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)

Testing and analysis of complete UAV (drone) propulsion chain with batteries and H2 fuel cell

Program : EM - Aeronautics - M-IREMR-A

Description

The objective will be to characterize with ground tests a complete electric propulsion chain for a fixed-wing UAV based on a small PEMFC (250 W) feeded with gaseous hydrogen (H2 tank + PEMFC + LiPo batteries + electric motor + propeller).
Based on the results to make an Aircraft Conceptual Design exercise to integrate this propulsion system into a fixed-wing UAV and define its in-flight performance.
MT topic possible for a group of 2 students.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	nan
Number of topics	Possible for 2 students (group of 2).

Supervision

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

Co-supervisor : Adrien Fita-Codina (adrien.fita-codina@ulb.be)

Topics offered to students by other master's programs

TARGET PROGRAM

EM – AERONAUTICS 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)

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

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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)

Electro-Mechanical Engineering
EM – Aeronautics

Master Thesis Topics
Academic year 2026–2027

Experimental and numerical investigation of structural adhesive behavior under multiple loading conditions

*Program : EM - Aeronautics - M-IREMR-A_*

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.

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

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

Supervision

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Investigation of Combined Noise Transmission and Reflection Cancellation in Industrial Duct Systems

Program : EM - Aeronautics - M-IREMR-A

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.

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

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Development of a thermal PID closed-loop controller for 316L/CuCr1Zr functionally graded additive materials

*_Program : EM - Aeronautics - M-IREMR-A_*

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.

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

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On-line measurement and validation of thermal gradients during 3D metal printing through IR-camera measurements.

*Program : EM - Aeronautics - M-IREMR-A*

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.

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

Supervision

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https://drive.google.com/file/d/1dZkuqUm0AP9lgYVYeURnttnwLSQ3KlXc/view?usp=sharing

Investigation of Microstructural Evolution and Corrosion Resistance in Hybrid DED-Manufactured Parts

*_Program : EM - Aeronautics - M-IREMR-A_*

Description

3D printing is a widely used additive manufacturing process in which layers of material are successively deposited to create a three-dimensional part. Over the past decade, it has gained significant interest due to increased accessibility and technological advancements.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) technique that uses a focused laser beam to melt metallic powder, which is simultaneously delivered through a nozzle. The Additive Manufacturing Research Lab (AM-Lab) at the Vrije Universiteit Brussel (VUB) has developed an in-house hybrid DED machine called the MiCLAD, which is extensively presented in [2].

The MiCLAD system is equipped with a 5-axis CNC controller and allows for a rapid transition between additive deposition (DED) and subtractive machining (milling/drilling). This combination of processes is referred to as hybrid manufacturing. An in-situ image of the DED process is shown in Fig. 1, where the nozzle, powder particles, and melt pool (visible as a high-intensity spot) can be observed. Fig. 2 illustrates a hybrid 3D tower manufactured using the MiCLAD system, combining additive and subtractive operations to directly integrate functional features into the part. The milling operations are indicated by the red dashed lines.

The subtractive process is further illustrated in Fig. 3 (cogwheel) and Fig. 4 (research sample). During hybrid manufacturing, the process parameters and thermal history play a critical role in determining the final part quality, as they directly influence the microstructure, residual stresses, corrosion behaviour, and mechanical properties.

An Electron Backscatter Diffraction (EBSD) map is shown in Fig. 5, highlighting a clear effect of the milling operation on grain size and crystallographic orientation. These microstructural modifications are expected to significantly affect the corrosion behaviour of the material and therefore require detailed investigation.

It is therefore essential to understand the combined effect of additive and subtractive operations on the microstructure and to monitor the melt pool temperature during processing. The SURF [3] and MECH [4] departments at VUB are collaborating closely to investigate these effects.

To evaluate the influence of hybrid manufacturing on corrosion resistance, a dedicated experimental campaign will be carried out on the MiCLAD machine, and the melt-pool temperatures during manufacturing will be measured. Samples produced via hybrid DED (additive + milling) will be compared to purely additive-manufactured samples.

The corrosion behaviour will be assessed using standard electrochemical and surface analysis techniques, including potentiodynamic polarization and immersion tests to evaluate the electrochemical response of the samples, as well as XPS and SEM/EDS to analyze the impact of the processing condition on the microstructure and passive oxide layer of the material. These analyses will help establish correlations between process conditions, melt-pool temperature, resulting microstructures, and corrosion performance.

The final objective of this master thesis is to design and conduct a hybrid experimental campaign using the MiCLAD system to manufacture samples suitable for corrosion analysis, and to compare their corrosion resistance with that of conventionally additively manufactured samples.

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

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

Supervision

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https://drive.google.com/file/d/1H46_xNGY7VllU3QpV_a9u3da10R666go/view?usp=sharing

Post-processor extension to 3D material allocation for metal 3D printing through Directed Energy Deposition manufacturing process.

Program : EM - Aeronautics - M-IREMR-A

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.

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

Supervision

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https://drive.google.com/file/d/1VCGK9h9RzbcXrYJJgk0eloc5Eob_J71H/view?usp=sharing

Development of the wedge test for thick adhesive joints to prevent crack deviation under mode I loading

Program : EM - Aeronautics - M-IREMR-A

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.

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

Supervision

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Control Strategy Development of a Variable Loudspeaker Enclosure for Minimal-Power Consumption During Active Noise Cancellation in Industrial Duct Systems

Program : EM - Aeronautics - M-IREMR-A

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.

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

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Co-supervisor: Jarl Beckers

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Parameter study for laser ablation of metal 3D-printed surfaces for patterning and roughness reduction.

Program : EM - Aeronautics - M-IREMR-A

Description

Context of the master thesis:
Metal 3D-printing or Additive Manufacturing (AM) of metallic structures is an emerging technology for making solid 3D object from a digital file. The design, fabrication, distribution of products and the use of components made with AM techniques are low carbon consuming and highly efficient in their use of virgin material [1]. Airbus and other aerospace companies have denoted AM as a game changing technology for 21 century. An article by The Economist [2] details "The third industrial revolution". Additive manufacturing is highlighted as the production technology of the future, enabling mass customization instead of mass production. One of the remaining key challenges is to eliminate and control the roughness level in the produced parts. The reduction of the roughness level is a crucial element to support the application of AM components in the aeronautical industry for critical applications. The objective of the thesis is to study the different parameter sets of a nano-second pulsed laser system available at the Additive Manufacturing Research Lab (AMRL) at the VUB. The tasks listed below are for information and depending on the student interest can be adapted. For more information don't hesitate to contact the contact person below.

