex and costly. This thesis designs and validates a mobile time-lapse camera system that acquires continuous image sequences along linear infrastructure corridors, enriched with GPS position and IMU orientation data at each capture event. By anchoring every frame to a precise spatial reference, the system enables the construction of georeferenced image timelines that can be compared across acquisition campaigns to detect and localize structural changes. Automated analysis modules identify surface deterioration, deformation patterns, and anomalies by applying computer vision techniques to temporally aligned image pairs. The result is a practical, low-cost survey tool that provides infrastructure managers and engineers with a structured, queryable visual record of asset condition, supporting proactive maintenance decisions and regulatory reporting.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Machine Learning-Based Digitization of Seismic Traces from Scanned Historical Seismograms for Archival Data Recovery

Description

Seismological observatories worldwide hold vast collections of paper seismograms recording earthquakes and ground motion events going back to the late nineteenth century. This historical data is of exceptional scientific value for long-term seismic hazard assessment, source characterization of pre-instrumental earthquakes, and the calibration of modern seismic models, yet it remains largely inaccessible because converting analog traces into digital waveforms requires expert manual tracing on a record-by-record basis. This thesis builds a machine learning system that automates the recovery of seismic waveform data from scanned seismogram images. Starting from raw scan inputs, the pipeline handles document restoration, trace isolation, and waveform vectorization, translating the visual trace geometry into calibrated time series data that can be ingested by standard seismological software. The system is designed to process large archival collections with minimal human intervention, enabling seismologists to unlock decades of previously inaccessible observational data for modern reanalysis.

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| Langue | FR (français) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Debeir Olivier (olivier.debeir@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

On intransitive indifference relations and PROMETHEE methods

Description

When a problem involves multiple (conflicting) criteria, the notion of an “optimal” solution is ill-defined. Consider for example the problem of choosing the best place to host a conference, i.e. the least expensive, fanciest, and most accessible. It seems very unlikely that one place is the best on all these criteria.

The field of Multiple Criteria Decision Aid (MCDA) emerged in the 1960s to help decision makers who face such problems. In this context, the PROMETHEE I and PROMETHEE II methods rely on pairwise comparisons and preference functions to construct rankings of the available alternatives. In PROMETHEE, decision makers begin by describing their preferences regarding each criterion. When these preferences are crisp (strict), the procedure yields, for each criterion, a binary relation between alternatives that generally satisfies transitivity of strict preference (if $a > b$ and $b > c$ then $a > c$) but not transitivity of indifference ($a \sim b$ and $b \sim c$ but $a > c$).

However, the PROMETHEE I and II aggregation procedure produce rankings, and hence a form of global indifference that is transitive, since alternatives with identical net flows are considered indifferent. This raises several theoretical and practical questions: how does the aggregation process “repair” the non-transitive local indifference into a globally transitive indifference? To what extent is the global indifference meaningful when the underlying unidimensional relations exhibit cycles of indifference? Can alternative aggregation procedures or variants of PROMETHEE preserve or reflect the structure of local indifference more faithfully?

In this master thesis, the student is expected to investigate the contrast between non-transitive indifference at the criterion level and transitive indifference in the final ranking, both from a theoretical and methodological perspective. This could include revisiting the formal properties of PROMETHEE preference functions and the binary relations they generate; studying the structure of local indifference cycles and their propagation during aggregation; exploring alternative formulations or extensions that preserve local structures (e.g., partial orders, forest orders, interval-based flows, robust PROMETHEE approaches); or evaluating whether modified procedures could yield rankings that better reflect decision makers' intent.

Concerning the supervision, I would be available for weekly meetings (at the student's

demand), and the student would be expected to give a ten-minute presentation of their work every six to eight weeks in order to receive regular feedback on their presentation skills. In case of questions or interest, feel free to contact me at alexandre.flachs@ulb.be with Dimitris Sacharidis (dimitris.sacharidis@ulb.be) in CC.

Expected profile: the student should be ready to work on theoretical mathematics, in particular on binary relations on sets and orders representations.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Sacharidis Dimitris (dimitris.sacharidis@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Non-compensatory grading methods for university exams

Description

At Ecole polytechnique de Bruxelles (EPB), most exams are composed of multiple questions supposed to evaluate the students' understanding or mastery of various concepts. Each question is graded independently and all grades are then aggregated, often using a weighted sum approach. In the fields of multiple-criteria decision aid (MCDA) and multi-objective optimization, the weighted sum approaches are often criticized for various reasons, one of which is that they are subject to compensations. In short, this means that a defect on one criterion can always be compensated by an improvement on another. In the context of grading mentioned above, if a student scores perfectly on one questions (20/20) and completely fails another (0/20) their final score is 10/20 and they succeed the exam. This would be the same if the student scored 10/20 at both questions, though from the perspective of the teacher the second case might be considered better or worse than the first. Some MCDA methods are non-compensatory by construction, for example ELECTRE methods, the lexicographic methods or treshold-based methods.

In this master thesis, the student is expected to navigate between theoretical aspects of MCDA and practical constraints of teaching activities to explore and propose realistic grading methods with good mathematical properties (non-compensations, monotony, robustness, etc.).

Concerning the supervision, I would be available for weekly meetings (at the student's demand) and the student would be expected to give a ten minutes presentation of their work every six to eight weeks in order to have regular feedback on their presentations skills. In case of questions or interest, feel free to contact me at alexandre.flachs@ulb.be with Dimitris Sacharidis (dimitris.sacharidis@ulb.be) in CC. Expected profile: the student should be interested in didactics and will be confronted to an open problem with many possible leads to try.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M- IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Sacharidis Dimitris (dimitris.sacharidis@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Explainability of decisions from PROMETHEE based models

Description

In many real-world decision problems — selecting candidates for a position, ranking infrastructure projects, or allocating research funding — stakeholders are not only interested in the outcome of a decision process, but also in understanding why a particular alternative was preferred over another. This need for transparency is both ethical, as decisions may significantly affect individuals or organizations, and practical, as trust in a decision support tool should be constructed.

The PROMETHEE I and PROMETHEE II methods, developed in the 1980s, are widely used outranking methods in multiple-criteria decision aid (MCDA). They rely on pairwise comparisons across criteria, weighted preference functions, and the aggregation of these into net flow scores that induce a ranking of alternatives. While the mathematical structure of PROMETHEE is relatively transparent compared to black-box approaches such as neural networks, translating its outputs into natural language justifications that are meaningful to a non-expert decision maker remains an open challenge. For instance, stating that alternative a outranks alternative b because its net flow is higher offers little intuitive value without further context about which criteria drove that difference, how decisive those differences were, and whether the conclusion is robust to small changes in the model parameters.

In this master thesis, the student is expected to investigate explainability in the context of PROMETHEE-based decision models, drawing on concepts from both MCDA and the broader literature on explainable artificial intelligence (XAI). This could include formalizing notions of explanation suited to outranking methods (e.g., criterion-level contribution decompositions, contrastive or counterfactual explanations of the form “alternative a would have been preferred if criterion k had been weighted differently”); studying the relationship between robustness analysis tools already available in PROMETHEE and the production of explanations; or developing a prototype explanation module that generates human-readable justifications for a given ranking. The practical applicability of the proposed approach should be evaluated, ideally on a real or realistic decision problem. Concerning the supervision, I would be available for weekly meetings (at the student's demand) and the student would be expected to give a ten minutes presentation of their work every six to eight weeks in order to have regular feedback on their presentation skills.

In case of questions or interest, feel free to contact me at alexandre.flachs@ulb.be with Dimitris Sacharidis (dimitris.sacharidis@ulb.be) in CC.

Expected profile: the student should be interested in didactics and will be confronted to an open problem with many possible leads to try. The student should be comfortable with discrete mathematics and logic. Familiarity with probability and statistics is a plus.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Nombre de sujets | 2 |

Supervision

Supervisor : Sacharidis Dimitris (dimitris.sacharidis@ulb.be)

Master's program offering the topic: Computer science and engineering - M-IRIFS

Learning preferences of students towards course practices

Description

University courses are composed of a wide variety of teaching and assessment practices: lectures, exercise sessions, project work, oral examinations, written tests, flipped classroom approaches, peer feedback, and many others. While instructors often choose these practices based on experience or tradition, little is typically known about how students themselves perceive and value different combinations of course activities.

Understanding student preferences is non-trivial. A student may prefer oral exams over written ones in general, yet that preference may weaken or reverse when the course involves heavy mathematical content. Such context-dependent and potentially inconsistent preferences are difficult to capture with simple questionnaires or Likert scales. The field of preference learning, at the intersection of machine learning and multiple-criteria decision aid (MCDA), offers structured methods to elicit, represent, and reason about such preferences from observed data or pairwise comparisons.

In this master thesis, the student is expected to design and apply a preference learning methodology to model how students rank or evaluate different course practice profiles. This includes identifying relevant course attributes (e.g., type of assessment, frequency of feedback, degree of autonomy), collecting preference data through an appropriate elicitation protocol, and fitting a preference model - such as a utility function, a sorting rule, or an outranking relation - to the collected data. The work should also address the robustness of the inferred preferences and discuss the practical implications for course design. Ideally, the methodology could be piloted within one or more courses at Ecole polytechnique de Bruxelles and the results compared across student profiles (year of study, discipline, prior academic performance).

Concerning the supervision, I would be available for weekly meetings (at the student's demand) and the student would be expected to give a ten minutes presentation of their work every six to eight weeks in order to have regular feedback on their presentation skills. In case of questions or interest, feel free to contact me at alexandre.flachs@ulb.be with Dimitris Sacharidis (dimitris.sacharidis@ulb.be) in CC.

Expected profile: the student should be interested in didactics and will be confronted to an open problem with many possible leads to try. The student should be ready for data-driven

approaches. Ideally, the student would propose an end-to-end pipeline to apply on courses or cohorts.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Nombre de sujets | 2 |

Supervision

Supervisor : Sacharidis Dimitris (dimitris.sacharidis@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

[JUNO1] Generative AI for Fast Detector Simulation in Low-Level Trigger Studies

Description

The Jiangmen Underground Neutrino Observatory (JUNO) is a large particle physics experiment whose main goal is to act as a multipurpose observatory for neutrinos produced by artificial and natural sources. JUNO is currently in construction in the Jiangmen underground facility in Southern China.

- **Background:** Accurate simulation of detector response is fundamental for developing and optimizing trigger algorithms in high-energy physics experiments like JUNO. However, traditional Monte Carlo (MC) methods, while precise, are computationally intensive, creating a significant bottleneck for the rapid exploration and tuning of low-level trigger strategies.

- **Objective:** This project aims to develop and validate a fast simulation framework based on Generative AI to produce realistic JUNO detector response data tailored specifically for low-level trigger algorithm research. The goal is to drastically reduce the time needed for data generation compared to full MC simulations, while maintaining sufficient fidelity for trigger-relevant features, thereby accelerating the trigger R&D cycle.

- **Methodology:** The research will leverage JUNO's unique structure (20,000 Photo-Multiplier Tubes (PMTs), representable as a graph) and the availability of high-fidelity MC simulation data for training.

- **Key steps include:**

- Designing and optimizing generative AI models (e.g., Graph Neural Networks combined with GANs, VAEs, or Diffusion Models) capable of capturing the spatio-temporal characteristics of PMT responses.

- Training these models on large datasets generated by the existing, reliable JUNO simulation tools.

- Developing rigorous validation metrics to compare AI-generated data against MC data, focusing on distributions and correlations critical for low-level triggering (e.g., hit times, charge patterns, cluster properties).

- Demonstrating the utility of the fast simulator by integrating it into a typical workflow for trigger algorithm evaluation or optimization.

- **Expected Outcomes:** The primary outcome will be an efficient and validated generative AI model capable of rapidly producing JUNO detector response data. The research will

provide a quantitative assessment of the speed-up factor and the fidelity achieved compared to traditional MC methods.

• Keywords: Generative AI, Deep Learning, Detector Simulation, Fast Simulation, Surrogate Modeling, JUNO, Trigger System, Low-Level Trigger, Monte Carlo Simulation, Graph Neural Networks, High Energy Physics.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Robert Frederic (frederic.robert@ulb.be)

Master's program offering the topic: Electrical engineering - M-IRELE

[JUNO2] An Intelligent Agent System for Automated Monitoring and Debugging Support of the JUNO Electronics system

Description

The Jiangmen Underground Neutrino Observatory (JUNO) is a large particle physics experiment whose main goal is to act as a multipurpose observatory for neutrinos produced by artificial and natural sources. JUNO is currently in construction in the Jiangmen underground facility in Southern China.

- **Background:** The JUNO Electronics system is a complex, distributed system responsible for processing signals from 20,000 PMTs (photomultipliers). Ensuring its stable operation requires continuous monitoring of performance metrics, analysis of large data volumes, and timely diagnosis of potential hardware faults. Current approaches often rely heavily on manual inspection and expert intervention, which can be time-consuming and difficult to scale, especially with evolving personnel.
- **Objective:** This project aims to develop an Intelligent Agent system designed to automate the monitoring, analysis, and debugging support workflow for the JUNO Electronics system. The agent will act as an "intelligent assistant," proactively analyzing operational data, identifying anomalies, providing contextual information, and streamlining the troubleshooting process for human experts.
- **Methodology:** The research will focus on integrating modern AI agent frameworks with existing analysis tools and domain knowledge.

Key steps include:

- Designing the agent architecture using a framework like AutoGen or LangChain, enabling it to perceive system status, plan analysis steps, and execute actions.
- Implementing automated workflow execution, allowing the agent to orchestrate existing data analysis scripts and algorithms (developed by previous researchers) as callable "tools."
- Developing data-driven anomaly detection modules to continuously monitor key performance indicators and flag statistically significant deviations potentially indicative of hardware issues.
- Building a local JUNO Electronics system knowledge base (from design documents, historical logs, expert notes) and integrating it using Retrieval-Augmented Generation (RAG) with Large Language Models (LLMs) and vector databases. This allows the agent to query the knowledge base to provide context for anomalies or answer expert queries.

-Designing the system with modularity and extensibility in mind, allowing easy integration of new tools, data sources, or diagnostic capabilities.

- Expected Outcomes: The project will deliver a functional prototype of the Intelligent Agent system for JUNO Electronics system monitoring and debugging support, including demonstrated automation of routine analysis tasks, successful identification of predefined anomaly types, effective knowledge retrieval via RAG, and a well- documented, extensible framework. This system aims to significantly enhance operational efficiency, accelerate problem resolution, and preserve critical expert knowledge for the JUNO experiment.

- Keywords: Intelligent Agents, AI Agent, Automation, System Monitoring, Fault Diagnosis, Debugging Support, JUNO, Backend Electronics , Workflow Automation, Knowledge Base, RAG (Retrieval-Augmented Generation), Large Language Models (LLM), Anomaly Detection, High Energy Physics Operations, Extensible Framework.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M- IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Robert Frederic (frederic.robert@ulb.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Experimental and numerical investigation of structural adhesive behavior under multiple loading conditions

Description

Context of the master thesis

Adhesive joints are commonly used to bond components in composite structures. Adhesive bonding not only facilitates lightweight designs but also offers significant advantages over mechanical fastening, including excellent durability, fatigue resistance, and the ability to evenly distribute stress across the joint. Despite these benefits, adhesive joint failure often reduces the lifespan of composite structures [1]. Therefore, comprehensive experimental characterization of structural adhesives and the development of reliable numerical models are essential for understanding adhesive joint behavior in large-scale structures, such as wind turbine blades. Due to the cross-linking nature of epoxy adhesives, their tensile, shear, and compressive behaviors differ. These differences can be accounted for using a pressure-dependent material model [2]. The Drucker-Prager model, a commonly used pressure-dependent material model, has been applied by researchers to simulate epoxy-based adhesives, though most studies are limited to the linear form of the model [3]. In this master's thesis, structural adhesive specimens will be tested under tensile, shear, and compressive loading to characterize material behavior, including post-yield response, and to extract material constants for the Drucker-Prager exponential model. Each experiment will be simulated using ABAQUS finite element (FE) software to replicate the observed material behavior and damage propagation. Following complete characterization and modeling of the adhesive, fracture tests will be performed on Single Edge Notch Bending (SENB) specimens under various loading conditions. The developed advanced material model will then be used to numerically replicate these experiments, demonstrating the applicability of the exponential Drucker-Prager model in simulating the behavior of epoxy adhesives.

References

- [1] P. Zuo and A. P. Vassilopoulos, "Review of fatigue of bulk structural adhesives and thick adhesive joints," *Int. Mater. Rev.*, vol. 66, no. 5, pp. 313–338, 2021, doi: 10.1080/09506608.2020.1845110.
- [2] X. P. Morelle, J. Chevalier, C. Bailly, T. Pardoën, and F. Lani, "Mechanical characterization and modeling of the deformation and failure of the highly crosslinked RTM6 epoxy resin,"

Mech. Time-Dependent Mater., vol. 21, no. 3, pp. 419–454, 2017, doi: 10.1007/s11043-016-9336-6.

[3] A. Sharma et al., “Combined computational-experimental investigation of residual stresses and pre-cracking in mode I behaviour of thick adhesively bonded GFRP composite joints,” Compos. Struct., vol. 351, p. 118549, Jan. 2025, doi: 10.1016/J.COMPSTRUCT.2024.118549.

Objectives of the master thesis

1. To perform advanced mechanical characterization of epoxy-based adhesives experimentally.
2. To develop a numerical model that replicates adhesive behavior under tensile, shear, and compressive loading.
3. To assess the model’s capability to predict damage propagation in cracked specimens.

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| Langue | EN (english) |
| Ouvert à d’autres masters | Yes |
| Masters concernés | M-IRMAE, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Kalteremidou Kalliopi-Artemi (Kalliopi-Artemi.Kalteremidou@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Investigation of Combined Noise Transmission and Reflection Cancellation in Industrial Duct Systems

Description

Industrial compressors produce significant pressure pulsations, and thus noise, within their exhaust system. Conventional solutions to dampen these acoustic waves is the use of passive silencers. However, their integration becomes challenging for state-of-the-art variable speed drive (VSD) applications. Active noise cancellation, with the implementation of an actively controlled loudspeaker, to dampen the compressor's pressure pulsations is an interesting alternative that provides various benefits in VSD applications, compared with conventional silencers.

