Topics offered to students by other master's programs

TARGET PROGRAM

EM – Automotive 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.

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 drines 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.

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.

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.

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.

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.

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

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)

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 0D Modelling Study of Water Injection in Hydrogen Spark-Ignition Engines for CHP Applications Development of a Hydrogen–Diesel Dual-Fuel Engine Test Bench and 0D Combustion Model for CHP Applications CFD Modeling of Water Injection in Hydrogen-Fueled Internal Combustion Engines and Development of a 0D 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.

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.

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.

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.

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 CH_4. 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 CH_4 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, CO_2 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 CH_4-based heating on campus.

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, CO_2 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.

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)

Topics offered to students by other master's programs

TARGET PROGRAM

EM – Automotive Engineering

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.

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)

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 S21. 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.

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)

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.

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, M- IRPH
Number of topics	1

Supervision

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

Co-supervisor
Iorio Carlo (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 drines 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.

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.

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.

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.

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.

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

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)

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 0D Modelling Study of Water Injection in Hydrogen Spark-Ignition Engines for CHP Applications Development of a Hydrogen–Diesel Dual-Fuel Engine Test Bench and 0D Combustion Model for CHP Applications CFD Modeling of Water Injection in Hydrogen-Fueled Internal Combustion Engines and Development of a 0D 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.

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.

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.

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.

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 CH_4. 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 CH_4 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, CO_2 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 CH_4-based heating on campus.

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, CO_2 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.

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)

Topics offered to students by other master's programs

TARGET PROGRAM

EM SUSTAINABLE TRANSPORT 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.

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 ex-cept 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 endo-scopic 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 characteriza-tion (Tips).
Prerequisites:

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

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.

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.

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.

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.

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 thir 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.

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.

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.

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 lab-yrinth, 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 limita-tions. 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 evalua-tion of the built prototype.

Prerequisites:

- Mechanical design
- Interest for mechanical and biomedical engineering

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.

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

Biopsies in the periphery of the lung: shape sensing catheter tip

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 lab-yrinth, with sections that shrink with each division, and access to a precise peripheral zone is difficult. In addition, the need to use flexible and miniaturised tools implies certain limita-tions. 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. One way to ensure that the biopsy is taken at the right location is to have knowledge on the position and deformation of the catheter tip. Despite the exploration of various technologies such as electromagnetic sensors (EM), optical fibers, X-rays, etc [2], [3] , biopsy outcomes remain highly variable and dependent on a variety of factors including the type and number of used equipment, experience of the practician, location of the nodule in the lung. [4]

Objectives: This master thesis aims to design and develop a system enabling the practicians to know how the tip of the catheter is deformed in the lungs, due to their mechanical contact with the bronchii and the internal efforts developed in the catheter. Given the very small size of the peripheral bronchi (<1 mm), the system can be initially developed at a larger scale. Some inspiration can be taken from textile-based sensors, or other resistive strain gauges [5].

Methods: Literature review. Functional analysis and requirements. Design. Fabrication and charac-terization of a shape sensing catheter tip.

Prerequisites:

- Mechanical design, electronics
- Interest for mechanical and biomedical engineering

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IREMR-A, 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(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.

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 considered be 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.

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 pol-ymer, 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 µm × 50 µm × 50 µm active cubes capable of bending, contract-ing, twisting, or shearing in heated water [1]. To achieve precise, multidirectional motion control, multiple actuators could be combined and selectively triggered by different wave-lengths of light. This is possible by doping them with photothermal nanomaterials that lo-cally convert light into heat [2]. Metallic nanostructures like gold (Au) and silver (Ag) nano-particles 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, pre-cise 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 mo-tion by shrinking the hydrogel.
Methods: Literature review. Hydrogel fabrication (with 2PP printing). Printing of Ag/Au nanoparti-cles i.e., tune the printing parameters to obtain nanoparticles and optimize the actuation. Characterization: UV absorbance spectra, SEM imaging, and measuring the light respon-siveness of the structures.
Prerequisites: Materials (to develop the fabrication process and understand the behavior of the hydrogels with and without nanoparticles).