Tasks:

- Literature study of surface roughness reduction and laser patterning with nano-second lasers.
- Definition of evaluation framework of the parameter study.
- Definition of parameter sets to be evaluated.
- Development of an experimental set-up
- Performance of experimental study with developed experimental set-up.

See also external link

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

Supervision

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Reduction of large plasma-assisted combustion simulations using principal component analysis and machine-learning techniques

Program : EM - Aeronautics - M-IREMR-A

Description

New technological challenges in combustion science require reliable ignition and flame stabilization in demanding conditions. Some examples are ultra-lean combustion, fuel flexibility (using alternative, low-carbon fuels), supersonic combustion (scramjets), and the active control of thermo-acoustic instabilities. Non-thermal plasma discharges have been proposed as an innovative solution to ensure efficient and stable operation in these particular regimes. Nanosecond discharges are introduced to obtain a more favourable ignition of reactive mixtures, where conventional methods fail. However, an in-depth knowledge of the effects of nonequilibrium plasma on the initiation and stability of these challenging combustion processes is still lacking in the field. The current literature on the subject is incomplete and mostly experimental. The modelling and numerical simulation of plasma discharges and their influence on combustion therefore remains a critical need to understand and support experiments working towards the development of the next combustion technologies.

The numerical simulation of plasma-assisted combustion (PAC) problems remains a key challenge in the community because of (1) the multi-scale nature of the flow: plasma chemistry occurs at the nanosecond time scale and combustion at millisecond scales; (2) non-equilibrium effects: combustion chemistry and transport are coupled with detailed plasma chemistry in nonequilibrium thermodynamics; and (3) the large dimensionality of the mechanisms: hundreds of species are coupled tightly in large and stiff kinetic mechanisms.

Principal Component Analysis (PCA) has been used in previous work to reduce large kinetic mechanisms. The goal is to couple local PCA methods with machine-learning regression techniques in order to optimally reduce the kinetic mechanism.

The candidate should have coding knowledge (python/fortran/matlab) and have an interest in CFD for reacting flows (combustion physics / plasma flows).

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

Supervision

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Integration of Internal Capillaries in Hybrid Directed Energy Deposition parts: Impact on Microstructure and Corrosion Behaviour

*_Program : EM - Aeronautics - M-IREMR-A_*

Description

3D printing is a widely used additive manufacturing process in which layers of material are successively deposited to create a three-dimensional part. Over the past decade, it has gained significant interest due to increased accessibility and technological advancements.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) technique that uses a focused laser beam to melt metallic powder, which is simultaneously delivered through a nozzle. The Additive Manufacturing Research Lab (AM-Lab) at the Vrije Universiteit Brussel (VUB) has developed an in-house hybrid DED machine called the MiCLAD, which is extensively presented in [2].

The MiCLAD system is equipped with a 5-axis CNC controller and allows for a rapid transition between additive deposition (DED) and subtractive machining (milling/drilling). This combination of processes is referred to as hybrid manufacturing. An in-situ image of the DED process is shown in Fig. 1, where the nozzle, powder particles, and melt pool (visible as a high-intensity spot) can be observed. Fig. 2 illustrates a hybrid 3D tower manufactured using the MiCLAD system, combining additive and subtractive operations to directly integrate functional features into the part, such as internal capillaries (see red vertical arrow). These capillaries can serve as cooling channels or for Structural Health Monitoring of the part. The milling operations are indicated by the red dashed lines.

The subtractive process is further illustrated in Fig. 3 (drilling) and Fig. 4 (milling). During hybrid manufacturing, the process parameters and thermal history play a critical role in determining the final part quality, as they directly influence the microstructure, residual stresses, corrosion behaviour, and mechanical properties.

An Electron Backscatter Diffraction (EBSD) map is shown in Fig. 5, highlighting a clear effect of the milling operation on grain size and crystallographic orientation. These microstructural modifications are expected to significantly affect the corrosion behaviour of the material and therefore require detailed investigation. In particular, the drilling operations required to integrate capillaries are also expected to alter the local microstructure and may influence corrosion performance.

It is therefore essential to fully understand the effect of subtractive drilling operations on the microstructure. The SURF [3] and MECH [4] departments at VUB are collaborating closely to investigate these effects.

To evaluate the influence of hybrid manufacturing with integrated capillaries on corrosion resistance, a dedicated experimental campaign will be carried out using the MiCLAD system. Melt pool temperatures will be monitored during fabrication. Samples with embedded capillaries produced via hybrid DED (additive + drilling) will be compared to purely additively manufactured samples.

The corrosion behaviour will be assessed using standard electrochemical and surface analysis techniques, including potentiodynamic polarization and immersion tests to evaluate the electrochemical response of the samples, as well as XPS and SEM/EDS to analyze the impact of the processing condition on the microstructure and passive oxide layer of the material. These analyses will help establish correlations between process conditions, melt-pool temperature, resulting microstructures, and corrosion performance.

The main objective of this master thesis is to design and conduct a hybrid experimental campaign using the MiCLAD system to manufacture samples with embedded capillaries suitable for corrosion analysis, and to compare their corrosion resistance with that of conventionally additively manufactured samples.

Upon successful completion of the master thesis, the continuation in a PhD position is a possibility to be evaluated.

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

Supervision

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Processing and characterization of a 316L to CuCr1Zr functionally graded additive materials

Program : EM - Aeronautics - M-IREMR-A

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.