The loudspeaker itself will generate anti-phase pressure waves that destructively interfere with the pressure waves produced by the compressor. Noise transmission cancellation is therefore achieved towards the remaining exhaust system. However, a single loudspeaker will inherently also reflect pressure waves back towards the compressor which is not desired. Implementing 2 loudspeakers, 1 for noise transmission and 1 for noise reflection can solve this problem. Thus, a detailed investigation of the coupling between these 2 loudspeakers is necessary.

You will be performing simulations and experiments with loudspeakers in an exhaust system in order to study the interaction between them when cancelling the exhaust noise, thereby trying to minimize the pressure pulsations that gets transmitted and reflected.

The simulations will be performed in MATLAB Simulink. The basic models will be provided by the supervisor. The goal will be to simulate various configurations of these devices as well as performing parametric studies. An experimental setup is available to validate the simulations. The setup is comprised of various duct elements and loudspeakers that can be put in various configurations. Here, incoming noise can be generated (that simulate the industrial machinery noise). The passive and active attenuation devices will then be steered to dampen the noise. The most optimal configuration will then be searched for based on the power consumption of the actuator.

Depending on the fluidity of the project, a final experiment on a 45 kW compressor can be performed.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Verrelst Bjorn (Bjorn.Verrelst@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Development of a thermal PID closed-loop controller for 316L/CuCr1Zr functionally graded additive materials

Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the Directed Energy Deposition process, each region can be processed individually, with different processing conditions and material compositions. On-demand tailoring of the microstructure results in locally varying and optimized material properties across the part, generating an unprecedented level of design freedom for the parts of the future. However, ensuring that each alloy composition (of a multi-material) is processed in the optimal manner requires the development of a dedicated and advanced (thermal) closed-loop controller.

The current thesis proposal targets the challenging processing of a 316L to CuCr1Zr multi-material. The student will first perform system identification for the different materials / mixtures considered in the framework of this thesis. The student will develop a model between the laser power input and thermal response of the melt, highlighting the differences that exist depending on the processed mixture. The student will then develop, simulate and implement a (PI) controller and perform practical tests to evaluate the controller's actions, depending on the processed mixture. The student will evaluate the necessity of a mixture-specific controller, and will propose a framework as to how to adjust controller parameter based on varying compositions (e.g. additional controller input). The student may suggest machine modifications with the purpose of enhancing the quality of the produced multi-material samples through closed-loop control.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 2 |

Supervision

Supervisor : Hinderdael Michaël (michael.hinderdael@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

On-line measurement and validation of thermal gradients during 3D metal printing through IR-camera measurements.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. It is equipped with a 5-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive drilling/milling operations for the production of a part. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, the powder particles, and the melt pool (high intensity spot) are visible.

Fig. 2 shows a 3D tower part that has been manufactured in a hybrid way with the MiCLAD machine. During the DED process, the thermal history of the part is very important for the final quality and directly influences the residual stresses. It is therefore very important to monitor the temperature of the part during the process and to set up efficient numerical tools in order to study the effect of process parameters and build strategy on the thermal history of the part.

In this context, two thermal cameras (FLIR and SWIR) have been integrated into the machine, and a dedicated tool has been developed to enable in-process thermal gradient monitoring. The use of both cameras allows for broader thermal range coverage, capturing the various temperature the part experiences during the process. The tool enables simultaneous recording from both cameras and provides real-time visualization of thermal gradients through a dedicated application, with the aim of enabling online thermal gradient control in the future. An example of a captured thermal field of the build plate during

process is shown in Fig. 5.

This setup and tool now require further development and validation to assess the accuracy of the results. To this end, an experimental campaign will be conducted under varying

heat input boundary conditions, primarily focusing on laser power and build plate preheating settings. The resulting data will be analyzed to gain a deeper understanding of the thermal history of parts during the DED process and ultimately to reduce the thermal gradient and resulting residual stresses.

In parallel, the measured thermal gradients will be compared with numerical simulations using an existing DED process model. This comparison aims to validate the model as well as the associated material parameters (such as density, latent heat, and heat capacity) and boundary conditions against the experimental results. A specific parameter matrix will be defined for both the experimental and numerical campaigns. The thermal history simulations will be carried out using Morfeo (Manufacturing Oriented Finite Element tOol), an extended finite element (FEM) code developed by the Belgian research center Cenaero [3].

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

| Langue | EN (english) |
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| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Post-processor extension to 3D material allocation for metal 3D printing through Directed Energy Deposition manufacturing process.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. It is equipped with a 5-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive drilling/milling operations for the production of a part. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, the powder particles, and the melt pool (high intensity spot) are visible. Fig. 2 shows a 3D part/sprocket that has been manufactured with the MiCLAD machine.

Functionally Graded Materials (FGM) are components with gradual changes in composition or structure across their volume, designed to optimize mechanical or thermal performance. In DED, FGMs are produced by dynamically adjusting the metal powder or wire feed rates during the deposition process. This enables smooth transitions between different metal alloys (e.g., stainless steel to copper), reducing residual stresses and improving bonding. Such FGMs are ideal for applications requiring a combination of properties like high strength, corrosion resistance, and thermal stability within a single part.

FGMs are used for example in injection molding molds, as shown in Fig. 3 [3], to optimize performance by combining high thermal conductivity near the mold surface for faster cooling with a tougher core for structural strength. This gradient in properties improves cycle times, reduces wear, and extends mold life. The production of such a part required a

different material allocation in 3 dimensions (x, y, and z), see Fig. 4.

CAD/CAM software (Computer-Aided Design / Manufacturing) plays a crucial role in DED by converting CAD models into toolpaths that guide the deposition head and define process parameters. However, current commercial solutions lack the capability to handle FGMs by assigning specific materials and corresponding process settings to precise locations within a part. To address this, the AM-Lab developed the CamLink post-processor, which serves as a translator between the CAD/CAM software and the CNC machine, enabling advanced control over material deposition.

It allows the generation of machine compatible Gcode from any geometry, incorporating the desired material gradient at specified locations, via a standalone MATLAB application. However, at this stage, material allocation is limited to the -z and -x directions. An example of a composition transition from copper to 316L in the x-direction is shown in Fig. 6–7.

The aim of this master thesis is to further develop the existing CamLink post-processor to enable material allocation in all three spatial dimensions, thereby allowing complete design freedom in the manufacturing of FGMs. In the next phase, this extension will be validated through simple experiments using the DED machine. Subsequently, process parameters will be optimized, based on microstructural analysis, to ensure defect-free transitions between material compositions. Finally, the enhanced post-processor will be validated through the production of a demonstrator part featuring composition gradients in all three directions.

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

| Langue | EN (english) |
|----------------------------------|---|
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Development of the wedge test for thick adhesive joints to prevent crack deviation under mode I loading

Description

Context of the master thesis

Adhesive joints are widely used across various industries, including wind turbine manufacturing, shipbuilding, aerospace, and automotive applications. Compared with traditional joining methods, adhesive bonding offers several advantages, such as the ability to join similar and dissimilar materials, weight savings, improved stress distribution along the bond line, and enhanced corrosion and fatigue resistance. When considering thick adhesive joints, however, the definition varies across industries. For example, in the wind turbine and shipbuilding sectors, thick adhesive joints typically have an adhesive layer thickness of approximately 10 mm or greater [1]. The influence of adherend constraint, joint geometry, and residual stresses on crack kinking under mode I loading conditions is well documented in the literature [2], [3]. Nevertheless, to date, no experimental setup has been proposed that enables stable crack propagation within the mid-plane of the adhesive layer under pure mode I loading. To address this gap, the present master's thesis will employ a combined numerical–experimental approach to develop a test method capable of promoting stable crack growth in thick joints. A series of numerical models will first be developed using ABAQUS finite element (FE) software to evaluate fracture parameters under mode I loading using conventional Double Cantilever Beam (DCB) specimens subjected to point loading. In the subsequent step, in addition to the opening load applied normal to the crack plane, an auxiliary load will be applied in a perpendicular direction. This auxiliary load is intended to reduce crack-tip constraint arising from joint geometry and residual stresses. Based on the numerical results, the appropriate load ratio between the parallel and perpendicular loading directions will be determined, and a wedge-based support system capable of delivering this load ratio will be designed. Experimental tests will then be conducted on pre-cracked thick adhesive joint specimens to assess the feasibility and effectiveness of the proposed method. Finally, the wedge test experiments will be replicated through FE simulations to provide a comprehensive understanding of the underlying fracture mechanisms and crack propagation behavior.

References

[1] R. Lopes Fernandes, S. Teixeira de Freitas, M. K. Budzik, J. A. Poulis, and R. Benedictus,

“From thin to extra-thick adhesive layer thicknesses: Fracture of bonded joints under mode I loading conditions,” Eng. Fract. Mech., vol. 218, no. August 2019, p. 106607, 2019, doi: 10.1016/j.engfracmech.2019.106607.

[2] A. S. Kojouri et al., “A new equivalent crack length technique for mode I fracture of adhesively bonded joints,” Compos. Part B Eng., p. 112733, Jun. 2025, doi: 10.1016/j.compositesb.2025.112733.

[3] A. Sharma et al., “Combined computational-experimental investigation of residual stresses and pre-cracking in mode I behaviour of thick adhesively bonded GFRP composite joints,” Compos. Struct., vol. 351, p. 118549, Jan. 2025, doi: 10.1016/J.COMPSTRUCT.2024.118549.

Objectives of the master thesis

1. To determine the fracture parameters of thick adhesive joints under point-load conditions.
2. To identify fracture parameters that mitigate unstable crack propagation in adhesive joints and to design a wedge-based loading system accordingly.
3. To experimentally evaluate the proposed setup for facilitating stable crack propagation.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Kalteremidou Kalliopi-Artemi (Kalliopi-Artemi.Kalteremidou@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Control Strategy Development of a Variable Loudspeaker Enclosure for Minimal-Power Consumption During Active Noise Cancellation in Industrial Duct Systems

Description

Industrial compressors produce significant pressure pulsations, and thus noise, within their exhaust system.

Conventional solutions to dampen these acoustic waves is the use of passive silencers. However, their integration

becomes challenging for state-of-the-art variable speed drive (VSD) applications. Active noise cancellation, with

the implementation of an actively controlled loudspeaker, to dampen the compressor's pressure pulsations is an

interesting alternative that provides various benefits in VSD applications, compared with conventional silencers.

The actively controlled loudspeaker generates anti-phase pressure waves that destructively interfere with the

pressure waves produced by the compressor. The loudspeaker therefore consumes a certain amount of electrical

power. This power can be minimized when the loudspeaker operates at its mechanical resonance frequency.

However, in VSD applications, the excitation frequency shifts with operating speed, hence the need for a variable

resonance frequency of the loudspeaker. The mechanical resonance frequency of the loudspeaker can be shifted

by having a variable back-cavity enclosure volume. Doing so, the loudspeaker can operate in a wider frequency

range at minimal power.

Previous work has already been conducted where an initial design of a variable back-cavity volume loudspeaker

was made. Experiments have shown that the resonance frequency of the system could be shifted from 200 to 300

Hz by varying the piston position via a stepper motor.

Previous work has already been conducted where a fixed-volume loudspeaker was used to perform active noise cancellation in an industrial duct system.

Your job will be to combine these 2 systems. The idea will be to control the loudspeaker to achieve active noise cancellation (reduce noise in the duct system) while the loudspeaker operates at minimal power consumption.

MATLAB Simulink models will be provided to you by the supervisor in order to investigate different control methods (feedforward/feedback) to control the stepper motor, and hence the enclosure volume, in such a way that the loudspeaker works in its most efficient working point. Afterwards, the control strategies can be experimentally evaluated on an academic test setup.

Depending on the fluidity of the project, a final experiment on a 45 kW compressor can be performed.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Verrelst Bjorn (Bjorn.Verrelst@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Reduction of large plasma-assisted combustion simulations using principal component analysis and machine-learning techniques

Description

New technological challenges in combustion science require reliable ignition and flame stabilization in demanding conditions. Some examples are ultra-lean combustion, fuel flexibility (using alternative, low-carbon fuels), supersonic combustion (scramjets), and the active control of thermo-acoustic instabilities. Non-thermal plasma discharges have been proposed as an innovative solution to ensure efficient and stable operation in these particular regimes.

Nanosecond discharges are introduced to obtain a more favourable ignition of reactive mixtures, where conventional methods fail. However, an in-depth knowledge of the effects of nonequilibrium plasma on the initiation and stability of these challenging combustion processes is still lacking in the field. The current literature on the subject is incomplete and mostly experimental. The modelling and numerical simulation of plasma discharges and their

influence on combustion therefore remains a critical need to understand and support experiments working towards the development of the next combustion technologies.

The numerical simulation of plasma-assisted combustion (PAC) problems remains a key challenge in the community because of (1) the multi-scale nature of the flow: plasma chemistry occurs at the nanosecond time scale and combustion at millisecond scales; (2) non-equilibrium effects: combustion chemistry and transport are coupled with detailed plasma chemistry in nonequilibrium thermodynamics; and (3) the large dimensionality of the mechanisms: hundreds of species are coupled tightly in large and stiff kinetic mechanisms.

Principal Component Analysis (PCA) has been used in previous work to reduce large kinetic mechanisms. The goal is to couple local PCA methods with machine-learning regression techniques in order to optimally reduce the kinetic mechanism.

The candidate should have coding knowledge (python/fortran/matlab) and have an interest in CFD for reacting flows (combustion physics / plasma flows).

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Bellemans Aurelie (aurelie.bellemans@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Processing and characterization of a 316L to CuCr1Zr functionally graded additive materials

Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the Directed Energy Deposition process, each region can be processed individually, with different processing conditions and material compositions. On-demand tailoring of the microstructure results in locally varying and optimized material properties across the part, generating an unprecedented level of design freedom for the parts of the future.

The current thesis proposal targets the challenging processing of a 316L to CuCr1Zr multi-material. The student will engage in the explorative research regarding the process-material-property relationship of this multi-material. Especially the effect of ultrasound excitation during the DED processing of such 316L/CuCr1Zr multi-material will be explored. Samples with varying/gradient compositions will be manufactured and mechanically/microstructurally characterized to further optimize the processing conditions. The effects on corrosion resistance will be evaluated as well. The student will suggest process parameter optimizations and machine modifications with the purpose of enhancing the quality of the produced multi-material samples.

Practically, coupons will be produced under varying processing conditions, amongst which the amplitude of the ultrasonic excitation, after which metallurgical evaluation will reveal the obtained microstructure. The work will then continue to print larger coupons with gradient microstructures, which will then be metallurgically and mechanically characterized. Additionally, corrosion testing will be conducted macroscopically, and at localized regions to carefully evaluate the performance along the build direction. The functional properties (thermal/mechanical/corrosion) will be compared to reference conditions without ultrasound excitation.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |

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| Nombre de sujets | 2 |
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Supervision

Supervisor : Hinderdael Michaël (michael.hinderdael@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Development of a MIMO closed-loop controller for 316L/CuCr1Zr functionally graded additive materials

Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the Directed Energy Deposition process, each region can be processed individually, with different processing conditions and material compositions. On-demand tailoring of the microstructure results in locally varying and optimized material properties across the part, generating an unprecedented level of design freedom for the parts of the future. However, ensuring that each alloy composition (of a multi-material) is processed in the optimal manner requires the development of a dedicated and advanced closed-loop controller.

The current thesis proposal targets the challenging processing of a 316L to CuCr1Zr multi-material. The student will first investigate the particular challenges related to the development of a closed-loop process controller for multi-materials. By utilizing the existing closed-loop controller (only laser power control), the student will compare samples against open loop trials. The existing closed-loop controller will then be further optimized (PID parameter tuning, setpoint, temperature estimation models), challenged for different geometries and extended (e.g. including scan speed control). The student may suggest machine modifications with the purpose of enhancing the quality of the produced multi-material samples through closed-loop control.

The student will characterize the process (system identification) and develop a state-space model of the process. A Model Predictive Controller (MPC), based on Matlab/Python scripting, will be developed. The student will be involved in the practical integration, machine control implementation and parameter tuning of the to-be-developed closed-loop process controller. Coupons will then be produced under varying controlling strategies (open loop, existing closed-loop, new solution) after which metallurgical evaluation will reveal the obtained part quality. Machine modifications may be suggested towards further enhancing the DED process.

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| Langue | EN (english) |
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| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 2 |

Supervision

Supervisor : Hinderdael Michaël (michael.hinderdael@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

test

Description

test

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : test test (test@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Unraveling the effect of geometry on crack kinking under mode I loading using biaxial testing

Description

Context of the master thesis

Fracture mechanics is a branch of solid mechanics that studies the behavior of structures in the presence of cracks. In real structures, crack initiation can occur in regions of high stress or due to material voids, among other causes. Understanding material and structural behavior in the presence of cracks is crucial for avoiding catastrophic failure and enabling fail-safe design methodologies. To achieve this, fracture behavior must be studied under different loading modes, i.e., mode I, mode II, and mode III [1]. Mode I, or opening mode, is the most common loading condition encountered in real structures [1]. Experimental studies on mode I have shown that cracks do not always propagate in a straight path; rather, they often kink due to geometric constraints. In other words, changing the specimen geometry under the same loading conditions can lead to different crack propagation behaviors [2], [3]. Despite extensive experimental work, the primary factors triggering crack kinking remain not fully understood. It is well recognized that altering the geometry from Single Edge Notch Tension (SENT) to Double Cantilever Beam (DCB) specimens under mode I loading can induce unstable crack propagation [2], [3]. In this master's thesis, PMMA (polymethyl methacrylate) DCB specimens will be modeled under the Linear Elastic Fracture Mechanics (LEFM) framework using ABAQUS finite element (FE) software to determine the stress field and fracture parameters at the crack tip. Subsequently, biaxial loading conditions will be applied to the specimens, and the corresponding fracture parameters will be evaluated. The main objective is to identify a biaxial loading condition that suppresses crack kinking in the DCB specimen. Once the appropriate loading conditions are determined, the specimens will be tested using a biaxial testing machine to validate the simulations. This research will provide high-quality insights into the influence of geometry and loading conditions on crack trajectory under mode I, enhancing our understanding of fracture behavior in engineering structures.