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

Mesoscale computational model of continuously reinforced fused filament fabrication

Description

The goal of this master’s thesis is to achieve a thorough understanding of the influence of reinforcements on mesoscale stress concentrations. To this end, the addition of geometric features representing reinforcing fiber tows to the geometries presented in [2] is envisioned.

Langue	EN (english)
Ouvert à d’autres masters	Yes
Masters concernés	M-IREMR-A, M-IREMR-M, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Berke Péter (peter.berke@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 dis-placement). 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 50µm soft actua-tors out of a thermo-responsive polymer (pNipam = poly(N-isopropylacrylamide)). These active cubes demonstrate bending, contraction, twist, or shear deformation in a heated wa-ter 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 ap-proach 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 sys-tem [4], at EMPA (Thun, Switzerland).
Prerequisites: Numerical methods

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: Civil engineering - M-IRCNE

Computational analysis of the dynamic transformation behavior of bistable scissor structures

Description

This work consist of (i) understanding the concept and challenges of bistable scissor structures and a literature review on modeling efforts of their dynamic behavior, (ii) set up of 3D FEM models in a commercial FE software, (iii) investigating their dynamic deployment including the proposal of damping solutions, using appropriate loads and boundary conditions, (iv) proposing a design strategy that incorporates notions of the dynamic behavior of BDS.

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

Supervision

Supervisor : Berke Péter (peter.berke@ulb.be)

Master's program offering the topic: Civil engineering - M-IRCNE

Incorporating adaptivity in quasi-discrete modeling of the fracture of heterogeneous materials

Description

This work consist of (i) the in-depth understanding of the quasi-discrete (QD) approach, (ii) the application of the quasi-discrete methodology to benchmark problems, (iii) the extension of QD by adaptivity, i.e. the coarsening and refinement of the spatial resolution on the fly.

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

Supervision

Supervisor : Berke Péter (peter.berke@ulb.be)

Master's program offering the topic: Civil engineering - M-IRCNE

Computational modeling of the residual stresses generated in the 3D printing process employing continuous fiber reinforced filaments

Description

The objective of this master's thesis is a thorough understanding and the development of a FEM-based workflow to generate thermal histories and a good estimate of residual stresses in FDM printed parts, accounting for the thermo-mechanical anisotropy of continuous carbon fiber reinforced filaments. The modeling is envisioned to be done in Abaqus by progressively activating finite elements in the mesh based on the printing path.

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

Supervision

Supervisor : Berke Péter (peter.berke@ulb.be)

Master's program offering the topic: Civil engineering - M-IRCNE

Treatment of contact conditions within the isogeometric method, application to complex contact geometries

Description

The main task is the implementation of the contact treatment within the isogeometric framework. This will require: (i) understanding the concepts of the isogeometric method for structural applications in linear elasticity, (ii) a literature review on the available contact formulations (with and without friction), (iii) the implementation and validation of the chosen one and (iv) the application of the resulting non-linear computational tool to a contact problems (e.g. rough surface contact).

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

Supervision

Supervisor : Berke Péter (peter.berke@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.

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.

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.

Langue	FR (français)
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

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.

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.

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.

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.

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.

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.

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.

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.

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. Pardoen, 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.

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.

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.

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 an 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)
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.

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.

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

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.

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

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.

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

test

Description

test

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.ENGFRACMECH.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.

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.

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 captures 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.

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.

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.

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.

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).

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, ...).

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.

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.

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.

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 ai 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 considered be 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.

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.

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 : Deraemaeker Arnaud (arnaud.deraemaeker@ulb.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

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

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.

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

Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.be)

Master’s program offering the topic: EM - Energy - M-IREMR-E

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

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 differen-tial equations.

- Familiarity with simulation and modeling tools e.g., COMSOL, MATLAB/Simulink, Python, or PyBaMM is an added advantage.

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

Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.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.