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

Supervision

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Measurement, modelling and compensation of a modulated high power fiber laser for metal 3D-print applications

Program : EM - Aeronautics - M-IREMR-A

Description

Context of the master thesis:
Additive manufacturing (AM), particularly selective laser melting, and directed energy deposition have a significant potential impact on the production of complex parts and components. The ability to create intricate geometries layer by layer offers advantages in various industries, from aerospace to medical devices. Conventionally, continuous-wave lasers have been the workhorses for metal AM, operating at high power levels. However, emerging new fiber laser technologies present an exciting opportunity to enhance the precision and efficiency of this process. Continuous wave lasers have been evaluated with calorimetric measurement solutions. Since calorimetry is based on a thermal process, its time constant is relatively high compared to the time constants associated with lasers. This implies that the calorimeter effectively behaves as a lowpass filter, filtering out any laser dynamics, i.e. only statements concerning the average laser power can be made. The new available thin film sensor technology enables a significant extension of the dynamic range (10 kHz) without jeopardizing laser damage resistance property. Two dynamic laser effects are distinguished in literature viz. 'steady state power variation' and 'switching behaviour'. Continuous lasers, while effective, lack the fine-grained control necessary for intricate AM processes. The modulated laser is a dynamic light source that allows precise modulation of output power. By adjusting the amplitude, duty cycle and/or the modulation frequency, we can tailor the energy deposition during the AM. The aim of the master's thesis is to measure, model and compensate for the dynamic behaviour of a modulated laser source. More specifically you will:

Tasks:
- Use a modulated laser system and optimized input excitations signals to characterize its behaviour using advanced laser power and PXI measurement equipment. Here it is key to accurately measure the dynamic behaviour of the laser, including power fluctuations, modulation frequency, and other relevant parameters during AM experiments.
- Apply system identification tools to model the laser's dynamic response to the modulation input.
- Develop a compensation algorithm based on the earlier retrieved model to compensate for the dynamic behaviour of the laser.

Don't hesitate to reach out to us if you want more information!

See also external link

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

Supervision

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Machine-learning prediction of flow properties for space vehicles during atmospheric reentry

*_Program : EM - Aeronautics - M-IREMR-A_*

Description

In the present research project, machine-learning methods will be explored to accurately predict the thermodynamic and transport properties of carbon-phenolic mixtures for atmospheric re-entry applications. The objective is to develop a reliable methodology to calculate the properties of new ablative materials or mixtures for which the physical properties are not reported in the current literature. When spacecraft re-enter the atmosphere, small particles originating from the ablative heat shield are injected in the plasma flow developed in front of the vehicle. These ablation species change the thermodynamic and transport properties of the mixture and contribute to the total heat flux developed during the re-entry phase. However, the calculation of these properties is a burdensome task as it involves computations at a molecular level for each collision pair.

In the current research project, we will develop a machine-learning framework to bypass these complex computations and offer a fast prediction of the missing properties. The strategy is based on the training of an artificial neural network (ANN) using physical data of ablation mixtures that are well known in the community. Some examples are the ablation of carbon-phenolic shields made out of new materials (carbon grid with phenolic resin) developed by NASA and ESA.

The first part of the project is centered around the training of the neural network to predict documented properties. Once the methodology is verified and validated, we will use the machine-learning framework to predict the properties of new materials. For instance, we will predict the properties for cork, which is used for the protection of CubeSats during re-entry.

This project builds on a previous master thesis project and is in collaboration with the aeronautics and aerospace department at the von Karman Institute for Fluid Dynamics (Prof. Thierry Magin).

The candidate should have an interest in reacting flows (chemistry, plasma flows, combustion) and comfortable with programming (python / matlab).

Contact: Prof. Aurélie Bellemans (aurelie.bellemans@vub.be)

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

Supervision

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Development of a MIMO closed-loop controller for 316L/CuCr1Zr functionally graded additive materials

Program : EM - Aeronautics - M-IREMR-A

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.

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

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Design, Construction, and Testing of a Solid Rocket Motor for the CanSat Launcher (Be-Rocket)

*_Program : EM - Aeronautics - M-IREMR-A_*

Description

The CanSat launcher is the most important ongoing project of Be-Rocket. Currently, a solid rocket motor by Cesaroni is being used. However, due to a recent fire in one of Cesaroni's facilities, it is impossible to acquire new motors. Finding other suitable options has proven to be exceptionally difficult. It would therefore be highly benificial for Be-Rocket to have the capacitity of producing its own solid rocket motors. This Master's thesis would therefore consist of designing, building, testing and - if time permits - qualifying a solid rocket motor based on the one by Cesaroni that is currently used. The requirements for the motor are precisely determined by the CanSat launcher of Be-Rocket. The dry mass of the rocket and the desired apogee are known. As part of the thesis, clear instructions should be written to allow RMA-students who are a member of Be-Rocket to keep producing the engine, therefore guaranteeing a continued and independent provision to the required sold rocket motor for the team.
Please contact Riccardo Gelain (riccardo.gelain@mil.be) or Mariano Di Matteo (Mariano.DiMatteo@mil.be) for more information. This master thesis is in collaboration with the Royal Military Academy and ULB.

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

Supervision

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Unraveling the effect of geometry on crack kinking under mode I loading using biaxial testing

Program : EM - Aeronautics - M-IREMR-A

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.

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

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

Supervision

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Effects of Passive Attenuation Devices on the Requirements of an Active Noise Cancellation Loudspeaker in Industrial Duct Systems

Program : EM - Aeronautics - M-IREMR-A

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.

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

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Development of a ML-based controller for 316L/CuCr1Zr functionally graded additive materials

*_Program : EM - Aeronautics - M-IREMR-A_*

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.

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

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Numerical study for thermal gradient reduction during 3D printing Directed Energy Deposition process.

Program : EM - Aeronautics - M-IREMR-A

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.

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

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

Supervision

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Feasibility study of Probability of Dectection for new Structural health monitoring solutions of 3D printed aeronautical structures.

Program : EM - Aeronautics - M-IREMR-A

Description

Context of the master thesis:
Structural health monitoring (SHM) is an emerging technology for continuously monitoring of the structural integrity of the structural system. SHM has a high added value potential for different industries. A new innovative crack detection SHM system has been developed within the acoustics and vibration research group. The technological readiness level of the new SHM system can be extended if the Probability of Detection (PoD) is clarified. A PoD allows the user to verify the likelihood of detecting cracks with a certain length by the SHM system. The main objective for the Master thesis student would be to investigate the feasibility and applicability of the PoD concept for the developed SHM system in numerically or experimentally manner.