References

- [1] T. L. Anderson, FRACTURE MECHANICS: Fundamentals and Applications, Fourth Edition. 2017. doi: 10.1201/9781315370293.
- [2] N. Razavi, M. R. Ayatollahi, and F. Berto, "A synthesis of geometry effect on brittle

fracture,” Eng. Fract. Mech., vol. 187, pp. 94–102, 2018, doi:
10.1016/j.engfracmech.2017.10.022.

[3] M. R. Ayatollahi, M. Rashidi Moghaddam, N. Razavi, and F. Berto, “Geometry effects on fracture trajectory of PMMA samples under pure mode-I loading,” Eng. Fract. Mech., vol. 163, pp. 449–461, Sep. 2016, doi: 10.1016/J.ENGFRACTMECH.2016.05.014.

Objectives of the master thesis

For the first time, the combined effects of specimen geometry and loading on mode I fracture will be investigated. This study aims to achieve the following objectives:

1. To understand the effect of geometry on crack trajectory under mode I loading.
2. To identify loading conditions that mitigate unstable crack propagation under mode I.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Kalteremidou Kalliopi-Artemi (Kalliopi-Artemi.Kalteremidou@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Effects of Passive Attenuation Devices on the Requirements of an Active Noise Cancellation Loudspeaker in Industrial Duct Systems

Description

Industrial compressors produce significant pressure pulsations, and thus noise, within their exhaust system. Conventional solutions to dampen these acoustic waves are the use of passive silencers. However, their integration becomes challenging for state-of-the-art variable speed drive (VSD) applications. Active noise cancellation, with the implementation of an actively controlled loudspeaker, to dampen the compressor's pressure pulsations is an interesting alternative that provides various benefits in VSD applications, compared with conventional silencers.

However, a hybrid approach using both passive and active attenuation devices could be beneficial to lower the actuator's dynamic requirements. One example of a passive resonator is a quarter-wavelength resonator side branch. When incoming pressure waves arrive at this side branch, part of the noise will go inside the resonator. At the resonator's resonance frequency, this pressure wave will get reflected back to the main duct with the opposite phase, hence cancelling the primary wave. The loudspeaker, when placed downstream of the resonator, would in theory need to deliver very little anti-noise since a large portion of the noise cancellation is already achieved via the passive device. However, many different configurations can be thought of to place these devices with respect to each other. Therefore, a detailed investigation of the interaction between these passive (acoustic resonators) and active (loudspeakers) attenuation devices is of interest.

You will be performing simulations and experiments with passive and active attenuation devices in an acoustic duct network in order to study the interaction between these devices and the effect on the loudspeaker's dynamic requirements.

The simulations will be performed in MATLAB Simulink. The basic models will be provided by the supervisor. The goal will be to simulate various configurations of these devices as well as performing parametric studies. The most interesting configurations can afterwards be experimentally evaluated on an academic setup.

A modular academic test-setup is available where various ducts, passive resonators, and active loudspeakers can be assembled in various configurations. Different configurations can be examined where the interaction between the passive and active devices is measured, as well as the power consumption of the loudspeaker for full cancellation of the

noise. The most optimal configuration, where the loudspeaker's power draw is minimal will then be searched for.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Verrelst Bjorn (Bjorn.Verrelst@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Development of a ML-based controller for 316L/CuCr1Zr functionally graded additive materials

Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the Directed Energy Deposition process, each region can be processed individually, with different processing conditions and material compositions. On-demand tailoring of the microstructure results in locally varying and optimized material properties across the part, generating an unprecedented level of design freedom for the parts of the future. However, ensuring that each alloy composition (of a multi-material) is processed in the optimal manner requires the development of a dedicated and advanced closed-loop controller.

The current thesis proposal targets the challenging processing of a 316L to CuCr1Zr multi-material. The student will first investigate the particular challenges related to the development of a closed-loop process controller for multi-materials. The student will select and train multiple regression-based machine-learning (ML) models and compare their performance to classify coaxial melt-pool images with varying alloy compositions. A real-time process controller will be implemented to control the DED-LB process, thereby utilizing the ML model classification as input to know how to process the alloy optimally (e.g. target melt-pool temperature, adjust powder feed rates). A comparison between open-loop processing, traditional closed-loop control and ML-based controller is planned (target composition (EDS), and part quality (metallurgical analysis)).

The student will propose processing trials in which melt-pool images are captured to train a regression-based ML model. The developed model will be evaluated against an unseen set of melt-pool images with varying compositions to evaluate the estimation accuracy and pinpoint classification errors. The resulting coupons will be metallurgically characterized (EDS) and serve as the ground truth for classification purposes. A second part of the thesis will then involve the development of a control loop in which the actual melt-pool composition is compared to the targeted one, allowing to change the powder feed rates and utilize the optimal processing conditions for the actual melt pool composition.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 2 |

Supervision

Supervisor : Hinderdael Michaël (michael.hinderdael@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Numerical study for thermal gradient reduction during 3D printing Directed Energy Deposition process.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. It is equipped with a 5-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive drilling/milling operations for the production of a part. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, the powder particles, and the melt pool (high intensity spot) are visible. Fig. 2 shows a 3D part that has been manufactured on the MiCLAD machine.

During the DED process, the thermal history of the part is very important for the final quality and directly influences the residual stresses, see Fig. 3. It is therefore very important to monitor the temperature of the part during the process and to set up efficient numerical tools in order to study the effect of process parameters and build strategy on the thermal history of the part. Next to the process parameters, as shown on Fig. 3, buildplate preheating involves heating the baseplate before material deposition begins, is also used to reduce the thermal gradients.

Preheating minimizes the temperature difference between the incoming molten material and the cooler buildplate. This helps controlling the thermal history of the part, and might lead to better overall quality of the printed part.

The aim of this master thesis is to investigate numerically the effect of temperature dependent material parameters (density, latent heat, heat capacity, ...) and build plate

preheating settings on the thermal history of the part.

The DED thermal history simulations are runned with Morfeo (Manufacturing Oriented Finite Element tOol) an eXtended Finite Element (X-FEM) code developed by the Belgian research center Cenaero [4] and compared with the in-situ thermal monitoring tools available on the MiCLAD (pyrometer data and hyperspectral melt pool temperature estimation).

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Thermo-mechanical simulation of milling process on 3D printed metal parts.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. It is equipped with a 5-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive milling operations for the production of a part. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, the powder particles, and the melt pool (high intensity spot) are visible. Fig. 2 shows a 3D part that has been manufactured on the MiCLAD machine.

During the additive and subtractive operations, the thermal history of the part is very important for the final quality and directly influences the residual stresses. It is therefore very important to monitor the temperature of the part during the process and to set up efficient numerical tools in order to study the effect of process parameters and build/cutting strategy on the thermal history of the part. The MeMC and MECH departments of the VUB are cooperating to study these effects in the context of the HiPAS SBO project [3].

The DED thermal history simulations are runned with Morfeo (Manufacturing Oriented Finite Element tOol), an eXtended Finite Element (X-FEM) code developed by the Belgian research center Cenaero [4] and compared with the in-situ thermal monitoring tools available on the MiCLAD (pyrometer data and hyperspectral melt pool temperature estimation).

The aim of this master thesis is to extend the existing simulation tool of the DED addition process by investigating numerically the effect of a post milling operation (subtraction process) on the thermal history and residual stresses of a DED part, and to identify the main influencing parameters [5,6].

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Thermo-mechanical simulation of ablation process on 3D printed metal parts.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, the powder particles, and the melt pool (high intensity spot) are visible. Fig. 2 shows a 3D part that has been manufactured on the MiCLAD machine.

Hybrid Additive Manufacturing is based on the combination of multiple processes improving the cost, quality, functionality, and efficiency of the

parts [3]. Possible examples of additive-subtractive combination are Hybrid-AM by Machining or hybrid-AM by Ablation [4]. The MiCLAD machine is equipped with a 5-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive milling operations for the production of a part. The lab is also equipped with an external ablation stage that will be soon integrated in the machine.

During the additive and subtractive operations, the thermal history of the part is very important for the final quality and directly influences the residual stresses. It is therefore very important to monitor the temperature of the part during the process and to set up efficient numerical tools in order to study the effect of process parameters on the thermal history of the part. The MeMC and MECH departments of the VUB are cooperating to study these effects in the context of the HiPAS SBO project [5].

The DED thermal history simulations are runned with Morfeo (Manufacturing Oriented Finite Element tOol), an eXtended Finite Element (X-FEM) code developed by the Belgian research center Cenaero [6] and compared with the in-situ thermal monitoring tools available on the MiCLAD (pyrometer data and hyperspectral melt pool temperature estimation).

The aim of this master thesis is to extend the existing simulation tool of the DED addition process by investigating numerically the effect of the ablation process (subtraction process) on the thermal history and residual stresses of a DED part, and to identify the main influencing parameters [7].

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Development of manufacturing strategies for functionally Graded Additively Manufactured Parts

Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the production process, each region can be processed individually, with different processing conditions and material compositions, ultimately targeting varying material properties across the part. Generating an unprecedented level of design freedom for the parts of the future. In view of many mechanical applications that involve heat, the use of a copper-to-steel gradient is considered a viable solution to increase part performance. The examples below show two example cases in which functional graded materials are used/researched.

Computer Aided Manufacturing (CAM) tools generate, based on the CAD design, the necessary machine code to automate the manufacturing process (planned motion path & process parameters). While such software tools exist for homogeneous, single material prints, those tools are in need to be further developed to accommodate multi-material prints and incorporate the necessary transient conditions. The current thesis proposals targets the extension of CAM tools for such complex geometries for multi-materials 3D printing. The outcome of the thesis is ultimately a software-add on/Matlab program, that manipulates the CAM program to accommodate the multi-material aspect of the print.

The thesis will start with an exploration of existing CAM tools at their disposal (Siemens NX, Cura, etc.) and will explore the current capabilities and limitations. Based on this analysis, one CAM software package will be selected for further development. The thesis work will then comprise the development of such add-on tool to modify the original CAM code, starting with simplest geometries and gradually increasing the complexity of the modification. The work then comprises a dry-run of the generated code to evaluate the proper running thereof, before effective trials are executed on the 3D printing machine. Subsequent analysis of the process behavior should then confirm the modifications that were implemented.

As the thesis mostly comprises software development, we especially look for a student

that has strong programming skills in combination with interests in advanced manufacturing processes (and 3D printing in specific).

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Hinderdael Michaël (michael.hinderdael@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

A passive bi-directional overrunning clutch for compliant actuation

Description

The integration of clutches in actuators and drivetrains enables advanced dynamics suitable for a wide range of applications. This project will concentrate on passive, bi-directional, overrunning clutches. These clutches allow for the transmission of power from input to output in both clockwise and counterclockwise directions but freewheel when power flows from the output. The ability to switch between these two modes (driving and freewheeling) passively, without the need for additional actuators, is particularly advantageous. If well designed and characterized, this clutch has the potential to be useful for a wide range of robotic applications: for robot arms to avoid shock damage, for wearable robotics such as exoskeletons to allow freedom of motion to the user and enable the use of smaller actuators, etc.

In this thesis, the student will design and build a passive, bi-directional, overrunning clutch with a particular emphasis on understanding the switching behaviors. Then, its performance and impact on the drivetrain will be studied and tested (efficiency, switching behavior, torque capability, etc.). Lastly, the student will use the clutch for compliant actuation. The ability of the clutch to disconnect when backdriving will be used to protect an actuator from shocks; this ability will be tested by implementing the prototype in a drivetrain and studying a use case to be chosen by the student (exoskeleton, robotic arms, ...).

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Verstraten Tom (Tom.Verstraten@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Characterization of the liner/composite overwrap interface in type IV hydrogen storage vessels

Description

Context of the master thesis

Hydrogen is widely recognized as a promising clean energy carrier due to its high specific energy and zero direct emissions. However, its low volumetric energy density under ambient conditions necessitates the use of high-pressure storage vessels to achieve practical storage efficiency for applications such as fuel-cell electric vehicles and stationary energy systems. Among the available storage technologies, Type IV hydrogen storage tanks, consisting of a polymer liner fully wrapped with a carbon fibre-reinforced composite overwrap, have emerged as a leading solution for on-board gaseous hydrogen storage, owing to their lightweight construction and high pressure-bearing capability. In these vessels, the polymer liner primarily serves as a hydrogen permeation barrier, preventing gas leakage and isolating the stored hydrogen from the composite structure, while the composite overwrap bears the mechanical loads associated with high-pressure operation. Hydrogen is widely recognized as a promising clean energy carrier due to its high specific energy and zero direct emissions. However, its low volumetric energy density under ambient conditions necessitates the use of high-pressure storage vessels to achieve practical storage efficiency for applications such as fuel-cell electric vehicles and stationary energy systems. Among the available storage technologies, Type IV hydrogen storage tanks, consisting of a polymer liner fully wrapped with a carbon fibre-reinforced composite overwrap, have emerged as a leading solution for on-board gaseous hydrogen storage, owing to their lightweight construction and high pressure-bearing capability. In these vessels, the polymer liner primarily serves as a hydrogen permeation barrier, preventing gas leakage and isolating the stored hydrogen from the composite structure, while the composite overwrap bears the mechanical loads associated with high-pressure operation. Despite their advantages in weight reduction and performance, Type IV tanks present critical challenges at the interface between the polymer liner and the composite overwrap that directly affect safety and durability. During high-pressure filling, hydrogen can permeate into the polymer liner and subsequently accumulate at the liner-overwrap interface. Upon rapid depressurization, this trapped hydrogen may generate local pressure differentials, leading to binder cavitation, interfacial void growth, and, in severe cases, liner collapse [2]. Furthermore, repeated pressurization-depressurization cycles can induce

fatigue damage and progressive interfacial degradation, increasing hydrogen permeation, reducing structural reliability, and ultimately shortening the service life of the storage vessel. This thesis will focus on the characterization of the liner–composite overwrap interface in a Type IV hydrogen storage vessel. Mechanical testing will include double cantilever beam and T-pull tests to quantify the interfacial adhesion between the polymer liner and the composite overwrap. The effects of temperature and hydrogen exposure on interfacial properties will also be investigated. In addition, fatigue testing will be conducted to evaluate the long-term durability of the storage vessel.

References

- [1] U. Eberle, R. von Helmolt, GMHydroGen4 – A Fuel Cell Electric Vehicle based on the Chevrolet Equinox, Fuel Cells Data, Facts Fig. (2016) 75–86. <https://doi.org/10.1002/9783527693924.ch08>.
- [2] Y.T. Li, W.J. Huang, Y.M. Zhang, M. Fan, Z.M. Xiao, W.G. Li, Investigation of liner collapse behaviors in Type IV hydrogen storage vessels at different temperatures, J. Energy Storage 129 (2025) 1–18. <https://doi.org/10.1016/j.est.2025.117307>.
- [3] J. Pépin, E. Lainé, J.C. Grandidier, G. Benoit, D. Mellier, M. Weber, C. Langlois, Replication of liner collapse phenomenon observed in hyperbaric type IV hydrogen storage vessel by explosive decompression experiments, Int. J. Hydrogen

Objectives of the master thesis

This thesis will aim to develop a comprehensive understanding of the interfacial behaviour between the polymer liner and the composite overwrap in Type IV hydrogen storage tanks under service-relevant conditions, including hydrogen exposure, cryogenic temperatures, and cyclic mechanical loading. The insights obtained from this work are expected to support the design, material selection, and optimization of hydrogen storage systems with improved durability and safety performance.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Kalteremidou Kalliopi-Artemi (Kalliopi-Artemi.Kalteremidou@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Ultrasonic welding of thermoplastics and thermoplastic composites- Parametric study and optimization

Description

Context of the master thesis

Thermoplastic materials are widely used in many industries, either as plain materials or in composites where they are reinforced with fibers, leading to lightweight and resistant structures, which at the same time offer sustainable solutions. The reason for this is that thermoplastics are processed at high temperatures in order to obtain their final shape and since they can be melted, solidified and re-heated, they offer great recyclability potential. This property however offers much more industrial interest, since thermoplastics can also be welded, providing therefore alternatives compared to traditional mechanical fastening using e.g. bolts or rivets. One of the most promising welding methods is ultrasonic welding. Ultrasonic plastic welding (USW) is the joining or reforming of thermoplastics through the use of heat generated from high-frequency mechanical motion. It is accomplished by converting high-frequency electrical energy into high-frequency mechanical motion. That mechanical motion, along with applied force, creates frictional heat at the plastic components' mating surfaces (joint area) so the plastic material melts and forms a molecular bond between the parts. Ultrasonic welding can offer a very fast and energy-efficient way for joining materials and in particular thermoplastics. Despite its potential and the fact that ultrasonic welding is being used in some industries for joining thermoplastics together, there is still a lot of open research related to the understanding of the impact of the different parameters involved in the process on the quality of the obtained joints. Moreover, automation of the welding process and optimization of the different parameters is of great importance, towards its further and more well-established industrialization. During this thesis subject, the student will initially have to perform a dedicated literature review on ultrasonic welding. Then, an experimental campaign will be performed, during which joints of thermoplastic parts will be manufactured by altering the parameters related to the ultrasonic welding process, e.g. applied load, weld time and hold time. The quality of the manufactured joints will be controlled through ultrasonic measurements after their production, in order to be directly correlated to the combination of welding parameters used. Moreover, mechanical testing will be performed and the damage of the joints will be evaluated through non-destructive methods, i.e. acoustic emission and digital image correlation. Based on the data collection through the ultrasonic

welding process and the performed tests, in the final step of the thesis, the student will use machine learning/AI tools in order to use the obtained data in the most optimal way for the optimization of the method through closed-loop automation controls.

Objectives of the master thesis

1. Parametric study on ultrasonic welding of thermoplastics.
2. Damage evaluation of ultrasonic welds using non-destructive methods.
3. Optimisation of ultrasonic welding parameters combining experiments with machine learning.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Kalteremidou Kalliopi-Artemi (Kalliopi-Artemi.Kalteremidou@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Metallurgical, mechanical & corrosion characterization of ultrasonic assisted additively manufactured 316L

Description

Additive Manufacturing (AM) is a manufacturing process that individually processes every region of the part. Layer by layer, a metal part is built from a feedstock material (powder) that is molten together to form a three-dimensional object. During the Directed Energy Deposition process, each region can be processed individually, with different processing conditions and material compositions. On-demand tailoring of the microstructure results in locally varying and optimized material properties across the part, generating an unprecedented level of design freedom for the parts of the future.