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

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

Description

Accurate knowledge of the specific heat capacity (Cp) of lithium-ion batteries is essential for reliable thermal modelling and prediction of thermal runaway behavior. This thesis investigates a novel methodology for determining Cp 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 Cp values will then be integrated into an existing thermal runaway model to evaluate their impact on simulation accuracy and safety-critical predictions.

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

Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@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.

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)

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

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

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.

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

Supervision

Supervisor : Berecibar Uribe Maitane (maitane.berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

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

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.

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

Supervision

Supervisor : Berecibar Maitane (Maitane.Berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

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

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3. Model Development: Implementing and benchmarking various time-series models such

as TimesFM.
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5. Performance Analysis: Comparing models' performance.

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• Experience with Python and data analysis libraries.

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

Supervision

Supervisor : Berecibar Maitane (Maitane.Berecibar@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 anomaleous behaviour, the automatic integration between database and simulation, ...

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

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.

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

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

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.

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

Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.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

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

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

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.

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

Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.be)

Master's program offering the topic: EM - Energy - M-IREMR-E

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

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

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

Supervision

Supervisor : Berecibar Maitane (Maitane.Berecibar@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

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.

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

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

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

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

Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@vub.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

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 V ehicle-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.

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

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.

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 occassionally to 24SEA, situated just outside Brussels.

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

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

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

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

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.

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	M-IRELE, M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Berecibar Maitane (maitane.berecibar@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 stimu-lus (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 character-istics of such actuators. Inspired by Micro-Electro-Mechanical Systems (MEMS) force sen-sors [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 materi-als 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 character-ized 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 un-derstand the material model obtained from experimental measurements).

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/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6l_fYt8wBzDMGZXZs?e=NJRPtg
When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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

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 senser 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/)

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.

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

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/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6l_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.

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

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)

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 - 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/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6l_fYt8wBzDMGZXZs?e=NJRPtg
When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6l_fYt8wBzDMGZXZs?e=NJRPtg
When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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.

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 50µm 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/photonics 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

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

Actuation and control of a clutchable-elastic lower-limb exoskeleton

Description

Context

Many people who have limited mobility (due to age or medical conditions) for example when trying to stand from a seated position, ascend stairs,…. This can heavily limit the quality of life for these people and even result in injuries from falling or other complications that can arise from poor posture and fatigue. These issues can be solved by providing assistance with wearable robotics such as exoskeletons. One of the main challenges with exoskeletons is to limit their weight to allow the user to still perform tasks. To reduce the weight of exoskeletons, we study the use of springs and clutches to capture and store energy during some parts of the motion and release it later when beneficial, thus removing the need for heavy motors and actuators and allowing assistance for motions such as sit-to-stand without external power. This system has already shown its ability to assist tasks such as sit-to-stand, reducing the effort made by the user; however, it requires manual control of the system by the user.

Goal of the thesis

In this thesis, you will improve a clutch and spring-based knee exoskeleton that is currently manually controlled. You will incorporate a semi-active actuation and control system allowing the clutch and spring to be connected and disconnected automatically with the right timing to provide assistance.

This project will be based on the existing exoskeleton but will require designing and building the system controlling the clutch, studying and modeling the system to build an efficient and versatile controller, and finally validating the exoskeleton with experimental results on multiple tasks.

Prerequisites:

It is recommended to have experience with the following aspect:

System identification

Controller design

Actuator design

CAD

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRCBS, M-IREMR-A, 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 - 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/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6l_fYt8wBzDMGZXZs?e=NJRPtg
When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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 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/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6l_fYt8wBzDMGZXZs?e=NJRPtg
When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6l_fYt8wBzDMGZXZs?e=NJRPtg
When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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

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 localisaiton
- 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.

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

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.

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

Design and Performance Study of a multi-level inverter based battery Systems for Light Electric Vehicle Drivetrain

Description

This thesis focuses on designing and evaluating a 60 V, 2 kWh MLC (multi-level converter)-based battery system for light electric vehicle drivetrains. It aims to analyze system architecture, efficiency, thermal performance, and integration with motor drives. Research objectives include modeling and simulation, hardware design, control strategy development, and performance comparison with conventional DC battery systems to assess feasibility, reliability, and overall energy efficiency.