Tasks:

- Literature study of existing SHM and NDT (Non Destructive Testing) system for aeronautical structures and additive manufacturing.
- Literature study of Probability of Detection (PoD) for SHM and NDT operational systems.
- Definition of potential approaches.
- Development of experimental setup or/and numerical simulation in order to verify working principles.
- Selection of potential PoD approach.
- Implementation of an initial verification tests or/and numerical simulation procedure to generated data to support a PoD.
- Conclusion on the feasibility of the PoD approach for the new SHM concept.

If time permits the research can be extended to 3D printed aeronautical structures. Further details regarding the concepts can be provided by the contact person on request.

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

Supervision

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Thermo-mechanical simulation of milling process on 3D printed metal parts.

Program : EM - Aeronautics - M-IREMR-A

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.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRMAE, M-IRIFS, M-IRELE, M-IREMR-A, M-IREMR-E, M-IREMR-M, M-IREMR-O

Number of topics	1

Supervision

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Development of aeronautical demonstrator 3D printed component with integrated Structural health monitoring solution.

Program : EM - Aeronautics - M-IREMR-A

Description

Context of the master thesis:
Structural health monitoring (SHM) is an emerging technology for continuous monitoring of the structural integrity of the structural components. They can unleash the full potential of 3D printed (additive manufactured AM) components and in the long run improve our carbon footprint. The technological readiness (TRL) level of an in house developed SHM system can be further increased by proving its applicability also on a demonstrator level besides the current available coupon level results. The main objective for the Master thesis student would be to investigate and develop new designs with integrated SHM technology of typical mechanical system such as lug bolt configurations. The objective is to prove numerically and if time permits also experimentally the increase of the TRL level.
Tasks:

- Literature study of additive manufacturing and topological optimization.
- Manual redesign of the component exploiting the design freedom offered by AM with integrated SHM solution.
- Static hand calculations in conjunction with Finite Element Analysis of manually optimized design solutions.
- Static Finite Element Analysis of topology optimized design solutions.
- Crack growth analysis at one specific location on the component.
- Analysis of the performance of a structure with an without integrated SHM solution.
- Conclusion on the increase in TRL level.

If time permits the research can be extended with printing of the component and experimental testing. Further details regarding the concepts can be provided by the contact person on request.

See also external link

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

Supervision

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Thermo-mechanical simulation of ablation process on 3D printed metal parts.

Program : EM - Aeronautics - M-IREMR-A

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.

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

Supervision

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Temperature estimation methods study for metal 3D-printing.

Program : EM - Aeronautics - M-IREMR-A

Description

Context of the master thesis:
Metal 3D-printing or Additive Manufacturing (AM) of metallic structures is an emerging technology for making solid 3D object from a digital file. The design, fabrication, distribution of products and the use of components made with AM techniques are low carbon consuming and highly efficient in their use of virgin material [1]. Airbus and other aerospace companies have denoted AM as a game changing technology for 21 century. An article by The Economist [2] details "The third industrial revolution". Additive manufacturing is highlighted as the production technology of the future, enabling mass customization instead of mass production. To obtain good quality manufactured parts in AM, temperature control of the printing process is required. Therefore, one of key challenges resides on the temperature estimation method. The objective of the master thesis is to get acquainted with different temperature estimation methods, identify the advantages and disadvantages of each method, and define what methods are suitable for monitoring the AM process.

Tasks:
- Literature review of different temperature estimation methods
- Understanding of hyperspectral cameras
- Development of temperature estimation algorithms
- Temperature estimation methods assessment

See also external link

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

Supervision

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Development and test of an in-situ monitoring framework for wire-based Directed Energy Deposition

Program : EM - Aeronautics - M-IREMR-A

Description

This master thesis focuses on the implementation of a synchronized in-situ monitoring framework for the LW-DED system at VUB AMRL, the generation of a multi-modal dataset through a structured experimental campaign, and its preliminary analysis using unsupervised learning techniques. The objective is to establish a foundation for future intelligent monitoring and control strategies, ultimately improving process reliability and part quality.

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

Supervision

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Development of manufacturing strategies for functionally Graded Additively Manufactured Parts

Program : EM - Aeronautics - M-IREMR-A

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).

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

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A passive bi-directional overrunning clutch for compliant actuation

Program : EM - Aeronautics - M-IREMR-A

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, ...).

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

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Modelling atmospheric mass deposition from space debris re-entry

Program : EM - Aeronautics - M-IREMR-A

Description

This master thesis aims to develop a simplified yet robust modelling framework to quantify the contribution of space debris re-entry to atmospheric mass deposition, focusing on a bottom-up approach from single-object physics to global annual estimates. The student will first model the aerothermal ablation of a single spherical debris object composed of one representative material (e.g., aluminum), deriving altitude-resolved mass loss and emission profiles during atmospheric entry using simplified heat transfer and ablation laws. Based on this single-object analysis, the work will then scale up to annual global estimates by compiling and critically assessing literature data on debris re-entry frequency and mass distributions, allowing the derivation of total yearly injected mass and its vertical distribution in the atmosphere. The objective is to produce a first-order model of mass deposition as a function of altitude, suitable for integration into atmospheric simulations. In a second phase, the results will be prepared for coupling with atmospheric chemistry and transport models, in collaboration with prof. Irene Dedoussi (Cambridge), to assess the impact of such emissions at different atmospheric layers. The project sits at the interface between aerospace engineering and atmospheric science and will provide a scalable methodology to estimate the growing anthropogenic contribution of space debris to the upper atmosphere, addressing an emerging gap in current literature.

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

Supervision

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Characterization of the liner/composite overwrap interface in type IV hydrogen storage vessels

*_Program : EM - Aeronautics - M-IREMR-A_*

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
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[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.

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

Supervision

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Ultrasonic welding of thermoplastics and thermoplastic composites-Parametric study and optimization

Program : EM - Aeronautics - M-IREMR-A

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.