The current thesis proposal targets the processing of single 316L alloy, yet Functionally Graded, constituting of a microstructural gradient by grain refinement through ultrasonic assisted additive manufacturing. Without such ultrasound assistance, grains tend to grow to elongated and larger grains during the solidification step, typically resulting in undesired, anisotropic material properties. The ultrasound excitation perturbs the melt pool during the solidification step, causing an interrupted grow of these elongated grains, and leading to a more refined and more isotropic material properties. The student will engage in the explorative research regarding the process-material property relationship through the addition of ultrasound excitation.

Practically, the student will be involved in the practical integration and machine control implementation of an ultrasonic stack to harmonically work alongside the additive manufacturing process. Coupons will then be produced under varying processing conditions, including primarily the amplitude of the ultrasonic excitation, after which metallurgical evaluation will reveal the obtained microstructure. The work will then continue to print larger coupons with gradient microstructures, which will then be metallurgically and mechanically characterized. The anisotropy of the mechanical properties will be compared to reference conditions without ultrasound excitation. Besides, a systematic microstructural characterization will be conducted by SEM to evaluate, not only the grain structure, but also the sub-granular micro-segregation cell structure and inclusion formation along the build direction; since these aspects have a very important impact on the properties of the material.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 2 |

Supervision

Supervisor : Hinderdael Michaël (michael.hinderdael@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Process parameter optimization for 3D printing of single alloy rocket nozzle through Directed Energy Deposition process.

Description

3D printing is a very popular additive process during which layers of material are superposed to create a 3D part. In the past decade it gained a lot of interest due to an important increase in accessibility.

Directed Energy Deposition (DED) [1] is a specific metal additive manufacturing (AM) or 3D printing technique which uses a focused laser source to melt metal powder which is simultaneously fed by a nozzle.

The Additive Manufacturing Research Lab (AM-lab) of the VUB developed an in-house hybrid DED machine, called the MiCLAD, which is extensively presented in [2]. It is equipped with a 3-axis CNC control and has the particularity to allow the combination of and fast change between DED additive deposition and subtractive drilling/milling operations for the production of a part. An in-situ monitored image of the process is shown in Fig. 1 on which the nozzle, and the melt pool (high intensity spot) are visible.

Rocket nozzles must be extremely resistant to withstand the intense thermal and mechanical loads experienced during launch, see Fig. 2-3. They are exposed to temperatures exceeding 3000 °C and high-pressure exhaust gases moving at supersonic speeds. In addition, they endure significant thermal gradients, vibrations, and mechanical stresses from the combustion chamber and external aerodynamic forces. As a result, nozzle materials and designs must ensure high thermal conductivity, oxidation resistance, mechanical strength, and structural integrity throughout the mission.

Producing the rocket nozzle using DED offers significant advantages. It allows for precise control over material deposition, enables the fabrication of complex geometries, function integration minimizes material waste, and supports rapid iteration.

The BE Rocket Team [3] is a Belgian inter university student initiative (VUB, KU Leuven, ULB, RMA, Liège, Mons, Bruges) aiming to design, build, test, and launch amateur solid fuel rockets to compete in the European Rocketry Challenge (EuRoC). The 21st of October

2024, Be-Rocket successfully launched their first rocket, Bossart-I, at the military base of Elsenborn in Belgium. Fig. 4-6 shows the rocket during boost phase, and the nozzle design that was used for the tests. However, the nozzle has been conventionally manufactured and not with additive manufacturing techniques.

In parallel at the AM-Lab of VUB, preliminary experiments have been performed for the production of miniature rocket nozzles. During the DED process, the thermal history of the part is critical to the final quality and directly influences residual stresses. Many interconnected physical phenomena occur, and the process is defined by several parameters such as laser power, scan speed, powder feed rate, scanning path, track overlap, and more. The results of the manufacturing of the miniature rocket nozzle are shown in Fig. 7-10. However, several processing challenges remain, including dripping due to the printing on inclined surfaces, lack of fusion, and other microstructural defects. These issues highlight the need for further process optimization to produce a high-quality rocket nozzle.

This master thesis will aim to manufacture a structurally sound rocket nozzle for the next Be-Rocket student rocket, the design of which is shown in Fig. 6. The work will involve conducting an extensive parametric study to enable the production of a high-quality miniature nozzle demonstrator, meeting criteria such as dimensional accuracy, appropriate microstructure, and minimal defects like pores or lack of fusion. Various manufacturing strategies available in our lab must be considered and explored (for example remelting, controlled cooling to reduce cracking, regulation of melt pool temperature, etc.).

The results of these strategies will need to be compared to identify the most efficient manufacturing approach for manufacturing a real size nozzle. The best demonstrator will then be on the test bench for solid rocket motors at the rocket propulsion test facility of the ULB, as shown on Fig. 11-12.

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRMAE, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Jardon Zoé (zoe.jardon@vub.be)

Master's program offering the topic: EM - Aeronautics - M-IREMR-A

Novel Indicators for Detecting Structural Changes During Vibration Testing of Satellites During Qualification Tests

Description

Satellites undergo high levels of vibrations during the different phases of launch to orbit, which can be the cause of partial or total loss of structural integrity, and potentially failure of the mission.

Qualification tests are designed to reproduce as well as possible the intensity of such vibrations in the laboratory, before the launch, to make sure that the satellites are resistant enough and avoid partial or total mission failure.

During qualification tests, the current practice is to use damage indicators based on frequency and amplitude shifts which are often misleading due to “settling” phenomena—components stabilize under vibration without actual damage, triggering false nonconformities.

Objectives of the master thesis

The main objective of the master thesis is to develop alternative damage indicators which are not sensitive to the settling phenomena, while being still sensitive to structural damage. This will require to

- Analyze vibration signatures across multiple test campaigns to characterize variability.
- Develop alternative indicators based on energy distribution over a broader bandwidth.
- Recommend criteria to distinguish real damage from normal settling behavior.

The master thesis is proposed in collaboration with Dr Cédric Dumoulin from Aerospacelab, a Belgian company designing and manufacturing satellites.

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| Langue | EN (english) |
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| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Deraemaeker Arnaud (arnaud.deraemaeker@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Clean energy & sustainable propulsion: Adjoint optimization for LES of hydrogen flames

Description

- Hard-to-abate industries and heavy-duty transportation will keep relying on combustion-based applications due to the high required energy densities and high process temperatures. Hydrogen-based fuels are a viable option to decarbonize these sectors.
- Hydrogen and ammonia flames dynamics are entirely different to conventional fuels and burner geometries need to be adapted.
- The goal is to couple an adjoint based optimization algorithm with an existing LES framework, which models hydrogen combustion.
- The goal is to apply the developed framework to a particular burner geometry and optimize it, e.g. such that minimal emissions are obtained.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Grid-Forming Droop Control with Seamless Islanding Transition for a Battery-Based Vehicle-To-Grid Unit

Description

The ability of a vehicle-to-grid (V2G) unit to transition seamlessly between grid-connected and islanded operation is critical for microgrid resilience. This thesis will design a droop-based grid-forming controller that detects islanding and autonomously reconfigures its control loops, validated experimentally using the battery-connected inverter as the grid-forming source and a machine as a local load.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Nombre de sujets | 1 |

Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Clean energy & sustainable propulsion: Machine learning methods in LES of hydrogen flames

Description

- Hard-to-abate industries and heavy-duty transportation will keep relying on combustion-based applications due to the high required energy densities and high process temperatures. Hydrogen-based fuels are a viable option to decarbonize these sectors.
- Hydrogen and ammonia flames dynamics are entirely different to conventional fuels and local flame propagation, which is a key design parameter, is challenging to predict. However, validated simulation tools are indispensable for technology development nowadays
- The goal is to learn the flame propagation from direct numerical simulation (DNS) with machine learning methods
- Apply data-driven model to industrial-relevant large-eddy simulations (LES)

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH |
| Nombre de sujets | 2 |

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Digital twin simulations of offshore wind turbines

Description

At the Vrije Universiteit Brussel (VUB) we are heavily involved in monitoring the structural health of offshore wind turbines (OWT) in the Belgian North Sea. We are currently monitoring wind turbines on all Belgian offshore wind farms for fatigue life, structural integrity and their overall dynamic behaviour. Digital twin are more and more used in the wind industry to predict remaining lifetime, predictive maintenance, and structural integrity. Commonly differentiated in data-driven digital twins, which represents the structure completely based measured inputs, and physics based digital twins, which are build based on existing physical relations. Through their rooting in known physical relations, physics-based digital twins often provide better transparency of their behaviour.

- Objective:

In this Master Thesis you will validate the physics-based digital twin of an offshore wind turbine in the Belgian North Sea with real-world data using the aeroelastic simulation software ASHES.

- Prerequisites/special skills (optional)

An interest in structural dynamics and programming is desired. A good knowledge of numerical methods such as the finite element method as well as prior experience with aeroelastic software such as OpenFast can be advantageous. This master thesis gives you the opportunity to learn about the modelling and dynamic behaviour of Offshore Wind Turbines as well as the work of OWI-lab in the structural health monitoring of wind turbines.

- Other information:

This topic is an umbrella topic in which direction can be given aligned with the student's interests and skillset. E.g. the focus can be put on the control of the turbine, the soil-structure interaction, the performance under anomalous behaviour, the automatic integration between database and simulation, ...

Your thesis work builds on past master thesis's and starts from their latest findings.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Three-phase Active Power Filter for Vehicle-To-Grid Applications

Description

Harmonic pollution injected into the grid by nonlinear loads is a well-known power quality issue, and V2G inverters can be leveraged to actively suppress these harmonics without relying on heavy and expensive passive filters. Building directly on experience already acquired with single-phase proportional-resonant (PR) controllers for active filtering, this thesis extends the concept to the three-phase case using the existing bench inverter and MicroLabBox II platform. The student will implement selective harmonic compensation using parallel resonant controllers tuned to the 5th, 7th, and 11th harmonics in a synchronous reference frame, and validate the results experimentally with a nonlinear load.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Nombre de sujets | 1 |

Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Sustainable Aviation Fuels: Controlling Soot Emissions in Aircraft Engines

Description

- Sustainable Aviation Fuels (SAF) are key to decarbonize the aviation sector
- The reduction of soot and other emissions is critical to reduce the environmental impact of the aviation sector
- Soot formation is strongly sensitive to the local flow conditions and combustion process in an aircraft engine
- The goal is to analyze the effect of the flow field on soot formation in laminar well controlled counterflow flames
- In a second step, soot formation in turbulent flames is simulated using LES and a comparison to experimental reference data is performed
- the development of a validated LES framework for industrial applications is key to enable the design of future aircraft engines

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

PEM fuel cells to decarbonize aviation: Modeling liquid water transport

Description

- PEM fuel cells are considered a viable option for emission free flying (see e.g. ZEROe from Airbus or the Flying Fuel Cell by MTU Aero Engines AG etc.) using hydrogen as a fuel
- operation of PEM fuel cells is challenging and requires in-depth understanding of the small-scale processes in the porous media, e.g. liquid water transport
- the goal is to model liquid water transport in macro-homogeneous models and validate the simulations against experimental reference data
- Particular focus lies on the modeling of the channel/GDL interface

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Finite-Control-Set Model-Predictive Control for a Vehicle-To-Grid Bidirectional Inverter

Description

Classical PI current controllers with PWM are the industry standard for grid-connected inverters, but finite-control-set model-predictive control (FCS-MPC) has emerged as an attractive alternative that eliminates the modulator and offers intuitive multi-objective tuning. This thesis will implement both control strategies in Simulink on the MicroLabBox II for the same two-level inverter and battery setup, and compare them experimentally in terms of current THD, dynamic response, and ease of tuning. The FCS-MPC implementation will use a single prediction step (horizon = 1) as a baseline, with extension to longer horizons left as an option for motivated students.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Nombre de sujets | 1 |

Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Clean energy & sustainable propulsion: Modeling hydrogen/ammonia flames in LES

Description

- Hard-to-abate industries and heavy-duty transportation will keep relying on combustion-based applications due to the high required energy densities and high process temperatures. Hydrogen-based fuels are a viable option to decarbonize these sectors.
- Hydrogen and ammonia flames dynamics are entirely different to conventional fuels and predictive combustion models for LES are yet not available
- The goal is to analyze detailed data-heavy DNS data, where all turbulent fluctuations are resolved, and to extract the underlying physics regarding the interactions of the flame and turbulence
- The goal is to develop models for unclosed terms in LES and then apply the newly developed models in an LES to show its improvements
- The analysis will be done for different hydrogen/ammonia blends

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Real-Time State-of-Charge-Aware Vehicle-To-Grid Power Scheduling with Grid Frequency Support

Description

Effective vehicle-to-grid (V2G) participation requires the inverter controller to be aware of the battery's state of charge and to respond to grid frequency deviations in a coordinated way. This thesis will develop a supervisory layer combining a real-time SoC estimator (e.g. extended Kalman filter or adaptive observer) for the LiFePO4 pack with a primary frequency droop response, dynamically modulating injected/absorbed power according to SoC constraints. The MicroLabBox II will run both the SoC estimator and the power reference generator in real time, enabling full closed-loop V2G frequency support experiments.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Nombre de sujets | 1 |

Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

PEM fuel cells to decarbonize aviation: Pore-resolved simulations in porous media

Description

- PEM fuel cells are considered a viable option for emission free flying (see e.g. ZEROe from Airbus or the Flying Fuel Cell by MTU Aero Engines AG etc.) using hydrogen as a fuel
- operation of PEM fuel cells is challenging and requires in-depth understanding of the small-scale processes in the porous media, e.g. liquid water transport
- the goal is to establish a modeling framework for pore-resolved simulations of liquid water transport in PEM fuel cells
- the goal is to apply this framework to relevant questions in flow field and stack design

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Virtual-Synchronous-Machine Control of a Vehicle-To-Grid Bidirectional Inverter Using a LiFePO4 Battery Pack

Description

Grid-forming control via Virtual Synchronous Machine (VSM) emulation is one of the most active research areas in power electronics, as inverter-dominated grids increasingly lack the natural inertia of synchronous generators. This Master thesis will build upon previous work and implement a VSM algorithm on the MicroLabBox II to make the battery-side inverter behave like a synchronous generator, providing synthetic inertia and voltage support. The student will tune the virtual inertia and damping coefficients and validate the frequency response experimentally.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Nombre de sujets | 1 |

Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

Experimental testing of a monitoring hardware for application in floating offshore wind turbines.

Description

At the Vrije Universiteit Brussel (VUB) we are heavily involved in monitoring the structural health of offshore wind turbines (OWT) in the Belgian North Sea. We are currently monitoring wind turbines on all Belgian offshore wind farms for fatigue life, structural integrity and their overall dynamic behavior. Floating Offshore Wind Turbines (FOWT) refer to offshore wind turbines mounted on floating platforms, allowing them to be deployed in deeper waters where fixed-bottom turbines are not feasible.

- Objectives of the master thesis;

This master's thesis focuses on building and testing a small-scale experimental setup to evaluate a monitoring hardware system (GNSS/IMU). The objective is to assess the hardware's ability to provide accurate position for an instrumented device—such as a scaled FOWT. When combined with other sensor types, this data will help us better understand the motion characteristics of FOWTs and how they relate to mooring line tensions and overall system dynamics. This project is conducted in collaboration with 24SEA, a company specializing in monitoring solutions for offshore wind turbines.

- Prerequisites/special skills (optional)

An interest in structural dynamics, experimental work and programming is desired. The thesis also includes working with sensors and hardware, and doing experimental validation of the sensor setups. A thesis suitable for someone with a strong 'MacGyver'/'Maker' - spirit.

- Other information

This thesis might require you to travel occasionally to 24SEA, situated just outside Brussels.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |

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| Nombre de sujets | 1 |
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Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

PEM fuel cells to decarbonize aviation: Modeling degradation in PEM fuel cells

Description

- PEM fuel cells are considered a viable option for emission free flying (see e.g. ZEROe from Airbus or the Flying Fuel Cell by MTU Aero Engines AG etc.) using hydrogen as a fuel
- operation of PEM fuel cells is challenging and handling cell degradation is a key challenge for future technologies
- the goal is to develop a simulation framework to model degradation mechanisms in PEM fuel cells
- the new library will be coupled to CFD solvers to enable predictions of degradation in a 3D realistic cell

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Berger Lukas (lukas.berger@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Mechanical characterization of polymeric soft materials to be used as miniaturized actuators

Description

Context: Soft matter is used as an actuator in microrobotics. It can deform under an external stimulus (light, heat, or pH...) to generate a mechanical output (force and displacement). In the lab, we utilize the two-photon polymerization method (2PP) to shape 50µm soft actuators from a thermo-responsive polymer (pNIPAM = poly(N-isopropylacrylamide)). These active cubes demonstrate bending, contraction, twist, or shear deformation in a heated water bath [1]. Their mechanical performances must be characterized statically, to determine the elastic properties (Young modulus, Poisson coefficients) and/or dynamically, to determine the viscoelastic properties.

Objective: The aim of this thesis is to develop a setup to measure the force-displacement characteristics of such actuators. Inspired by Micro-Electro-Mechanical Systems (MEMS) force sensors [2] and/or atomic force microscopy (AFM) [3], this set-up will be fabricated in using glass microstructures (to be produced with the FemtoPrint machine) or with other materials deemed relevant by the candidate.

Methods: Literature review on characterizing the mechanical performance of soft material at microscale. Design the set-up considering the following criteria: 1) samples are characterized in water to allow them to swell and shrink, 2) a heating system (conventional or laser) will be used to drive the actuators, and 3) the sensor must be in contact with small samples (50 to 200 µm). Eventually, the results obtained may be supplemented and compared with data obtained with an environmental AFM, at UMons, and/or a nanoindentation system [4], at EMPA (Thun, Switzerland).

Prerequisites: Mechanics (to determine the device shape and develop the different part of the set-up using CAD software), coding (to automatically control the setup), and materials (to understand the material model obtained from experimental measurements).

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| Langue | EN (english) |
| Ouvert à d'autres masters | No |
| Masters concernés | M-IRCBS, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 2 |

Supervision

Supervisor : Lambert Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Aerial Robot Perching to a Wide Range of Surfaces with Tactile Sensing

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f:/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRPtg

When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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|----------------------------------|---------------------------------|
| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-O |
| Nombre de sujets | 3 |

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Optimized topologies of an actuator and arm for a humanoid robot

Description

Humanoid robots could revolutionize many sectors, but their progress is limited by the challenge of designing compact, efficient, and powerful joint actuators.