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	M-IREMR-O
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

A cloud-based Digital Twin framework for high-torque light electric vehicles (LEVs)

Description

Light electric vehicles (LEVs) are increasingly used in cities. The accurate monitoring and management of critical components in the system (battery, motor, inverter) are critical for the reliability of the system and the user experience incl. range anxiety. This thesis focuses on the implementation of a cloud-based digital twin of LEVs for accurate SoC estimation and condition monitoring. This includes the physics-based and data-driven modelling of the LEV based on data collection and preprocessing. A generic framework will be created based on different levels of modelling and available data. The models will be validated with actual data in real-world operation, and a proper graphical user interface will be developed. One main ebike use case will be considered, complemented with an escooter use case for replicability.

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	M-IREMR-O
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

Development of an -agnostic vehicle-level digital twin platform

Description

A vehicle-level digital twin enabling tool-independent, data-driven parameterisation and rapid calibration without full component-level knowledge, supporting accurate energy behaviour replication w.r.t test data

Langue	EN (english)
Ouvert à d'autres masters	No
Masters concernés	M-IREMR-O
Nombre de sujets	1

Supervision

Supervisor : Omar HEGAZY (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.

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)

Electro-Mechanical Engineering – Sustainable Transport & Automotive

Master Thesis Topics (M-IREMR-O)

Academic year 2026–2027

Environmental impact of the battery considering size and its impact on battery lifetime.

Program : EM - Sustainable transport and automotive M-IREMR-O

Description

Batteries are one of the main hotspots of the environmental impacts of electric cars, and it is widely assessed. LCA is the methodology of choice. However, at the level of passenger cars, most modelling considers the battery lifetime to be the vehicle lifetime whereas the battery could go longer. The real lifetime and usage is not always considered in such studies.

First, to understand the impacts of battery lifetime at battery level, the objective of this project is to carry out a detailed LCA and prospective LCA of different battery chemistries (i.e., NMC and LFP), varying their capacities. The modelling of the use phase of the LCA should consider the real lifetime of the battery and its variation depending on the size of the battery and its chemistry. The results should show the impacts on several indicators for all batteries to understand the effects of battery sizes and lifetime on battery environmental performance.
Secondly, the study should discuss, at the passenger cars level, the possibility of including it in the methodology and what the impacts could be.

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: Maeva Philippot Lavigne

Contact : Maeva.Philippot@vub.be

Lien : Geslin, A., Xu, L., Ganapathi, D. et al. Dynamic cycling enhances battery lifetime. Nat Energy 10, 172–180 (2025). https://doi.org/10.1038/s41560-024-01675-8

Design and Performance Study of a multi-level inverter based battery Systems for Light Electric Vehicle Drivetrain

Program : EM - Sustainable transport and automotive M-IREMR-O

Description

This thesis focuses on designing and evaluating a 60 V, 2 kWh MLC (multi-level converter)-based battery system for light electric vehicle drivetrains. It aims to analyze system architecture, efficiency, thermal performance, and integration with motor drives. Research objectives include modeling and simulation, hardware design, control strategy development, and performance comparison with conventional DC battery systems to assess feasibility, reliability, and overall energy efficiency.

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

Supervision

Supervisor : Omar HEGAZY

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Co-supervisor: Shahid Jaman

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Distributed Balancing Control for BMS Using Local Sensing and Decentralized Communication

Program : EM - Sustainable transport and automotive M-IREMR-O

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.