Language	EN (english)
Open to other master's programs	Yes
Eligible master's programs	M-IRMAE, M-IREMR-E, M-IREMR-M, M-IREMR-O

Number of topics	1

Supervision

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Metallurgical, mechanical & corrosion characterization of ultrasonic assisted additively manufactured 316L

Program : EM - Aeronautics - M-IREMR-A

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.

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

Supervision

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Process parameter optimization for 3D printing of single alloy rocket nozzle through Directed Energy Deposition process.

Program : EM - Aeronautics - M-IREMR-A

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.

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

Supervision

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Novel Indicators for Detecting Structural Changes During Vibration Testing of Satellites During Qualification Tests

Program : EM - Aeronautics - M-IREMR-A

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.

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

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Numerical Optimization of the Bossart II rocket and future successors

Program : EM - Aeronautics - M-IREMR-A

Description

The goal of this thesis is to further develop the numerical optimization work previously performed on the Bossart-II rocket configuration. The aim is to create a more automated framework to evaluate the aerodynamic performance of the rocket, focusing on drag coefficient (Cd) and stability margin (SM), while identifying design configurations that improve the overall flight performance. This can be achieved using computational tools such as Ansys Fluent, OpenFOAM, Star-CCM+ or a similar simulation software.
The student will extend the existing CFD workflow by introducing automated mesh generation and a Python-based optimization loop. This framework will allow the evaluation of multiple geometric configurations, such as variations in fin geometry or other aerodynamic features, in order to identify configurations that provide favorable trade-offs between drag and stability. The automation of the CFD setup is intended to make the process reproducible and scalable for future rocket designs.
In addition to the aerodynamic optimization, the student will integrate a simplified trajectory simulation to evaluate the effect of design changes on the predicted apogee. This will allow the optimization process to assess not only aerodynamic performance metrics but also the impact of these changes on the overall flight profile.
As this work is part of an actively running BE-Rocket project, the student is expected to collaborate with the aerodynamics sub-team and integrate the developed tools into the design workflow of the team. The outcome of this thesis should be a reusable optimization framework that can support the design of the current rocket as well as larger future rocket configurations.

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

Supervision

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Topics offered to students by other master's programs

TARGET PROGRAM

EM - AERO engineering

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

Investigation of the Micro-Profiling Effect on the Mechanical Behaviour of Thin Steel Sheeting

Description

Cold-formed steel sheeting is widely used in lightweight construction systems such as roofs, floors, and composite decks. In addition to the primary corrugation geometry that provides global bending stiffness, manufacturers increasingly introduce micro-profiling (small-scale surface indentations or ribs) in the flanges of the sheeting (Figure 1). These micro-profiles are intended to improve local stability (delay local buckling), and increase stiffness without significantly increasing material usage [1,2]. Composite slabs are outside the scope of this thesis; consequently, indentations related to composite action are not considered.

Two representative industrial products illustrate this concept:

Figure 1: JI 106-250-750 (Joris Ide) left and – T130M-75L-930 (Ruukki) (right) featuring light micro-profiling on the top flange, and on both top and bottom flanges, respectively.

While the global structural behaviour of profiled steel sheeting is well documented, the mechanical contribution of micro-profiling remains insufficiently quantified. Initiation and development of local buckling modes in the compressed flanges under bending loading will be studied in this thesis at the small scale.

This thesis is embedded in a broader research framework studying acoustic roof decking as sustainable and environmental friendly solution with light weight and low end-of-life impacts.

In this thesis, detailed FE models of micro-profiled, small-scale panels will be developed and used for a parametric study allowing a direct comparison between micro-profiling effects for different micro-profile geometries. To ensure reliability, the developed numerical models will be experimentally validated through compression tests on small-scale panels incorporating micro-profiling.

Research Objectives

To quantify and understand the mechanical influence of micro-profiling on thin cold-formed steel sheeting through validated finite element modelling.

1

Geometrical Characterisation and Performance

o

Digitally reconstruct representative micro-profiling geometries of selected sheeting types.

o

Develop parametrised small-scale panel models incorporating realistic micro-profile details. Systematically vary:

▪

Depth,

▪

Spacing,

▪

Shape,…

o

Quantify using finite element modelling the influence on:

▪

Bending stiffness,

▪

Elastic buckling resistance,

▪

Load redistribution mechanisms.

2

Experimental Validation

Manufacture or obtain small-scale micro-profiled panels.

Conduct controlled compression tests.

Measure:

Load–displacement response,

Buckling modes,

Strain development.

3

Validation

Calibrate and validate FE models against experimental results.

Summarize insights.

References

[1] R. Studziński, Z. Pozorski, A. Garstecki (2015). Structural behavior of sandwich panels with asymmetrical boundary conditions. Journal of Constructional Steel Research 104: 227–234

[2] X. Ma, J.W. Butterworth, G.C. Clifton (2008). Unilateral contact buckling of lightly profiled skin sheets under compressive or shearing loads. International Journal of Solids and Structures, 45: 840–849

Objectives of the master thesis

This research is expected to:

- Give a well-structured comprehensive overview of the state of the art.
- Provide a mechanistic understanding of how micro-profiling modifies elastic stress fields in thin steel sheeting.
- Establish validated finite element modelling strategies for small-scale micro-structured panels.
- Clarify the relative structural efficiency of micro-profiling compared to flat panels.
- Deliver quantitative design-oriented insights for manufacturers aiming to optimise sheet geometry without increasing material thickness.

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

Supervision

Supervisor : Pyl Lincy (Lincy.Pyl@vub.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

Investigation of thermal fields during the manufacturing of 3D printed composites

Description

Context of the master thesis

3D printed composites combine the flexibility of additive manufacturing with the improved mechanical properties of composite materials. An important aspect of the printing process is the thermal field that develops during material deposition, as it directly affects interlayer bonding, residual stresses, and defect formation. Quantifying these thermal fields allows better control of printing parameters and leads to improved print quality and structural performance. A clear understanding of the thermal behavior during printing is therefore essential for improving the reliability of 3D-printed composite components1.