This project aims to develop an optimized humanoid arm and actuator topology that improves performance, range of motion, and weight efficiency.

It involves comparing existing designs and creating a CAD model of an improved solution, ideal for students interested in mechanical design and robotics.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : LOPEZ GARCIA PABLO (plopezga@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive Dynamic Safety Margin Design for Force-Regulated Explicit Reference Governors

Description

This thesis investigates the design of adaptive safety margins for Explicit Reference Governors (ERG) applied to robotic manipulators operating under external forces and contact constraints.

Explicit Reference Governors ensure constraint satisfaction by predicting future system behavior and evaluating a Dynamic Safety Margin (DSM) that quantifies the distance to constraint violation. In current implementations, safety margins are typically defined using fixed worst-case bounds on modeling uncertainty and force-estimation errors. While this guarantees safety, it often leads to conservative robot behavior and reduced performance.

The objective of this thesis is to develop an adaptive tightening mechanism that adjusts the safety margin online based on measurable uncertainty indicators such as force-estimation residuals, prediction error, or disturbance dynamics. The proposed method will be integrated into an existing force-regulated ERG framework for robotic manipulators.

The student will:

Analyze the baseline ERG and DSM formulation

Design an adaptive uncertainty bound for force and motion prediction

Integrate the adaptive margin into the ERG safety mechanism

Validate the approach through simulation and experimental evaluation

Compare performance against fixed-bound safety margins

The expected outcome is a safer and less conservative ERG controller capable of maintaining constraint satisfaction while improving responsiveness and task efficiency.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E |

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| Nombre de sujets | 1 |
|-------------------------|---|

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Expansion of gearbox test bench for NVH testing

Description

Human-centered robots like humanoids and cobots require not only efficient actuators but also low noise and vibration for user comfort and acceptance.

This project expands a VUB gearbox test bench, in collaboration with AILOS, to include Noise, Vibration, and Harshness (NVH) analysis using specialized sensors and data processing methods.

The goal is to evaluate and compare gearbox performance and acoustic behavior, ensuring quieter and smoother operation for robotic applications.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E |
| Nombre de sujets | 2 |

Supervision

Supervisor : LOPEZ GARCIA PABLO (plopezga@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Commissioning of a robotics actuator for a humanoid robot

Description

Humanoid robots can transform sectors like healthcare and manufacturing, but their deployment is limited by the challenge of designing compact, powerful, and safe joint actuators.

This project focuses on integrating and testing an actuator for a humanoid arm using existing components, with evaluation based on torque, efficiency, and controllability under realistic conditions.

The goal is to build a functional, well-characterized actuator, suited for students interested in robotics, control systems, and mechanical design.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : LOPEZ GARCIA PABLO (plopezga@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Comparative study of physics-enhanced graph neural network approaches for multiple degrees-of-freedom system response estimation

Description

- Context of the master thesis

Wind turbines are the biggest dynamic, mass-produced, man-made structures. Their structural response to environmental and operational variations is highly complex and non-linear. As such, both physical modelling and data-driven inference have difficulties in accurately estimating the response. The former require simplifications which, along with unknown quantities (e.g. blade geometry), undermine accuracy. The latter may achieve high performance, but are limited to their training space, and extrapolation isn't trustworthy. This is also the case for virtual sensing, where limited instrumentation limits the ability to capture the full dynamics of the system, leading to uncertain predictions at unsensed locations, especially outside observed operational conditions.

In this context, physics-enhanced or hybrid modelling has come to the foreground. The philosophy behind it is straightforward: data-driven algorithms have problem-specific physical knowledge embedded into their architectures (loss function, differentiable equations, etc.) which improve generalization and performance. In this thesis, a comparative study of different approaches into embedding physical knowledge into a data-driven algorithm will be research by analyzing performance over multiple degrees-of-freedom systems (MDOF). These (MDOF), represent idealized reductions of real-world structures (e.g. wind turbines, bridges, etc.) and are extremely convenient, as they have low computational costs and their parametrization enables varied response simulation. The baseline algorithm will be a graph neural network.

- References

§ Haywood-Alexander, Marcus, et al. "Discussing the spectrum of physics-enhanced machine learning: a survey on structural mechanics applications." Data-Centric

Engineering 5 (2024): e30.

§ Cicirello, Alice. "Physics-Enhanced Machine Learning: a position paper for dynamical systems investigations." Journal of Physics: Conference Series. Vol. 2909. No. 1. IOP Publishing, 2024.

§ Mehrjoo, Azin, Eleonora M. Tronci, and Babak Moaveni. "A Physics-Informed Framework for Input Load Estimation in Offshore Wind Turbines." International Conference on Experimental Vibration Analysis for Civil Engineering Structures. Cham: Springer Nature Switzerland, 2025.

- Objectives

§ Review virtual sensing in offshore wind turbines.

§ Identify and review physics-enhanced/hybrid modelling approaches.

§ Generate MDOF systems with varying numbers of degrees and exciting load [both intensity and location] in a Python script.

§ Encode MDOF as a graph, including stiffness, damping and mass matrices.

§ Implement a Graph Neural Network (GNN) virtual sensor baseline in Python.

§ Assess and compare the addition of physics knowledge into the baseline with relation to: performance over unseen numbers of nodes [extrapolation and interpolation] and unseen excitations [intensity and location].

- Prerequisites/special skills

· Basic python programming.

· Knowledge of fundamentals of structural mechanics (e.g. equations of motion, etc.).

· Attendance of Prof. Deraemaker's Dynamics of Structures or Mechanical Vibrations course (<https://structuraldynamics.ulb.be/dynamics-of-structures-2025-2026/>)

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCNE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Nombre de sujets | 1 |

Supervision

Supervisor : Weijtjens Wout (wout.weijtjens@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Geometric and structural design of flexible joints for deployable scissor grids

Description

Note: if interested, come and discuss the topics with us, to refine the research question based on your skills and interests.

Context:

Deployable structures are fascinating structural mechanisms: they have the ability to transform themselves from a small, closed or stowed configuration to a much larger, open or deployed configuration. Mobile deployable structures have the great advantage of speed and ease of erection and dismantling compared to conventional building forms. They have a wide field of application, from space antennas to festival structures, to adaptable furniture and toys.

At VUB there is 20 years of expertise on these fascinating systems and recently a spin-off company called KONLIGO was created to design and build zero-waste event structures based on our scissor technology.

Because these deployable structures can be used and reused over and over again they are well-suited to support the transition to a zero-waste event industry, where currently the waste problem is huge. Because of the modular construction and high component uniformity, and easy repair and maintenance, they are well-suited for a 'circular business model'.

Topic:

Many new shapes have been developed by us in recent years. Digital models have been made, new shapes have been patented and small-scale models have been realised to test these concepts.

But every new shape has its specific detailing issues to be solved: e new joint that allows the required movement, a new material for the joint or the beams, a modular design that allows reconfiguration, adding stiffening cables or not, etc...

To be able to build our vast library of new and promising shapes for scissor structures, one possible strategy is to develop new joints that are flexible in one direction and stiff in the other. This requires 3D-printing/prototyping and some material engineering. This could potentially unlock very interesting new shapes for expanding the application potential of scissor grids.

Depending on the interest and the profile of the student(s) involved, different accents/directions can be identified, collaboration between students with a different profile is also accepted:

- Emphasis on the exploration of various configurations based on a range of design criteria and application contexts, through scale models and 2D-3D prototyping
- Parametric modelling of scissor geometry in Rhino/Grasshopper and 3D-models/rendered images
- Prototyping a scissor structure at full scale

The aim of this project is the successful experimental exploration and realisation of deployable scissor structures, based on realistic design criteria. Digital and physical design and fabrication tools can be explored and used for the successful realisation of these new shapes.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRARE, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 2 |

Supervision

Supervisor : Roels Ellen (ellen.roels@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Practical demonstration of a bidirectional converter topology for a hybrid energy storage system in mobile robotics

Description

Context:

Mobile robots are subject to highly dynamic load conditions, with repeated peak power demands during acceleration and opportunities for energy recovery during braking. A Hybrid Energy Storage System (HESS) can improve performance by combining storage units with different characteristics and interfacing them to a common DC bus through bidirectional power converters.

Objective:

The objective of this thesis is to identify, implement, and evaluate the most suitable bidirectional converter topology for connecting multiple battery modules to a common DC bus that feeds a robot power profile emulator.

This includes the development of a control and energy management strategy for stable bus operation, controlled power sharing, and handling of dynamic robotic load profiles.

The thesis will address the following questions:

1. Which bidirectional converter topology is the most suitable for interfacing multiple battery modules with different voltage or state-of-charge levels to a common DC bus in a mobile robotic application?
2. Can a control and energy management strategy maintain stable DC bus voltage and appropriate power sharing under representative robot load cycles, including peak power events?

Methodology:

The student will first perform a short literature review on Hybrid Energy Storage Systems (HESS) and bidirectional converter topologies for mobile robotic applications. Based on this review, a small number of candidate topologies will be selected and compared in terms of efficiency, controllability, complexity, and suitability for representative robotic load profiles. The selected topologies will then be modelled and simulated using a robot power profile emulator as the load. In parallel, the student will design a control and energy management strategy for DC bus regulation and coordinated power flow between the connected storage elements. Finally, a simple demonstrator will be built using the converter and battery-related modules provided by the group, and the simulation results

will be compared with experimental observations in order to identify and recommend the most suitable topology.

Requirements:

Preferred student qualifications include experience in power electronics, electrical systems, and their simulation tools such as MATLAB/Simulink. Interest in battery integration, control, and robotic applications is expected.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-E |
| Nombre de sujets | 2 |

Supervision

Supervisor : VANDERBORGHT Bram (Bram.Vanderborgh@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Autonomous Counter-Drone System

Description

Please find the details of the MA proposal on https://vub-my.sharepoint.com/:f:/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRptg

When interested in one of these 5 topics, please contact bryan.convens@vub.be for more information given during a Microsoft Teams meeting.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O |
| Nombre de sujets | 3 |

Supervision

Supervisor : Vanderborgh Bram (bram.vanderborgh@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Multiphysics analysis of oil injection for screw compressors.

Description

This thesis is in collaboration with Atlas Copco Airpower and will be under NDA.

To improve efficiency of the compression phase in a screw compressor, oil is often injected in the compression chamber to cool the compressed air as well as seal the gaps between the different components to minimize leakages. The time-dependency of the heat-transfer between the injected oil droplets and the compressed air, makes the cooling aspect extremely challenging in fast-turning machines. Therefore the goal of this Master Thesis would be to investigate different oil-injection strategies in a Multiphysics-simulation tool in Matlab/Simulink/Simscape to determine design rules for optimal oil-injection parameters. A basic working model will be provided as a starting point of the thesis This model needs to be adapted and extended in function of the needs for the analysis. A specific injection strategy will also be proposed, but this will not be disclosed before the start of the thesis.

The different domains include:

- Mechanical time-of-flight calculation of oil droplets in a compression chamber with dynamic modelling using the equations of motion.
- Heat transfer modelling of an oil droplet in a compressed air environment, using a basic heat transfer model and simplified assumptions on the air flow.
- Basic thermodynamic effects on the compression (isentropic vs. isothermal)

Depending on the initial findings and parallel research, an experimental validation of the injection strategy can be performed with high-speed camera measurements of different injection nozzles. The latter is a topic for another thesis work, thus close collaboration might be relevant.

Before selecting this topic, please contact:

Bjorn Verrelst (Bjorn.verrelst@vub.be)

Jarl Beckers (jarl.beckers@vub.be)

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |

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| Nombre de sujets | 1 |
|-------------------------|---|

Supervision

Supervisor : Verrelst Bjorn (bjorn.verrelst@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Teaching Robots Skills via Human-Machine Interfaces and Imitation Learning

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRptg

When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O |
| Nombre de sujets | 3 |

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Aerial Robot Collision-Resilient Navigation with Tactile Sensing

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f:/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRPtg

When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-O |
| Nombre de sujets | 3 |

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

3D printing of deployable scissor joints

Description

Note: if interested, come and discuss the topics with us, to refine the research question based on your skills and interests.

Context:

Deployable structures are fascinating structural mechanisms: they have the ability to transform themselves from a small, closed or stowed configuration to a much larger, open or deployed configuration. Mobile deployable structures have the great advantage of speed and ease of erection and dismantling compared to conventional building forms. They have a wide field of application, from space antennas to festival structures, to adaptable furniture and toys.

At VUB there is 20 years of expertise on these fascinating systems and recently a spin-off company called KONLIGO was created to design and build zero-waste event structures based on our scissor technology.

Because these deployable structures can be used and reused over and over again they are well-suited to support the transition to a zero-waste event industry, where currently the waste problem is huge. Because of the modular construction and high component uniformity, and easy repair and maintenance, they are well-suited for a 'circular business model'.

Topic:

The deployable bars of a scissor structure are connected by specifically designed joints, that allow the necessary movement. However, there is a specific class of structures that is left out because of the deployment is not possible, or difficult. Unless the joints are designed in such a way that they accommodate this special requirement movement. The projected outcome is an overview of the possibilities for innovative joints for deployable scissor structures that open up the possibilities for new shapes that have never been built before. Physical models (small and medium scale), digital parametric modelling, digital

fabrication and potential full-scale testing belong to the possibilities, depending on the chosen focus.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRARE, M-IRCNE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 2 |

Supervision

Supervisor : Roels Ellen (ellen.roels@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Instrumented glass gripper: Percipio Robotics' Tulip gripper revisited (+ internship – to be confirmed by the company Percipio Robotics)

Description

Context: Percipio Robotics is a spin-off from the FEMTO-ST research institute, which has designed the Tulip gripper [1]. This compact, lightweight gripper, weighing less than 30g, is designed for micromanipulation and can grip objects from 50 μ m to 10mm. It solves the problems of large grippers and fragility frequently encountered in micro-robotics. Parallely, the TIPS department designs and manufactures compliant mechanisms in glass (FemtoPRINT technique), whose deformation is measured with optical/photonic techniques.

Objectives: This thesis aims to design and develop an instrumented version of the Percipio Robotics' Tulip gripper. The master thesis can be preceded by a 3 months internship in the company (Besançon, France).

Methods: Literature review. Functional analysis and requirements. Design. Fabrication and characterization of the flexure mechanism.

Prerequisites: mechanical design, good command of French

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRCNE, M-IRMAE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IRPH |
| Nombre de sujets | 2 |

Supervision

Supervisor : LAMBERT Pierre (pierre.lambert@ulb.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive Dynamic Safety Margin Design for Force-Regulated Explicit Reference Governors

Description

This thesis investigates the design of adaptive safety margins for Explicit Reference Governors (ERG) applied to robotic manipulators operating under external forces and contact constraints.

Explicit Reference Governors ensure constraint satisfaction by predicting future system behavior and evaluating a Dynamic Safety Margin (DSM) that quantifies the distance to constraint violation. In current implementations, safety margins are typically defined using fixed worst-case bounds on modeling uncertainty and force-estimation errors. While this guarantees safety, it often leads to conservative robot behavior and reduced performance.

The objective of this thesis is to develop an adaptive tightening mechanism that adjusts the safety margin online based on measurable uncertainty indicators such as force-estimation residuals, prediction error, or disturbance dynamics. The proposed method will be integrated into an existing force-regulated ERG framework for robotic manipulators.

The student will:

Analyze the baseline ERG and DSM formulation

Design an adaptive uncertainty bound for force and motion prediction

Integrate the adaptive margin into the ERG safety mechanism

Validate the approach through simulation and experimental evaluation

Compare performance against fixed-bound safety margins

The expected outcome is a safer and less conservative ERG controller capable of maintaining constraint satisfaction while improving responsiveness and task efficiency.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-E |

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| Nombre de sujets | 1 |
|-------------------------|---|

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Design of new didactic devices for teaching control engineering

Description

Many of the pilot processes used in the SAAS department to teach control theory were developed through master's theses. This is the case for the rotary inverted pendulum, the ring positioner, the ball in the tube process, ...

The aim of this master thesis is to develop new pilot processes that are modular, evolving, and open-source to provide a better and more practical learning experience to the students.

Here are a few examples of processes that SAAS would like to develop (non-exhaustive list):

- Ball in hoop or Flying ball in hoop
 - o <https://www.youtube.com/watch?v=8FaNk6C2ckM>
 - o <https://www.youtube.com/watch?v=484GN4KBQnc>
 - o <https://github.com/aa4cc/flying-ball-in-hoop>
 - o <https://aa4cc.github.io/flying-ball-in-hoop/>
- Cubli - robot that can jump up and balance on its corner
 - o <https://www.wevolver.com/specs/cubli>
- ...

Key objectives:

- o selection of the sensors/actuators
- o design of the signal conditioning / acquisition stages
- o design of the experimental setup (SolidWorks, 3D printer ...)
- o design of the power supply & cable management
- o modeling of the process
- o implementation of a control strategy (Arduino/C programming or Matlab/data-acquisition board or Raspberry PI)
- o setup of some didactic experiments & their related teaching materials

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IRELE, M-IREMR-A, M-IREMR-E |

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| Nombre de sujets | 2 |
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Supervision

Supervisor : Garone Emanuele (emanuele.garone@ulb.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Autonomous Drone Racing Using Only Onboard Sensing and Computation

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRptg

When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-O |
| Nombre de sujets | 3 |

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Safety-Aware Coordination for Collaborative Multi-Robot Systems using Explicit Reference Governors

Description

Collaborative robotic systems increasingly rely on multiple robots operating in shared workspaces to perform coordinated tasks such as object transfer, cooperative manipulation, and parallel assembly. While high-level planning methods can generate feasible schedules for multiple robots, ensuring safe execution during runtime remains a critical challenge, particularly when robots operate in close proximity.

This thesis investigates the design of a safety-aware coordination mechanism for multi-robot systems using Explicit Reference Governors (ERG). The ERG framework provides a predictive safety layer that adjusts the robot reference in real time to prevent constraint violations. In a multi-robot context, this mechanism can be extended to account for the motion of neighboring robots and maintain safe coordination during task execution.