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

Supervision

Supervisor : Omar HEGAZY

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Co-supervisor: Alfie Robert Peña

Contact : Robert.Alfie.Pena@vub.be

A cloud-based Digital Twin framework for high-torque light electric vehicles (LEVs)

Program : EM - Sustainable transport and automotive M-IREMR-O

Description

Light electric vehicles (LEVs) are increasingly used in cities. The accurate monitoring and management of critical components in the system (battery, motor, inverter) are critical for the reliability of the system and the user experience incl. range anxiety. This thesis focuses on the implementation of a cloud-based digital twin of LEVs for accurate SoC estimation and condition monitoring. This includes the physics-based and data-driven modelling of the LEV based on data collection and preprocessing. A generic framework will be created based on different levels of modelling and available data. The models will be validated with actual data in real-world operation, and a proper graphical user interface will be developed. One main ebike use case will be considered, complemented with an escooter use case for replicability.

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

Supervision

Supervisor : Omar Hegazy

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Co-supervisor: tHOMAS GEURY

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Development of an -agnostic vehicle-level digital twin platform

Program : EM - Sustainable transport and automotive M-IREMR-O

Description

A vehicle-level digital twin enabling tool-independent, data-driven parameterisation and rapid calibration without full component-level knowledge, supporting accurate energy behaviour replication w.r.t test data

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

Supervision

Supervisor : HEGAZY Omar

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Co-supervisor: Sajib Chakraborty

Contact : Sajib.Chakraborty@vub.be

Fast High-Fidelity Modeling of Traction Inverters for Electric Powertrain Digital Twin Applications

Program : EM - Sustainable transport and automotive M-IREMR-O

Description

Accurate switching-level models of traction inverters are essential for analyzing current ripple, losses, and thermal stress. However, these models are computationally expensive, especially for long drive cycles and complex converter topologies. This thesis explores a faster modeling approach based on average-to-switching reconstruction, where switching behavior is reconstructed from averaged signals. By combining this method with parallel computation, the aim is to significantly reduce simulation time while maintaining acceptable accuracy. The approach will be applied to a two-level inverter and extended to a modular converter structure. Simulation results will compare accuracy and computational speed against conventional switching models, providing practical guidelines for efficient high-fidelity modeling.

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

Supervision

Supervisor : Omar HEGAZY

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Co-supervisor: Talib Faiz

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Electrical motors for EV traction, design and control --- internships and Master theses, at/in collaboration with Punch Powertrain (Sint-Truiden)

Program : EM - Sustainable transport and automotive M-IREMR-O

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.

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

Lien : https://www.dropbox.com/scl/fi/z8wy34w8d2ubp9vgx65bf/Internships-Punch-Powertrain-ULB-2026.pdf?rlkey=pit55l09nbamzwk359piya8zj&dl=0

Circularity indicators for Life Cycle Assessment: Case study on electric motor

Program : EM - Sustainable transport and automotive M-IREMR-O

Description

Context
Given the objectives of reuse and repurposing for many products to reduce geopolitical dependency on certain raw materials, novel circularity indicator methods have been recently developed to be able to quantify their impacts when applying Life Cycle Assessment (LCA).
Objective
The objective of this study is first to provide a detailed overview of the different existing circularity indicators, how they are applied within the LCA framework, and their strengths and drawbacks by carrying out a literature review. Then, the relevant indicator methodologies should be applied to a specific case study of an electrical motor.
The results should provide the findings of the literature review, but also the main results of the LCA of the electrical machine, comparing different indicators.
Methods
- Literature review
- LCA

Prerequisite
* Python

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

Supervision

Supervisor : Maarten Messagie

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Lien : Palomero et al, Integrating circularity into Life Cycle Assessment: Circularity with a life cycle perspective, Cleaner Environmental Systems, Volume 12, 2024,100175,, https://doi.org/10.1016/j.cesys.2024.100175.

Design and Behavioural Study of Active-Inductor based Power Electronic Converters

Program : EM - Sustainable transport and automotive M-IREMR-O

Description

This thesis focuses on the design and analysis of power electronic converters using active inductors to replace bulky passive components. It aims to investigate performance, efficiency, stability, and dynamic behavior through simulation and prototyping. Objectives include optimizing circuit design, evaluating control strategies, and comparing active-inductor converters with conventional designs.

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

Supervision

Supervisor : Omar HEGAZY

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Co-supervisor: Shahid Jaman

Contact : shahid.jaman@vub.be