The master's student will employ infrared cameras during the printing of simple structures to capture thermal fields and use them to perform finite element analysis (FEA). This approach facilitates learning the intricacies of the 3D printing process, camera setup, and subsequent data post-processing along with the basics of FEA. The post processing will be achieved in Python using image processing techniques and the FEA in the ABAQUS software. Through this master thesis, the student will gain a holistic understanding of: additive manufacturing (printing process), thermal mechanics (influence of thermal fields), and FEA, equipping them with valuable skills for future endeavors in technology and engineering fields.

Fig. 1 Thermal image during printing.

References

1)

Cattenone, A., Morganti, S., Alaimo, G., & Auricchio, F. (2019). Finite element analysis of additive manufacturing based on fused deposition modeling: Distortions prediction and comparison with experimental data. Journal of Manufacturing Science and Engineering, 141(1), 011010.

Objectives of the master thesis

•

Measure transient thermal fields during the 3D-printing process using infrared cameras.

•

Process infrared data using Python-based image processing techniques.

•

Analyze the influence of printing parameters on the evolution of thermal fields.

•

Implement simplified thermal finite element models in Abaqus using experimentally obtained data.

•

Assess the implications of thermal fields on the printing process.

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

Supervision

Supervisor : Pyl Lincy (Lincy.Pyl@vub.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

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

Investigation of Microstructural Evolution and Corrosion Resistance in Hybrid DED-Manufactured Parts

Description

3D printing is a widely used additive manufacturing process in which layers of material are successively deposited to create a three-dimensional part. Over the past decade, it has gained significant interest due to increased accessibility and technological advancements.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) technique that uses a focused laser beam to melt metallic powder, which is simultaneously delivered through a nozzle. The Additive Manufacturing Research Lab (AM-Lab) at the Vrije Universiteit Brussel (VUB) has developed an in-house hybrid DED machine called the MiCLAD, which is extensively presented in [2].

The MiCLAD system is equipped with a 5-axis CNC controller and allows for a rapid transition between additive deposition (DED) and subtractive machining (milling/drilling). This combination of processes is referred to as hybrid manufacturing. An in-situ image of the DED process is shown in Fig. 1, where the nozzle, powder particles, and melt pool (visible as a high-intensity spot) can be observed. Fig. 2 illustrates a hybrid 3D tower manufactured using the MiCLAD system, combining additive and subtractive operations to directly integrate functional features into the part. The milling operations are indicated by the red dashed lines.

The subtractive process is further illustrated in Fig. 3 (cogwheel) and Fig. 4 (research sample). During hybrid manufacturing, the process parameters and thermal history play a critical role in determining the final part quality, as they directly influence the microstructure, residual stresses, corrosion behaviour, and mechanical properties.

An Electron Backscatter Diffraction (EBSD) map is shown in Fig. 5, highlighting a clear effect of the milling operation on grain size and crystallographic orientation. These microstructural modifications are expected to significantly affect the corrosion behaviour of the material and therefore require detailed investigation.

It is therefore essential to understand the combined effect of additive and subtractive operations on the microstructure and to monitor the melt pool temperature during processing. The SURF [3] and MECH [4] departments at VUB are collaborating closely to investigate these effects.

To evaluate the influence of hybrid manufacturing on corrosion resistance, a dedicated experimental campaign will be carried out on the MiCLAD machine, and the melt-pool temperatures during manufacturing will be measured. Samples produced via hybrid DED (additive + milling) will be compared to purely additive-manufactured samples.

The corrosion behaviour will be assessed using standard electrochemical and surface analysis techniques, including potentiodynamic polarization and immersion tests to evaluate the electrochemical response of the samples, as well as XPS and SEM/EDS to analyze the impact of the processing condition on the microstructure and passive oxide layer of the material. These analyses will help establish correlations between process conditions, melt-pool temperature, resulting microstructures, and corrosion performance.

The final objective of this master thesis is to design and conduct a hybrid experimental campaign using the MiCLAD system to manufacture samples suitable for corrosion analysis, and to compare their corrosion resistance with that of conventionally additively manufactured samples.

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-IREMR-A
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

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

Integration of Internal Capillaries in Hybrid Directed Energy Deposition parts: Impact on Microstructure and Corrosion Behaviour

Description

3D printing is a widely used additive manufacturing process in which layers of material are successively deposited to create a three-dimensional part. Over the past decade, it has gained significant interest due to increased accessibility and technological advancements.

Directed Energy Deposition (DED) [1] is a metal additive manufacturing (AM) technique that uses a focused laser beam to melt metallic powder, which is simultaneously delivered through a nozzle. The Additive Manufacturing Research Lab (AM-Lab) at the Vrije Universiteit Brussel (VUB) has developed an in-house hybrid DED machine called the MiCLAD, which is extensively presented in [2].

The MiCLAD system is equipped with a 5-axis CNC controller and allows for a rapid transition between additive deposition (DED) and subtractive machining (milling/drilling). This combination of processes is referred to as hybrid manufacturing. An in-situ image of the DED process is shown in Fig. 1, where the nozzle, powder particles, and melt pool (visible as a high-intensity spot) can be observed. Fig. 2 illustrates a hybrid 3D tower manufactured using the MiCLAD system, combining additive and subtractive operations to directly integrate functional features into the part, such as internal capillaries (see red vertical arrow). These capillaries can serve as cooling channels or for Structural Health Monitoring of the part. The milling operations are indicated by the red dashed lines.

The subtractive process is further illustrated in Fig. 3 (drilling) and Fig. 4 (milling). During hybrid manufacturing, the process parameters and thermal history play a critical role in determining the final part quality, as they directly influence the microstructure, residual stresses, corrosion behaviour, and mechanical properties.

An Electron Backscatter Diffraction (EBSD) map is shown in Fig. 5, highlighting a clear effect of the milling operation on grain size and crystallographic orientation. These microstructural modifications are expected to significantly affect the corrosion behaviour of the material and therefore require detailed investigation. In particular, the drilling operations required to integrate capillaries are also expected to alter the local microstructure and may influence corrosion performance.

It is therefore essential to fully understand the effect of subtractive drilling operations on the microstructure. The SURF [3] and MECH [4] departments at VUB are collaborating closely to investigate these effects.

To evaluate the influence of hybrid manufacturing with integrated capillaries on corrosion resistance, a dedicated experimental campaign will be carried out using the MiCLAD system. Melt pool temperatures will be monitored during fabrication. Samples with embedded capillaries produced via hybrid DED (additive + drilling) will be compared to purely additively manufactured samples.