The objective of this thesis is to develop and evaluate a coordination-aware ERG capable of enforcing safety constraints between multiple robots while preserving task performance. The work will build upon an existing multi-robot task and motion planning framework and focus on the execution-level safety and coordination problem.

The student will:

- Study safety and coordination challenges in multi-robot systems
- Implement predictive safety constraints between collaborating robots
- Design a coordination-aware reference governor
- Integrate the method into a multi-robot execution framework
- Evaluate safety and performance in representative collaborative scenarios

The expected outcome is a robust safety mechanism for coordinated multi-robot systems that enables reliable execution of parallel tasks in shared environments.

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| Langue | EN (english) |
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| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-M |
| Nombre de sujets | 1 |

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive Dynamic Safety Margin Design for Force-Regulated Explicit Reference Governors

Description

This thesis investigates the design of adaptive safety margins for Explicit Reference Governors (ERG) applied to robotic manipulators operating under external forces and contact constraints.

Explicit Reference Governors ensure constraint satisfaction by predicting future system behavior and evaluating a Dynamic Safety Margin (DSM) that quantifies the distance to constraint violation. In current implementations, safety margins are typically defined using fixed worst-case bounds on modeling uncertainty and force-estimation errors. While this guarantees safety, it often leads to conservative robot behavior and reduced performance.

The objective of this thesis is to develop an adaptive tightening mechanism that adjusts the safety margin online based on measurable uncertainty indicators such as force-estimation residuals, prediction error, or disturbance dynamics. The proposed method will be integrated into an existing force-regulated ERG framework for robotic manipulators.

The student will:

- Analyze the baseline ERG and DSM formulation
- Design an adaptive uncertainty bound for force and motion prediction
- Integrate the adaptive margin into the ERG safety mechanism
- Validate the approach through simulation and experimental evaluation
- Compare performance against fixed-bound safety margins

The expected outcome is a safer and less conservative ERG controller capable of maintaining constraint satisfaction while improving responsiveness and task efficiency.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E |

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| Nombre de sujets | 1 |
|-------------------------|---|

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Design and Construction of a Tactile and Proximity Sensing End-effector for Physical Interaction by Contact with a Drone

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRptg

When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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|----------------------------------|---------------------------------|
| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E, M-IREMR-O |
| Nombre de sujets | 3 |

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Design, Fabrication and Experimental Evaluation of an Ultra-Fast Racing Drone

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRptg

When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O |
| Nombre de sujets | 3 |

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Study of a high-transmission ratio compliant actuator for robotics

Description

The project aims to improve a high-efficiency Wolfrom gearbox for robotics by adding compliance to enhance safety in human-centered applications.

You will model the gearbox in Simscape, design a compliant element, and determine its optimal placement, followed by experimental validation.

It requires motivation and hands-on skills in CAD design, manufacturing (3D printing/molding), and mechanical assembly

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E |
| Nombre de sujets | 2 |

Supervision

Supervisor : LOPEZ GARCIA PABLO (pablo@ailos-robotics.com)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Human-Aware Velocity Regulation using Explicit Reference Governors for Safe Human–Robot Interaction

Description

This thesis focuses on the development of a safety-aware control mechanism for robotic manipulators operating in environments shared with humans. According to international human–robot interaction standards, such as ISO 10218 and ISO/TS 15066, robot velocity and impact energy must be limited depending on the proximity to the human body and the specific body region involved.

The objective of this thesis is to design an Explicit Reference Governor (ERG) capable of detecting human presence in the robot workspace and dynamically regulating robot velocity to ensure safe interaction. The governor will enforce velocity limits derived from safety standards while maintaining smooth and predictable robot motion.

The student will:

Study human–robot interaction safety standards and velocity limits

Implement a perception-based human detection mechanism

Define distance-dependent velocity constraints

Integrate these constraints into the ERG framework

Evaluate safety and performance in simulated human–robot interaction scenarios

The expected outcome is a predictive safety mechanism that ensures compliant and safe robot behavior in the presence of humans while preserving operational efficiency.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Multi-robot localisation

Description

This thesis topic is a broad collection of subtasks that can be undertaken within multi-robot localisation research.

This includes topics such as:

- Multi-agent SLAM.
- UWB Anchored localisation
- Relative pose estimation
- Map sharing
- ODOMetry sensors: IMU, Camera, VIO, LiDAR, LIO.

And this on multiple different robots:

- AGVs
- Humanoids
- Drones.

In case you want to discuss possibilities in this research field please contact yuri.durodie@vub.be for more details.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRARE, M-IRCBS, M-IRCNE, M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI, M-IRPH |
| Nombre de sujets | 5 |

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Human-Aware Velocity Regulation using Explicit Reference Governors for Safe Human–Robot Interaction

Description

This thesis focuses on the development of a safety-aware control mechanism for robotic manipulators operating in environments shared with humans. According to international human–robot interaction standards, such as ISO 10218 and ISO/TS 15066, robot velocity and impact energy must be limited depending on the proximity to the human body and the specific body region involved.

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Integrate these constraints into the ERG framework

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The expected outcome is a predictive safety mechanism that ensures compliant and safe robot behavior in the presence of humans while preserving operational efficiency.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive Dynamic Safety Margin Design for Force-Regulated Explicit Reference Governors

Description

This thesis investigates the design of adaptive safety margins for Explicit Reference Governors (ERG) applied to robotic manipulators operating under external forces and contact constraints.

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The student will:

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Design an adaptive uncertainty bound for force and motion prediction

Integrate the adaptive margin into the ERG safety mechanism

Validate the approach through simulation and experimental evaluation

Compare performance against fixed-bound safety margins

The expected outcome is a safer and less conservative ERG controller capable of maintaining constraint satisfaction while improving responsiveness and task efficiency.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-A, M-IREMR-E |

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| Nombre de sujets | 1 |
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Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Power consumption estimation for legged mobile robots (humanoids or quadrupeds)

Description

Context:

Modern robotics is relying increasingly on legged mobile robots, such as humanoids and quadrupeds, because of their ability to operate in complex and unstructured environments. Compared with wheeled robots, legged systems offer greater mobility on uneven terrain, stairs, and obstacle-rich spaces, making them attractive for inspection, logistics, search and rescue, and service applications.

However, this improved mobility comes with higher energy demand and more complex power consumption patterns. The power usage of legged robots changes significantly depending on the mission, locomotion mode, terrain, payload, and task duration.

Understanding and predicting this power consumption is important for mission planning, battery sizing, energy-aware control, and robot reliability.

Objective:

The objective of this thesis is to create a power consumption dataset for legged mobile robots and develop a data-driven model to estimate and characterize their energy demand during operation.

The thesis will address the following research questions:

- How does a legged robot's mission profile affect its power consumption?
- How does the power load profile evolve during a mission, and which energy-related features best distinguish one mission from another in terms of power consumption?
- Is it possible to classify mission power requirements based on the observed power profile?

Methodology:

The student will collect and organize a dataset of power consumption measurements from an available legged mobile robots, with focus on humanoid or quadruped platforms, under different operating conditions and mission profiles. The dataset may include information such as robot state, locomotion mode, mission type, speed, terrain condition, actuators load, battery variables, and measured power consumption.

Based on this dataset, the student will develop and evaluate data-driven models for power consumption estimation. The work will also investigate how mission characteristics

influence the power load profile, identify meaningful energy-related features, and assess whether different mission types or power demand levels can be classified from the recorded profiles.

Requirements:

Preferred student qualifications include experience in AI modeling, knowledge of ROS (Robotic Operating System), and coding proficiency with Python and/or C++. A passion for multidisciplinary research and a willingness to learn and enhance their skills in these areas are essential.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IRELE, M-IREMR-E |
| Nombre de sujets | 2 |

Supervision

Supervisor : VANDERBORGHT Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Dual-motor drive for e-bikes

Description

Dual-motor actuators use two motors to improve control, torque distribution, and efficiency in applications like robotics and e-bikes, enhancing performance and user experience.

This project supports the characterization of the OWURU drivetrain by E2Drives, used in Decathlon BTWIN bikes, leveraging R&MM expertise.

It includes performance testing (torque, speed, efficiency, inertia) and development of a new dual-motor actuator concept.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : LOPEZ GARCIA PABLO (pablo@ailos-robotics.com)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Optimal Fidelity Level for a Battery Digital Twin in Robotic Applications

Description

Context:

Mobile robots operate in dynamic environments and rely on batteries as their main energy source. Because battery capacity is limited, energy availability directly affects mission duration, task execution, and system reliability. For efficient robot operation, it is important to estimate battery behavior accurately during runtime.

A battery digital twin can provide a virtual representation of the battery state and behavior by combining models with real-time data. In robotic applications, such a digital twin can support energy-aware operation, improve monitoring, and enable better prediction of remaining performance. However, higher model fidelity often increases computational cost and integration complexity. This creates a trade-off between model accuracy and real-time usability in robotic systems.

Objective:

This thesis focuses on determining the optimal fidelity level of a battery digital twin for robotic applications and integrating it into Robotic Operating System (ROS) for evaluation under representative robot operating conditions. The final digital twin will be validated on the ROS-based mobile robots available in the group

The thesis will address the following research questions:

- Which battery digital twin fidelity level achieves the best trade-off between estimation accuracy and computational cost when deployed on a mobile robot platform?
- To what extent can a battery digital twin model be adapted to different battery chemistries and pack configurations while maintaining acceptable modelling effort and estimation performance?
- How strongly do different robotic tasks and operating conditions affect the performance of pre-trained battery digital twin models, and when is model re-tuning or retraining required?

Methodology:

The student will use standard battery datasets and a robotic-specific battery dataset to train and validate battery digital twin models. Deep learning methods will be used to capture nonlinear battery behavior and degradation under realistic robotic operating conditions.

The models will be evaluated in terms of accuracy, computational efficiency, and robustness across different fidelity levels, battery chemistries, and robot task profiles. Their feasibility for practical deployment will then be assessed through implementation in ROS and testing on the group's mobile robots, with consideration of both cloud and edge platforms with limited computational capacity.

Requirements:

Preferred student qualifications include experience in AI modeling, knowledge of ROS (Robotic Operating System), and coding proficiency with Python and/or C++. A passion for multidisciplinary research and a willingness to learn and enhance their skills in these areas are essential.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRIFS, M-IREMR-E |
| Nombre de sujets | 2 |

Supervision

Supervisor : VANDERBORGHT Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Biomechanics-based optimization of bike drivetrain

Description

Context

When cycling, the cyclist applies a force on the back wheel through the pedals, chainwheel, chain, and pinion. The force and speed of the wheel depend on the ratio between the size of the chainwheel and pinion, as well as on the force applied by the user. However, for a given force applied by the user, the torque transmitted to the chainwheel varies based on the position of the pedals. Indeed, the rotation of the pedals changes the lever arm between the foot and the center of rotation, as well as the angle of application of the force. This leads to an uneven effort during the motion and wasted effort.

Goal of the thesis

Previously, the issue of uneven torque transmission was studied, and it was proposed to use a non-circular chainwheel to even the torque transmission. This project aims to propose an alternative non-circular chainwheel that, instead of trying to even the torque, will optimize its shape to maximize power transmission by optimizing the shape of the chainwheel and pinion.

Based on biomechanics studies, such as an available Biodex dataset (measurement of the torque capability of each joint of the leg), it can be observed that strength is highly dependent on the leg joint angle and speed. This project aims to combine this knowledge of biomechanics and the use of a non-circular chainwheel to allow the user to apply their maximum force at all points in the pedaling motion.

In this thesis, the student will analyze the biomechanics of the leg when cycling based on an existing Biodex dataset and then will design a bike drivetrain with a non-circular chainwheel to optimize power output. Finally, a prototype will be built and tested to assess the ability to increase performance.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRCBS, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Nombre de sujets | 1 |

Supervision

Supervisor : Tom Verstraten (Tom.Verstraten@vub.be)

Master's program offering the topic: EM - Sustainable transport and automotive M-IREMR-O

Distributed Balancing Control for BMS Using Local Sensing and Decentralized Communication

Description

Battery management systems (BMS) are critical for ensuring the safety, performance, and longevity of battery packs. Conventional balancing strategies often rely on centralized or wired communication architectures, which can limit scalability, robustness, and flexibility. This project investigates distributed cell balancing strategies in which individual cells or modules make control decisions based on locally available measurements and limited peer-to-peer communication. The goal is to design and evaluate control algorithms that enable effective balancing without reliance on centralized coordination or rigid communication structures.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : HEGAZY Omar (omar.hegazy@vub.be)

Master's program offering the topic: EM - Sustainable transport and automotive M-IREMR-O

Electrical motors for EV traction, design and control --- internships and Master theses, at/in collaboration with Punch Powertrain (Sint-Truiden)

Description

Internship subjects (see also the document with Dropbox link):

- 1) In-house Multi-disciplinary emotor design toolchain maintenance
- 2) Torque ripple requirements definition in electric machine pre-design
- 3) Harmonics limits definition in electric machine pre-design
- 4) Emotor design towards short circuit protection

Master thesis subject (and more coming):

Title: DC and AC Harmonics reductions techniques in electric machine design

Promoter: Dr. Ilja Siera

Contact person: ilja.siera@punchpowertrain.com

Description:

A critical design challenge in electric machines for the automotive market is the presence of electromagnetic harmonics, which can lead to undesirable effects such as torque ripple, increased losses, noise, vibration, reduced efficiency or inverter over-currents. In the current multi-disciplinary design methods applied at Punch powertrain, the potential issues often lay hidden until the latter stages of the design process.

This thesis proposes to investigate and implement advanced methods to reduce harmonic distortion early during the optimisation process of electric machines. The goal is to develop a multi-objective optimisation framework that explicitly includes harmonic reduction as a design target.

The current optimisation approach for electric machines focusses on objectives such as torque density, efficiency, and thermal performance. While torque ripple is considered, Current harmonic mitigation is only considered as a constraint, and then treated in the post design. This research aims to integrate harmonic reduction directly into the optimisation loop, allowing for a more balanced and robust design process.

The goals are to:

- (a) Review harmonic generation mechanisms in electric machines (with a focus on slot/pole combinations, winding distribution, and magnetic saturation).
- (b) Evaluate methods for harmonic analysis, including Fast Fourier Transform (FFT), Space Vector analysis, and Total Harmonic Distortion (THD) metrics.
- (c) Evaluating methods for detecting the presence or vulnerability of a design to harmonics (e.g. through flux map analysis).
- (d) Implement harmonic minimisation techniques in the design optimisation loop
- (e) Evaluate performance and the trade-offs in a design optimisation study.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O, M-IREMI |
| Nombre de sujets | 1 |

Supervision

Supervisor : Gyselinck Johan (johan.gyselinck@ulb.be)

Master’s program offering the topic: Physical engineering - M- IRPH

Efficient sampling techniques and classification methods in dynamic Probabilistic Safety Analysis (PSA)

Description

Nuclear Reactor Physics and Safety

PSA is used to identify scenarios contributing to the residual risk of the nuclear power plant (NPP) – i.e. the risk once properly dimensioned protection systems and emergency procedures are in function – and possibly suppress those scenarios or reduce their frequency of occurrence.

Passive safety systems and new reactor designs challenge the classical PSA practice (based on the combination of fault trees and event trees), as it does not allow capturing the dynamic response of the plant to the occurrence of an event triggering a transient.

Dynamic PSA corresponds to an extended framework, in which allowance is given to the coupling of transient calculations with branching events in an event tree.

Though conceptually more satisfying, dynamic PSA still requires efficient simulation techniques in order to identify “all” significant low-probable, risk-significant scenarios likely to develop in the plant. The proposed topic will review sampling techniques used in dynamic PSA simulations and identify new ones, which would better fit to the specific features of the new nuclear systems. Classification techniques will be considered in order to group similar transients and avoid the repetition of time-consuming computations. More details on the expected outcomes of the work will be discussed with the applicants.

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| Langue | EN (english) |
| Ouvert à d’autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : LABEAU PIERRE-ETIENNE (pierre.etienne.labeau@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

Computational Fluid Dynamics subjects - Liquid metal modelling in CFD

Description

Liquid metal coolants (such as sodium, lead or lead–bismuth eutectic) are key components in several advanced nuclear reactor concepts. Their very low Prandtl number leads to a strong decoupling between momentum and heat transfer, making turbulence modelling and heat transfer prediction particularly challenging for standard CFD approaches. The objective of this subject is to investigate the capability of ANSYS Fluent to model turbulent liquid metal flows, with a specific focus on predicting pressure losses and heat transfer coefficients (HTC) in simple yet representative configurations.

The work will start with a critical literature review of turbulence modelling approaches developed for liquid metals, including adaptations of RANS models (e.g. modified $k-\epsilon$, $k-\omega$ and Reynolds stress models) and the treatment of turbulent thermal diffusivity. Based on this review, a simple validation case (such as fully developed flow in a heated pipe or channel) will be implemented in ANSYS Fluent. Numerical results will be compared against reference correlations or experimental data, and a limited sensitivity study on turbulence model coefficients will be carried out to improve the prediction of pressure drop and HTC. This topic provides hands-on experience in CFD, turbulence modelling and nuclear thermal hydraulics, while addressing practical industrial challenges relevant to Tractebel's activities.

This involves that:

- You will develop competences in the use of ANSYS Fluent software;
- You will develop knowledge on low Prandtl flows;
- You will perform simulations in steady-state mode;
- Writing a scientific report.

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|----------------------------------|--------------|
| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Labeau Pierre-Etienne (pierre.etienne.labeau@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

CFD & Accident studies description

Description

You will work with the CFD & Accident Studies team. The group performs thermal-hydraulic calculations related to the normal, incidental and accidental functioning of Nuclear Power Plants (NPPs) including Severe Accidents leading to core degradation. The team is composed of about 20 engineers dedicated to design, plant support and licensing activities linked to nuclear applications, i.e. deterministic design basis and beyond basis accidents using TH system codes, deterministic severe accidents, design and root cause analysis using CFD and system codes,...