The corrosion behaviour will be assessed using standard electrochemical and surface analysis techniques, including potentiodynamic polarization and immersion tests to evaluate the electrochemical response of the samples, as well as XPS and SEM/EDS to analyze the impact of the processing condition on the microstructure and passive oxide layer of the material. These analyses will help establish correlations between process conditions, melt-pool temperature, resulting microstructures, and corrosion performance.

The main objective of this master thesis is to design and conduct a hybrid experimental campaign using the MiCLAD system to manufacture samples with embedded capillaries suitable for corrosion analysis, and to compare their corrosion resistance with that of conventionally additively manufactured samples.

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-IREMR-A
Nombre de sujets	1

Supervision

Supervisor : Jardon Zoé (zoe.jardon@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

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

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

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

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

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

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

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

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 - Robotics & mechatronics constructions - M-IREMR-M

Implementation of a controller for a lower-limb exoskeleton

Description

Context

Age-related mobility impairment is a major challenge for older adults and is strongly associated with reductions in muscle mass and muscle quality. Lower limb exoskeletons have been proposed as a promising strategy to help this population. They can serve as rehabilitation tools that facilitate repetitive, task-specific training and promote muscle strengthening. On the other hand, when used as assistive devices, exoskeletons may enable older adults with mobility impairments to remain physically active in daily life. One of the major challenges in exoskeletons is providing the correct amount of assistance throughout the different activities of daily life. The exoskeleton should be aware of the activity the user is performing (e.g. walking, stair ascent/descent), but also understand when and how much to provide assistance withing this specific activity. Many methods exist for controlling these devices, but each have different drawbacks that should be considered.

Objective

In this thesis the student will develop a controller for a lower-limb exoskeleton (hip-knee). Two control strategies are proposed, but the student can also choose to come up with their own control strategy.

Methods

The student can choose from one of following implementations of a controller:

- Previous work in the lab implemented an AFO algorithm that can synchronize to the joints’ trajectories for different tasks of daily living. Furthermore, when switching to a new activity of daily living, we can determine the phase shift of this AFO to predict the next activity of living. The student will integrate the found AFO algorithms into a lower-limb exoskeleton and validate whether the algorithm works in real-life scenario. This real-life scenario will introduce new difficulties such as noise and slight changes in gait. Furthermore, an important part of this work will be to adjust this algorithm to be generalizable for different individuals. The student will therefore have to come up with solutions for occurring problems due to the transfer from simulation to a real-life exoskeleton.

- you will build a neuromuscular controller and tune its parameters based on earlier recorded Muscular Voluntary Contractions (MVC's) of older adults. Neuromuscular controllers are based on formulations of a set of muscles using the Hill-type muscle model. These Hill-type muscles will receive kinematic data (i.e. joint angles) and output a specific joint torque. To link these joint angles to output torques, muscle reflexes are used. However, this tuning of the reflexes is done manually and takes a long time for each individual. We believe that by having MVC data, we can adjust the muscle properties used in this controller in a more guided approach and as such improve its tuning process and therefore the performance of the controller. To understand how these MVCs can be used for this tuning, biomechanical models can be used. In these models, an optimization between simulated joint torques and measured joint torques can be performed for different kinematic conditions to find muscle parameters for older adults.
- A control strategy proposed by the student with guidance of the supervisor(s)

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IREMR-A
Nombre de sujets	3

Supervision

Supervisor : Verstraten Tom (Tom.verstraten@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/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_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

Optimized topologies of an actuator and arm for a humanoid robot

Description

Humanoid robots could revolutionize many sectors, but their progress is limited by the challenge of designing compact, efficient, and powerful joint actuators.
This project aims to develop an optimized humanoid arm and actuator topology that improves performance, range of motion, and weight efficiency.
It involves comparing existing designs and creating a CAD model of an improved solution, ideal for students interested in mechanical design and robotics.

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

Supervision

Supervisor : LOPEZ GARCIA PABLO (plopezga@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive Dynamic Safety Margin Design for Force-Regulated Explicit Reference Governors

Description

This thesis investigates the design of adaptive safety margins for Explicit Reference Governors (ERG) applied to robotic manipulators operating under external forces and contact constraints.

Explicit Reference Governors ensure constraint satisfaction by predicting future system behavior and evaluating a Dynamic Safety Margin (DSM) that quantifies the distance to constraint violation. In current implementations, safety margins are typically defined using fixed worst-case bounds on modeling uncertainty and force-estimation errors. While this guarantees safety, it often leads to conservative robot behavior and reduced performance.

The objective of this thesis is to develop an adaptive tightening mechanism that adjusts the safety margin online based on measurable uncertainty indicators such as force-estimation residuals, prediction error, or disturbance dynamics. The proposed method will be integrated into an existing force-regulated ERG framework for robotic manipulators.

The student will:

Analyze the baseline ERG and DSM formulation
Design an adaptive uncertainty bound for force and motion prediction
Integrate the adaptive margin into the ERG safety mechanism
Validate the approach through simulation and experimental evaluation
Compare performance against fixed-bound safety margins

The expected outcome is a safer and less conservative ERG controller capable of maintaining constraint satisfaction while improving responsiveness and task efficiency.

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

Nombre de sujets	1

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Expansion of gearbox test bench for NVH testing

Description

Human-centered robots like humanoids and cobots require not only efficient actuators but also low noise and vibration for user comfort and acceptance.
This project expands a VUB gearbox test bench, in collaboration with AILOS, to include Noise, Vibration, and Harshness (NVH) analysis using specialized sensors and data processing methods.
The goal is to evaluate and compare gearbox performance and acoustic behavior, ensuring quieter and smoother operation for robotic applications.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IRELE, M-IREMR-A, M-IREMR-E
Nombre de sujets	2

Supervision

Supervisor : LOPEZ GARCIA PABLO (plopezga@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Commissioning of a robotics actuator for a humanoid robot

Description

Humanoid robots can transform sectors like healthcare and manufacturing, but their deployment is limited by the challenge of designing compact, powerful, and safe joint actuators.
This project focuses on integrating and testing an actuator for a humanoid arm using existing components, with evaluation based on torque, efficiency, and controllability under realistic conditions.
The goal is to build a functional, well-characterized actuator, suited for students interested in robotics, control systems, and mechanical design.