The studies in these domains require a large set of codes and tools, together with related validation databases. To remain competitive and to diversify its competencies to the new generation of reactors, Tractebel continuously follows the evolution of codes and methods used in such domain of application.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Labeau Pierre-Etienne (pierre.etienne.labeau@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

Computational Fluid Dynamics subjects - Improvement of the Reduced Order Model developed to optimize the cask management process

Description

We are looking to develop even further some Reduced Order Model (ROM) created to optimize the storage of the spent fuel within casks – the usual dry spent fuel storage path). Tractebel developed in the past years a ROM allowing to quickly predict the spent fuel cask surface temperature using some CFD evaluations as inputs (considering convection and radiation heat transfer). The work proposed is extend the capability of the ROM by considering Bayesian Optimization to improve the simplified model while using it to optimize the positioning of the casks within the spent fuel storage building.

This involves that:

- You will develop competences in the use of the CFX or Fluent software;
- You will develop competences in the use of Python and the associated pyDOE2 (language used to develop the ROM) ;
- You will develop knowledge on the spent fuel management in Belgium;
- Writing a scientific report.

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|----------------------------------|--------------|
| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Labeau Pierre-Etienne (pierre.etienne.labeau@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

System Thermal hydraulics subjects - ATHLET – ATLAS benchmark

Description

Tractebel is working with the USNRC thermal hydraulics system codes since many years. As such, Tractebel developed multiple in-house methodologies aiming to reproduce as best as possible key physical phenomena considering Separate and Integral Effects Tests.

Tractebel recently acquired ATHLET – the System Thermal hydraulics code developed by GRS – which allow to model systems considering liquid metal and molten salt in addition to the more traditional liquid/steam water systems.

In the frame of the OECD/NEA international ATLAS research project, Tractebel received the reference model developed by GRS to reproduce the C2.3 test (Steam line break with PAFS operation) for which Tractebel has a TRACE model.

The student will analyse and compare the responses predicted by both codes. If required, model adaptations will be proposed and tested with the aim of improving Tractebel's capabilities to develop ATHLET water based models.

This involves that:

- You will develop competences in the use of the ATHLET and/or TRACE software;
- You will develop knowledge on the functioning of Pressurized Water Reactor;
- You will perform simulations in steady-state and/or in transient modes;
- Writing a scientific report.

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|----------------------------------|---------------|
| Langue | FR (français) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Labeau Pierre-Etienne (pierre.etienne.labeau@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

Computational Fluid Dynamics subjects - Pressurized Thermal Shock (PTS) validation work

Description

We are looking to develop our capabilities to adequately predict PTS events which is a critical safety concern for nuclear reactors. It involves the rapid cooling of the reactor pressure vessel (RPV) due to emergency cooling water injection, which can lead to thermal stresses and potential cracking.

CFD helps in modeling the complex thermal-hydraulic interactions during a PTS event, including the mixing of hot and cold fluids, heat transfer, and fluid flow dynamics. Tractebel initiated an internal work aiming to reproduce the experimental results obtained on the ROCOM experimental facility dedicated to represent PTS events. As such, the student will take over this initial work with the aim of performing additional parametric and sensitivity analyses trying to improve our internal methodologies.

This involves that:

- You will develop competences in the use of Fluent software;
- You will develop knowledge on the functioning of Pressurized Water Reactor;
- You will perform simulations in transient modes;
- Writing a scientific report.

| | |
|----------------------------------|--------------|
| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Labeau Pierre-Etienne (pierre.etienne.labeau@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

Determinist Severe Accident: Severe Accident Code Benchmarking for Radiological Source Term Assessment (MELCOR / ASTEC)

Description

The assessment of radiological source terms is a key element of nuclear safety analyses, particularly in the context of Design Extension Conditions (DEC) as defined by WENRA. System-level severe accident codes such as MELCOR and ASTEC are widely used to simulate accident progression, including core degradation, fission product release, transport and retention within the reactor coolant system and containment. Despite their maturity, significant uncertainties remain in the modelling of severe accident phenomena, making code-to-code comparisons and benchmark analyses essential.

The objective of this subject is to revisit a reference WENRA DEC-B severe accident analysis by performing simulations with ASTEC, and to compare the results with available MELCOR reference results. The student will analyse and compare the accident sequence evolution (core heat-up, melting, vessel and containment behaviour) and the resulting radiological source term (timing, magnitude and composition of releases). Attention will be paid to identifying differences in modelling assumptions, physical models and numerical treatment between the two codes, and to assessing their impact on the predicted source term. This work contributes directly to Tractebel's expertise in severe accident analysis and regulatory-oriented safety assessments.

The work will involve:

- Learning and using the ASTEC severe accident simulation code
- Understanding WENRA DEC-B scenarios and severe accident phenomenology
- Performing system-level steady-state and transient severe accident simulations
- Conducting a code-to-code comparison (ASTEC vs MELCOR) of accident progression and radiological source terms
- Analysing uncertainties and modelling differences affecting source term predictions
- Writing a scientific report

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Labeau Pierre-Etienne (pierre.etienne.labeau@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

System Thermal hydraulics subjects - ATHLET – Phénix Benchmark

Description

Tractebel has recently acquired ATHLET, the system thermal-hydraulics code developed by GRS, which enables the modelling of reactor systems involving liquid metals and molten salts, in addition to conventional liquid water and steam systems. These working fluids are central to Generation IV reactor concepts, for which system-code validation is still an active topic at the international level. One of the key benchmarks for validating thermal-hydraulic system codes for sodium-cooled fast reactors is the Natural Circulation Test performed during the end-of-life experiments of the Phénix reactor. This experiment was part of an IAEA Coordinated Research Project, aimed at assessing the behaviour of sodium fast reactors under natural circulation conditions. Tractebel has developed its own ATHLET model of the Phénix reactor, calibrated to match Hot Full Power (HFP) operating conditions. Starting from this reference model, the student will implement the Natural Circulation Test transient specifications and analyse the simulation results through comparison with experimental data and/or reference ATHLET or other system-code results available in the literature.

This involves that:

- You will develop competences in the use of the ATHLET software;
- You will develop knowledge on the functioning of GenIV type reactors;
- You will perform simulations in steady-state and/or in transient modes;
- Writing a scientific report.

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|----------------------------------|--------------|
| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Labeau Pierre-Etienne (pierre.etienne.labeau@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

Production of medical isotopes in aqueous homogeneous reactors

Description

Nuclear Reactor Physics and Safety

Certain important medical isotopes, such as Tc-99m, are produced via nuclear reactions in centralised nuclear-reactor facilities. Belgium is one of the top-leading suppliers at world scale, from the production of Mo-99 in the BR2 reactor at SCK CEN to its postprocessing into Tc-99m at the Institut des Radioéléments (IRE) in Fleurus. Considering the growing demand in such radioisotopes and the current capacity of limited and aging production infrastructures in the world, an alternative is to develop small, dedicated reactors for local production. For example, aqueous homogeneous reactors are promising since they could provide a high yield per unit power, while allowing to produce the isotopes closer to the demand.

A master-degree thesis is proposed to characterise such a reactor core and optimise it towards medical isotope production, taking into account the timing and method of extraction, and the important safety parameters affected by the optimisation.

The type of thesis is computational. More details (type of software etc) will be discussed with the applicant.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Zanetti Matteo (matteo.zanetti@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

Probabilistic Severe Accident: Dynamic Probabilistic Safety Assessment (PSA) Prototyping Tool

Description

Traditional Probabilistic Safety Assessment (PSA) methods are largely based on static event trees and fault trees, which may face limitations when dealing with complex time-dependent phenomena, operator actions and dynamic system interactions. Dynamic PSA (DPSA) approaches aim to overcome these limitations by coupling system simulations with probabilistic models, allowing a more realistic representation of accident sequences and their evolution over time. In the framework of the potential BE-SAINT project, Tractebel is investigating the applicability and actual implementation of such dynamic approaches for advanced safety assessments.

The objective of this subject is to assess and prototype capabilities for generating dynamic event trees, focusing on key DPSA functionalities such as branch resampling, multi-level simulation assessment, and independent calculation sequence handling. The student will explore existing methodological approaches to DPSA, define a suitable prototype architecture, and implement or adapt simplified tools or workflows to demonstrate these capabilities on representative test cases. Emphasis will be placed on understanding how dynamic tree generation can support safety-relevant analyses, improve scenario coverage, and manage combinatorial complexity. This work will contribute to Tractebel's strategic capability development in next-generation PSA methodologies.

The work will involve:

- Gaining knowledge of classical and dynamic PSA concepts
- Reviewing existing Dynamic PSA methodologies and tools
- Defining requirements for a dynamic event tree prototyping framework
- Implementing and testing key functionalities (e.g. resampling strategies, multi level assessments, sequence handling)
- Applying the prototype to simplified illustrative scenarios
- Analysing strengths, limitations and perspectives of the approach
- Writing a scientific and/or technical report

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| Langue | EN (english) |
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|----------------------------------|-----------|
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Labeau Pierre-Etienne (pierre.etienne.labeau@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

Post-Accident Heat Removal (PAHR) in Fast Reactors

Description

Nuclear Reactor Physics and Safety

The safety analysis of nuclear reactors requires to consider scenarios in which damage to the reactor core happens and the coolability of the nuclear fuel, that produces decay heat, is altered. This extends to the relocation of fuel to areas of the reactor vessel that need to be cooled properly to avert thermal damage. Considering the renewed interest in fast reactors, using liquid-metal coolants, modelling and validation of PAHR for this kind of systems becomes an important issue to perform sound safety analysis.

A master-degree thesis is proposed in the framework of nuclear thermo-hydraulics with liquid metals, starting from the reproduction of in-pile experiments performed in the late eighties with sodium coolant with modern computational codes, followed by investigations with other liquid-metal coolants such as molten lead, which is relevant for the Belgian program carried out at SCK CEN to develop a prototype of a fast, lead-cooled SMR (Small Modular Reactor).

The type of thesis is computational. More details (type of software etc) will be discussed with the applicant.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Zanetti Matteo (matteo.zanetti@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

System Thermal hydraulics subjects - Containment Thermal-Hydraulics Benchmarking: COCOSYS / TRAPCON Comparison

Description

The prediction of containment behaviour following a Loss-of-Coolant Accident (LOCA) is a key aspect of nuclear safety analysis, particularly for assessing pressure, temperature and long-term integrity of the containment.

Lumped-parameter containment codes such as COCOSYS and TRAPCON are widely used for this purpose, each relying on different modelling assumptions and correlations for heat and mass transfer, condensation and recirculation phenomena.

Tractebel has developed an internal COCOSYS model of a reference reactor containment, which forms the basis of this subject. The objective is to simulate the long-term containment thermal-hydraulic response after a LOCA, with a particular focus on the post-blowdown and recirculation phase. Using the existing COCOSYS model, the student will perform transient simulations covering the evolution of pressure and temperature, and will compare the results with reference calculations performed with TRAPCON (in-house Tractebel software). The analysis will focus on identifying differences in predicted containment response, understanding their physical and modelling origins, and assessing the sensitivity of key safety parameters to containment modelling assumptions. This benchmark-type work contributes directly to code validation and to the robustness of containment safety assessments.

The work will involve:

- Learning and using COCOSYS for containment thermal-hydraulic analysis
- Understanding LOCA phenomenology and long-term containment behaviour
- Performing transient simulations including the containment recirculation phase
- Comparing COCOSYS results with reference TRAPCON calculations
- Analysing discrepancies related to modelling assumptions and correlations
- Synthesizing results into a scientific and technical report

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 |

Supervision

Supervisor : Labeau Pierre-Etienne (pierre.etienne.labeau@ulb.be)

Master's program offering the topic: Physical engineering - M- IRPH

Fast-Reactor Kinetics

Description

Nuclear Reactor Physics and Safety

Considering the renewed interest in fast reactors, their dynamic behaviour is of great impact for operational and safety concerns. These dynamics are governed by the neutron population in the reactor core of which the variation in time (reactor kinetics) is affected by the changes of temperature in the core components following the change in the reactor power that is established by the neutron population.

A master-degree thesis is proposed in the framework of fast-reactor kinetics, first by studying and modelling the transient behaviour in sodium fast reactors built and operated from the seventies to the nineties of the past century, then improving the methodologies or extending the developed modelling to modern designs, such as liquid-lead ones, which is relevant for the Belgian program carried out at SCK CEN.

The type of thesis is computational. More details (type of software etc) will be discussed with the applicant.

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| Langue | EN (english) |
| Ouvert à d'autres masters | Yes |
| Masters concernés | M-IREMR-E |
| Nombre de sujets | 1 - 2 |

Supervision

Supervisor : Zanetti Matteo (matteo.zanetti@ulb.be)

Stochastic modelling of load profiles for urban energy systems

Program : EM - Energy - M-IREMR-E

Description

The climate disruptions experienced globally over the past decades require a profound transformation of our societies, particularly of our energy systems. In urban environments such as the Brussels-Capital Region, space heating currently accounts for nearly 50% of total final energy consumption. As natural gas remains the dominant energy source to meet this demand, building heating systems must be decarbonised to achieve carbon neutrality targets by 2050.

Most decarbonisation plans rely on relatively rigid and conservative demand modelling. Yet demand estimation forms the basis for optimising decarbonisation pathways. Traditionally, the assessment of thermal demand (heating and cooling) is based on modelling the physical envelope of buildings and the technological systems installed within them. When the spatial and temporal scale of analysis increases – as in long-term urban or regional studies – numerous simplifying and often rigid assumptions are introduced to represent the entire building stock.

However, this aggregated approach tends to overlook the individuality of each building, both from a technical perspective (architectural characteristics, energy systems, and sector of activity) and from a social perspective (comfort preferences and user behaviours). Failing to account for these individual factors also leads to the neglect of other, more systemic dimensions, whether technical (e.g. network peak loads), social (e.g. usage inequalities), or legal (e.g. regulation and heritage protection). Consequently, urban transition strategies could be biased or even hindered.

The objective of this thesis is twofold: first, to highlight the unique characteristics of buildings; and second, to assess the systemic flexibility potential of energy demand through a disaggregated modelling approach.

The project is divided into two parts. First, the student will develop synthetic and stochastic demand-profile generators for gas and electricity consumption. Second, the model will be applied at the scale of the Brussels-Capital Region to evaluate the impact of different socio-technical demand-evolution scenarios.

The stochastic framework will make the underlying assumptions explicit and enable the quantification of uncertainty. The quality of the generated profiles will be assessed using currently available real-world consumption data. In particular, the student will analyse the impact of societal changes such as energy sharing practices or slow heating strategies on future demand scenarios.

A basic knowledge of Python and an interest in urban energy systems are essential prerequisites.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS |
| Number of topics | 1 |

Supervision

Supervisor : Procacci Alberto (alberto.procacci@ulb.be)

Co-supervisor : Coussement Axel (axel.coussement@ulb.be)

Can machine learning methods approximate the optimal power flow solution for electric transmission systems?

Program : EM - Energy - M-IREMR-E

Description

Context

Optimal Power Flow (OPF) determines the optimal operating point of a power system satisfying its physical and operational constraints. This problem already being non-linear, non-convex and computationally expensive, gets increasingly more complex with the increasing penetration of Renewable Energy Sources (RES). This evergrowing complexity motivates the growing interest in machine learning (ML) as a way to produce fast approximate solutions. However, applying ML to the operation of power systems is not straightforward as the problem is high-dimensional, physics imposes hard constraints, and model relevance depends on the operating regime of each power system case. This thesis takes the Power Grid Library for OPF Benchmarking (PGLib-OPF) as its experimental playground. This open dataset is a collection of AC transmission test cases curated for OPF, ranging from small pedagogical networks to realistic grids with thousands of buses.

Research question

How well do machine learning methods approximate OPF on the cases from the PGLib dataset, and what insights can be extracted on why they succeed or fail across cases and operating conditions?

Approach

The student will (i) familiarise with the provided OPF solvers and the PGLib dataset, (ii) generate labelled train/test data by perturbing case loads and re-solving, (iii) apply standard ML techniques (e.g. regression, random forests, MLPs...) to predict OPF outputs, (iv) evaluate prediction accuracy, optimality gap, constraint violations, and computational speed-up against the solver, and (v) analyse which case characteristics (size, congestion regime, topology...) correlate with model performance. An optional extension, time permitting, would explore graph-aware model architecture.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IRIFS, M-IREMR-M |
| Number of topics | 1 |

Supervision

Supervisor

Alberto Procacci (alberto.procacci@ulb.be)

Co-supervisor

Coussement Axel (axel.coussement@ulb.be)

Development of a Low-Power Gas Turbine Test Bench for RC-Size Engines
Feasibility Study of ULB as an Energy Hub within a Local Energy Community
Feasibility Study for the Decarbonisation of Heat Supply on ULB Campuses
Pedagogical Integration of Flight Simulators for Engineering Education
Development of a dynamic thermal energy storage model as a digital twin in a decentralized energy system
Investigation of Coupled CFD Modelling for Microwave Electrification of Industrial Heating
Experimental and OD Modelling Study of Water Injection in Hydrogen Spark-Ignition Engines for CHP Applications
Development of a Hydrogen–Diesel Dual-Fuel Engine Test Bench and OD Combustion Model for CHP Applications
CFD Modeling of Water Injection in Hydrogen-Fueled Internal Combustion Engines and Development of a OD Water Injection Model for CHP Applications
Implementation of a Temperature Control Strategy for CFD-Based Digital Twin of an Industrial Process
Modeling Electric Heating Resistance using multi-physics approach for industrial implementation
Adapted Chemical Reactor Networks for Fast Combustion Modelling under Variable Operating Conditions

Program : EM - Energy - M-IREMR-E

Description

Combustion modelling is a central challenge in energy and chemical engineering. Industrial systems such as gas turbines, furnaces, and engines involve strong interactions between fluid dynamics, chemical kinetics, turbulence, and heat transfer. High-fidelity CFD simulations coupled with detailed chemical mechanisms are powerful tools to analyse these systems, but they remain computationally expensive, especially when large reaction mechanisms are considered. This limits their use for parametric studies, design exploration, optimisation, or real-time applications. Reduced-order modelling approaches are therefore needed to retain the main physical and chemical behaviour of reacting flows at a much lower computational cost.

The objective of this master thesis is to investigate adapted Chemical Reactor Networks (CRN) as reduced-order models for combustion systems. A Chemical Reactor Network approximates a complex reacting flow by a set of interconnected ideal reactors, each representing a region of the flow with similar thermochemical properties. In conventional approaches, the network is generated from CFD data for one specific operating condition. When the operating conditions change, a new CFD simulation is often required to build a new network. This thesis will explore an alternative strategy: reusing a CRN structure obtained from a reference CFD case while modifying only the inlet conditions and operating parameters.

The work will first include a literature review on CRN methods, CFD-based reactor network

generation, clustering techniques, and reduced-order modelling for combustion. The student will then generate a CRN from existing CFD data by grouping computational cells into regions with similar thermochemical properties, such as temperature, mixture fraction, residence time, or species concentrations. Each region will be represented as an ideal reactor, and the mass exchanges between regions will define the reactor connectivity. The resulting network will be solved using a chemical kinetics tool such as Cantera.

The main part of the thesis will consist of assessing the robustness of the adapted CRN approach. The student will apply the same reactor network structure to operating conditions different from the reference case, by changing inlet temperature, equivalence ratio, mass flow rate, fuel composition, or other relevant parameters. The CRN predictions will then be compared with reference CFD simulations or experimental data when available. Key quantities may include temperature fields, major species, pollutant formation, heat release, and global combustion efficiency.

The expected outcome is a critical assessment of whether a CRN generated from one CFD case can be reused as a fast predictive tool over a range of operating conditions. The thesis will deliver a literature review, a CFD-to-CRN workflow, a set of adapted CRN simulations, and recommendations on the validity limits and possible improvements of the method. The project requires knowledge of fluid mechanics and thermodynamics, programming skills in Python, and an interest in combustion, CFD, and numerical modelling.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Alessandro Parente (alessandro.parente@ulb.be)

Co-supervisor : Asija Inciardi (asija.inciardi@ulb.be)

Development of a Hydrogen–Diesel Dual-Fuel Engine Test Bench and 0D Combustion Model for CHP Applications

Program : EM - Energy - M-IREMR-E

Description

Hydrogen–diesel dual-fuel engines are a promising solution for improving the efficiency and reducing the carbon intensity of combined heat and power systems. By introducing hydrogen into a conventional diesel engine, it becomes possible to partially substitute fossil fuel while maintaining the robustness, high efficiency, and ignition reliability of diesel combustion. Such systems are particularly relevant for CHP applications, where both mechanical or electrical power and useful heat recovery must be considered. However, hydrogen–diesel operation involves specific combustion challenges, including ignition delay, heat-release control, knock or abnormal combustion risks, NO_x emissions, and the interaction between diesel pilot injection and hydrogen–air combustion.

The objective of this master thesis is to design and implement a dedicated hydrogen–diesel dual-fuel engine test bench within the ULB-ATM laboratory, and to complement this experimental work with the development of a zero-dimensional combustion model. The test bench should enable controlled investigations of combustion behaviour, engine performance, emissions, and heat recovery potential under different operating conditions. The student will first carry out a literature review on hydrogen–diesel dual-fuel combustion, existing experimental setups, safety constraints linked to hydrogen use, and 0D modelling approaches for internal combustion engines.

The main part of the thesis will focus on the design and implementation of the experimental test bench. This will include the definition of the fuel supply architecture, hydrogen injection strategy, diesel operation mode, instrumentation, data acquisition system, safety procedures, and operating protocols. The bench should allow the measurement of relevant quantities such as engine speed, torque or load, fuel consumption, hydrogen flow rate, temperatures, pressures, exhaust composition, and recoverable heat. Particular attention will be paid to safe hydrogen handling, ventilation, leak detection, emergency shutdown, and compatibility with laboratory constraints.

In parallel, the student will develop or adapt a 0D combustion model of the hydrogen–diesel dual-fuel engine. The model should reproduce the main features of the combustion process, including pressure and temperature evolution, ignition delay, heat-release rate, diesel pilot contribution, hydrogen energy fraction, and global engine performance. When experimental data are available, the model will be compared with measurements in order to assess its accuracy and limitations.

The expected outcome is a first experimental and numerical platform for studying hydrogen–diesel dual-fuel engines in CHP conditions. The deliverables will include a literature review, the design and implementation of the test bench, initial experimental results, a validated or partially validated 0D model, and a preliminary analysis of operating conditions favourable to efficient heat recovery. The thesis will require knowledge of thermodynamics, combustion, heat transfer, and piston engines, as

well as programming skills in Python, MATLAB, or a similar environment. Practical skills and the ability to work with the ATM technical team will be important assets.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Cyril Freyling (cyril.freyling@ulb.be)

Experimental and 0D Modelling Study of Water Injection in Hydrogen Spark-Ignition Engines for CHP Applications

Program : EM - Energy - M-IREMR-E

Description

Hydrogen spark-ignition engines are a promising solution for low-carbon combined heat and power applications, where both mechanical or electrical power and useful heat can be produced. However, hydrogen combustion remains challenging because of high combustion temperatures, NO_x emissions, knock, and pre-ignition risks. Water injection is a potential strategy to mitigate these limitations by reducing in-cylinder temperatures and modifying the combustion process. In a CHP context, this temperature control is also important because it affects not only engine efficiency and emissions, but also the amount and quality of recoverable heat.

The objective of this master thesis is to design and implement an experimental setup to study water injection under conditions representative of hydrogen spark-ignition engines. A key question will be to determine whether the injected water enters the engine as liquid droplets, vapour, or a two-phase mixture, depending on injection pressure, temperature, timing, injected quantity, and operating conditions. The student will therefore first carry out a literature review on hydrogen engine combustion, abnormal combustion phenomena, NO_x formation, and water injection strategies in internal combustion engines.

The main part of the thesis will consist of developing a dedicated experimental setup for water injection characterisation. This setup should make it possible to study the evaporation behaviour, droplet dynamics, temperature evolution, and resulting phase of the injected water before its introduction into the engine. Once the methodology has been characterised, the system will be implemented on a real hydrogen spark-ignition engine. Experimental tests will then be used to assess the impact of water injection on combustion behaviour, performance, efficiency, knock tendency, thermal behaviour, and NO_x emissions.

In parallel, the student will develop or adapt a zero-dimensional combustion model of a hydrogen spark-ignition engine including the effects of water injection. The model should account for injected water quantity, evaporation, mixture dilution, temperature reduction, heat-release behaviour, engine performance, and CHP efficiency. When experimental results are available, the model will be compared with measurements in order to assess its validity and limitations.

The expected outcome is a first experimental and numerical framework for analysing water injection in hydrogen spark-ignition engines. The main deliverables will be a literature review, the design and implementation of the water-injection test setup, a first implementation on the hydrogen engine test bench, and a validated or partially validated 0D model. The thesis will require good knowledge of thermodynamics, heat transfer, and piston engines, as well as programming skills in Python, MATLAB, or a similar environment. Practical skills and the ability to work with the ATM technical team will be important assets.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Cyril Freyling (cyril.freyling@ulb.b)

Development of a dynamic thermal energy storage model as a digital twin in a decentralized energy system

Program : EM - Energy - M-IREMR-E

Description

In an attempt to reduce the impact of climate change on our planet, we are shifting away from fossil fuels toward more renewable energy sources. However, integrating more renewable energy sources, such as solar and wind, comes with its challenges. To maximize the use of energy produced by renewable sources, storage will become increasingly important in energy systems. This makes it possible to use excess energy at later times when necessary and to balance the energy production and demand curves more efficiently. When analyzing energy consumption, after electricity and transportation, heating for space heating and hot water production is a substantial part of our energy needs. An efficient way to meet our electricity and heating needs is to use combined heat and power (CHP) units, such as micro gas turbines (MGT) or internal combustion engines (ICE), where the excess heat from the exhaust gas can be used to heat water for district heating networks (DHN). Oftentimes, electricity production is the main driver in the CHP units, so reliable heat storage is necessary to benefit later.

The thesis will focus on developing a dynamic model of thermal energy storage (TES) that accounts for thermal inertia. This model can then be used as a digital twin, an accurate but fast model that receives information from the physical system and can be used for real-time optimization. The TES can be implemented in an energy system that needs to be optimized to ensure that the available power and heat match demand, and it can also be used to reduce fossil fuel emissions or utilization costs. The modeling, optimization, and control of the energy system can be used to predict our ideal energy generation mix and also allow us to adapt our plan in case of disturbances, e.g., more clouds than expected, which reduces available solar energy.

First, the student conducts an extensive literature review on thermal energy storage and examines how it is modeled to balance accuracy and computational speed. Once the student has developed an idea for this model, it will be implemented in Python. During this phase, different methods can be explored and compared to results in the literature. The thermal energy storage model will be integrated into an available district heating network model. The control system will be developed to demonstrate its use in optimizing the heating network.

The student does not need any prior knowledge of energy systems or thermal energy storage, but should be interested in learning. As this project will mainly consist of programming, basic knowledge of Python is required.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Co-supervisor : Zoraida Nti (zoraida.nti@ulb.be)

Feasibility Study for the Decarbonisation of Heat Supply on ULB Campuses

Program : EM - Energy - M-IREMR-E

Description

The objective of this master thesis is to perform a first feasibility study on the decarbonisation of heat supply on ULB campuses, in close collaboration with the ULB cellule énergie. At present, the university's heat demand is mainly covered by natural gas boilers using CH₄. The aim of the thesis is to assess possible pathways to reduce or eliminate fossil fuel use for heating, while taking into account the technical, economic, operational, and spatial constraints of university campuses.

The work will first consist of characterising the current heat demand and heat production infrastructure. The student will analyse available data on gas consumption, heating networks, boiler rooms, building uses, occupancy patterns, temperature levels, and seasonal demand profiles. Particular attention will be paid to the distinction between peak heat demand, annual heat consumption, supply temperatures, and the flexibility of the buildings, since these elements strongly influence the feasibility of low-carbon heating solutions.

The student will then identify and compare a broad range of decarbonisation options. These may include heat pumps, geothermal energy, shallow geothermal storage, connection to existing or future district heating networks, heat recovery from local sources, solar thermal systems, biomass where relevant, hybrid systems combining gas and low-carbon technologies, and progressive electrification strategies. The analysis should also consider demand-side measures, such as reducing supply temperatures, improving control strategies, exploiting thermal inertia, and prioritising building-level efficiency improvements when they enable more efficient low-carbon heat production.

A simplified modelling framework will then be developed to compare several transition scenarios. These may include a reference scenario based on the current CH₄ supply, partial electrification through heat pumps, geothermal-assisted heating, hybrid systems for peak demand, and more integrated campus-scale solutions combining storage, heat recovery, and demand management. The comparison should estimate key indicators such as energy consumption, fossil fuel reduction, CO₂ emissions, peak electrical power, seasonal performance, investment cost, operating cost, spatial requirements, implementation complexity, and robustness of supply.

Finally, the thesis will address practical aspects in collaboration with the ULB cellule énergie. This includes data availability, technical constraints in existing buildings, compatibility with current heating networks, regulatory aspects, phasing of investments, and the identification of priority sites or pilot projects. The expected outcome is a structured feasibility report assessing which decarbonisation pathways are most promising for ULB campuses, under which conditions they could be implemented, and what further studies would be required. The work will provide quantitative first estimates and a roadmap toward a progressive reduction of CH₄-based heating on campus.

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| Language | EN (english) |
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| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Feasibility Study of ULB as an Energy Hub within a Local Energy Community

Program : EM - Energy - M-IREMR-E

Description

The objective of this master thesis is to perform a first feasibility study on the potential role of ULB as an energy hub within a local energy community, at the scale of the urban block or neighbourhood surrounding the university campus. The project will be carried out in close interaction with the ULB cellule énergie, with the aim of evaluating how the university's buildings, energy infrastructure, consumption profiles, and potential local production assets could contribute to a collective energy strategy.

The work will focus on identifying the technical potential for ULB to act as a local energy hub. This includes assessing opportunities for photovoltaic production, demand-side management, heat recovery, battery or thermal storage, electric vehicle charging, and possible interactions with neighbouring buildings or users. The analysis should consider both electrical and thermal energy flows, and evaluate whether coupling these vectors could bring additional value at neighbourhood scale.

The student will then develop a simplified modelling framework to compare several energy-community scenarios. These may include a reference case without energy sharing, a scenario with increased local renewable production, a scenario including flexible loads or storage, and a more integrated energy-hub scenario. The model should estimate key indicators such as self-consumption, self-sufficiency, peak power reduction, CO₂ emissions, energy costs, and possible benefits for participating users. The level of modelling will remain compatible with a first feasibility study, while being sufficiently detailed to support concrete recommendations.

Finally, the thesis will address practical and organisational aspects in collaboration with the ULB cellule énergie. This may include data availability, regulatory constraints, metering requirements, governance models, and the identification of priority actions for a future demonstrator. The expected outcome is a structured feasibility report assessing whether, and under which conditions, ULB could become a central actor in a local energy community. The work will provide both quantitative first estimates and a roadmap for further technical, economic, and institutional development.

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| Language | EN (english) |
| Open to other master's programs | Yes |
| Eligible master's programs | M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O |
| Number of topics | 1 |

Supervision

Supervisor : Axel Coussement (axel.coussement@ulb.be)

Modelling of a hybrid hydrogen PEMFC / Heat Pump micro combined heat and power system

Program : EM - Energy - M-IREMR-E

Description

Combined heat and power systems (CHP) based on hydrogen fuelled PEMFCs (Proton Exchange Membrane Fuel Cells) present an attractive solution for decentralized, low carbon heat and power production. Its global efficiency can reach up to 85%, but at as a standalone system, it cannot cover large space heating demands during cold seasons due to the limited heat production that is retrieved from the PEMFC cooling system. Therefore, a novel idea consists in investigating a system in which a PEMFC exclusively powers an air-source heat pump (ASHP), forming a tightly coupled, grid-independent heating unit, and leveraging its high coefficient of performance in the process. The master's thesis will consist of developing the digital twin of an experimental facility investigating the performance of such CHP system. Particular care will be taken on modelling the stratified domestic water tank and sizing the air-source heat pump to guarantee that the whole CHP system satisfies energy demands throughout the year.

The student will also investigate the behaviour of a sized PEMFC-HP system deployed as a CHP unit within a residential energy community, and to determine which cases favour the use of a PEMFC-HP system (with regards to hydrogen supply cost, electricity tariffs, community demand profiles, and climate) offers advantages over competing alternatives.

Prerequisites:

- Interest in sustainability and renewable energy
- Programming in Python and/or MATLAB
- Background in electrical engineering, thermodynamics, energy systems, or building technologies

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| Language | EN (english) |
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Patrick Hendrick (patrick.hendrick@ulb.be)

Co-supervisor : Bilal Outirba (bilal.outirba@ulb.be)

Analysis of Heat and Mass Transport During Hydrogen Bubble Growth in Water Electrolysis

Program : EM - Energy - M-IREMR-E

Description

Hydrogen can be produced by splitting water through electrochemical reactions in electrolysis. Although the process is overall endothermic, additional heat can be generated locally, most notably through Joule heating at the electrode surface. This localized heating modifies the temperature field near the growing hydrogen bubble, creating temperature gradients that induce thermocapillary (Marangoni) flows along the bubble interface.

In addition to thermal effects, concentration gradients of surface active species such as ions or dissolved gases can also alter surface tension, resulting in solutal Marangoni convection. These interfacial flows strongly affect bubble growth, shape, and detachment dynamics. Understanding these coupled effects requires the ability to accurately resolve the local temperature and concentration fields around the bubble. However, measuring both fields at the same time remains a significant experimental challenge.

Previous studies have demonstrated that at high applied potentials, Joule heating dominates, and thermocapillary effects become the primary drivers of interfacial motion, while solutal effects can often be neglected. Various optical techniques such as Schlieren imaging, laser induced fluorescence, and interferometry have been used to study these fields.

Mach Zehnder interferometry stands out as a noninvasive and calibration free technique for resolving instantaneous temperature fields with high sensitivity.

This thesis will focus on hydrogen bubble dynamics on a microelectrode in acidic electrolysis, using two complementary experimental techniques:

- Mach Zehnder Interferometry, to quantify the temperature field near the electrode and at the base of the bubble, especially when concentration variations are negligible.
- High speed visualization, to qualitatively capture the bubble inception, growth, and detachment processes.
- Complementary Schlieren imaging may be used for qualitative validation as done in the previous study [1].

Methodology

1. Literature survey

The student will begin by familiarising themselves with the topic. A thorough review of recent literature, especially on interferometric and visualisation techniques applied to gas-evolving electrodes, will help define the research scope and objectives.

2. Experimental set-up

The student will work with the existing electrolysis cell, Mach Zehnder interferometer, and high-speed imaging system available at the TIPS laboratory. This phase will involve hands-on training with laser alignment, optical adjustments, electrode handling, and system calibration. The student will also participate in test runs to optimise measurement conditions and gain confidence in operating the setup independently.

3. Measurement campaign and data analysis

The student will conduct experiments to visualise hydrogen bubble growth on microelectrodes using high-speed imaging and Mach Zehnder interferometry. Interferometric data will be analysed to extract local temperature fields, while high-speed recordings will be used to characterise bubble shape, growth, and detachment dynamics. Post-processing and analysis will be carried out using MATLAB. If numerical simulation results are available, they will be compared with the experimental data. In parallel, the student will measure the refractive index, density, and viscosity of the electrolyte across different concentrations and temperatures, using the available facilities at the TIPs laboratory, ULB.

4. Reporting

- ☐ Weekly meetings with the supervisor to define tasks and discuss outcomes and practicalities.
- ☐ Monthly meeting with the team and the promotor to verify the progress and discuss follow-up
- ☐ Final presentation

References

- [1]. A. Babich, A. Bashkatov, X. Yang, G. Mutschke, and K. Eckert, "In-situ measurements of temperature field and Marangoni convection at hydrogen bubbles using schlieren and PTV techniques," *Int. J. Heat Mass Transf.*, vol. 215, p. 124466, 2023.
- [2]. J. Massing, G. Mutschke, D. Baczyzmalski, S. S. Hossain, X. Yang, K. Eckert, and C. Cierpka, "Thermocapillary convection during hydrogen evolution at microelectrodes," *Electrochimica Acta*, vol. 297, pp. 929–940, 2019.

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| Language | EN (english) |
| Open to other master's programs | No |
| Eligible master's programs | |
| Number of topics | 1 |

Supervision

Supervisor : Pierre Colinet (pierre.colinet@ulb.be)

Co-supervisor : Senthil Kumar Parimalanathan (senthil.parimalanathan@ulb.be)