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

Supervision

Supervisor : LOPEZ GARCIA PABLO (plopezga@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Comparative study of physics-enhanced graph neural network approaches for multiple degrees-of-freedom system response estimation

Description

- Context of the master thesis

Wind turbines are the biggest dynamic, mass-produced, man-made structures. Their structural response to environmental and operational variations is highly complex and non-linear. As such, both physical modelling and data-driven inference have difficulties in accurately estimating the response. The former require simplifications which, along with unknown quantities (e.g. blade geometry), undermine accuracy. The latter may achieve high performance, but are limited to their training space, and extrapolation isn’t trustworthy. This is also the case for virtual sensing, where limited instrumentation limits the ability to capture the full dynamics of the system, leading to uncertain predictions at unsensed locations, especially outside observed operational conditions.

In this context, physics-enhanced or hybrid modelling has come to the foreground. The philosophy behind it is straightforward: data-driven algorithms have problem-specific physical knowledge embedded into their architectures (loss function, differentiable equations, etc.) which improve generalization and performance. In this thesis, a comparative study of different approaches into embedding physical knowledge into a data-driven algorithm will be research by analyzing performance over multiple degrees-of-freedom systems (MDOF). These (MDOF), represent idealized reductions of real-world structures (e.g. wind turbines, bridges, etc.) and are extremely convenient, as they have low computational costs and their parametrization enables varied response simulation. The baseline algorithm will be a graph neural network.

- References

§ Haywood-Alexander, Marcus, et al. "Discussing the spectrum of physics-enhanced machine learning: a survey on structural mechanics applications." Data-Centric

Engineering 5 (2024): e30.
§ Cicirello, Alice. "Physics-Enhanced Machine Learning: a position paper for dynamical systems investigations." Journal of Physics: Conference Series. Vol. 2909. No. 1. IOP Publishing, 2024.
§ Mehrjoo, Azin, Eleonora M. Tronci, and Babak Moaveni. "A Physics-Informed Framework for Input Load Estimation in Offshore Wind Turbines." International Conference on Experimental Vibration Analysis for Civil Engineering Structures. Cham: Springer Nature Switzerland, 2025.

- Objectives

§ Review virtual sensing in offshore wind turbines.
§ Identify and review physics-enhanced/hybrid modelling approaches.
§ Generate MDOF systems with varying numbers of degrees and exciting load [both intensity and location] in a Python script.
§ Encode MDOF as a graph, including stiffness, damping and mass matrices.
§ Implement a Graph Neural Network (GNN) virtual 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/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRPtg
When interested in one of these 5 topics, please contact bryan.convens@vub.be for more information given during a Microsoft Teams meeting.

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/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_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

Design and Fabrication of an Aerial Manipulation Platform

Description

This project is part of a larger effort to enable aerial-ground cooperative manipulation where drones
and ground robots work together to transport objects. The drone platfrom, a X650 quadrotor
(Figure 1, left), currently lacks a suitable grasping mechanism for transporting items with handles,
such as kettlebells or beams. In prior work, a lightweight passive gripper was designed (Figure 1,
right), capable of mechanically intelligent grasping without active actuation. The next step is to
mount this gripper on the drone via a 2-DoF joint, allowing it to orient the gripper during flight for
successful object handling.

Langue	EN (english)
Ouvert à d’autres masters	Yes
Masters concernés	M-IRELE, M-IREMR-A
Nombre de sujets	2

Supervision

Supervisor : Van de Perre Greet (greet.van.de.perre@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Aerial Robot Collision-Resilient Navigation with Tactile Sensing

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f:/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRPtg
When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

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

Design of new didactic devices for teaching control engineering

Description

Many of the pilot processes used in the SAAS department to teach control theory were developed through master's theses. This is the case for the rotary inverted pendulum, the ring positioner, the ball in the tube process, ...
The aim of this master thesis is to develop new pilot processes that are modular, evolving, and open-source to provide a better and more practical learning experience to the students.
Here are a few examples of processes that SAAS would like to develop (non-exhaustive list):

- Ball in hoop or Flying ball in hoop
  - https://www.youtube.com/watch?v=8FaNk6C2ckM
  - https://www.youtube.com/watch?v=484GN4KBQnc
  - https://github.com/aa4cc/flying-ball-in-hoop
  - https://aa4cc.github.io/flying-ball-in-hoop/
- Cubli - robot that can jump up and balance on its corner
  - https://www.wevolver.com/specs/cubli
- ...

Key objectives:

- selection of the sensors/actuators
- design of the signal conditioning / acquisition stages
- design of the experimental setup (SolidWorks, 3D printer ...)
- design of the power supply & cable management
- modeling of the process
- implementation of a control strategy (Arduino/C programming or Matlab/data-acquisition board or Raspberry PI)
- setup of some didactic experiments & their related teaching materials

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

Nombre de sujets	2

Supervision

Supervisor : Garone Emanuele (emanuele.garone@ulb.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Autonomous Drone Racing Using Only Onboard Sensing and Computation

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f:/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRPtg
When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IREMR-A, M-IREMR-E, M-IREMR-O
Nombre de sujets	3

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Safety-Aware Coordination for Collaborative Multi-Robot Systems using Explicit Reference Governors

Description

Collaborative robotic systems increasingly rely on multiple robots operating in shared workspaces to perform coordinated tasks such as object transfer, cooperative manipulation, and parallel assembly. While high-level planning methods can generate feasible schedules for multiple robots, ensuring safe execution during runtime remains a critical challenge, particularly when robots operate in close proximity.

This thesis investigates the design of a safety-aware coordination mechanism for multi-robot systems using Explicit Reference Governors (ERG). The ERG framework provides a predictive safety layer that adjusts the robot reference in real time to prevent constraint violations. In a multi-robot context, this mechanism can be extended to account for the motion of neighboring robots and maintain safe coordination during task execution.

The objective of this thesis is to develop and evaluate a coordination-aware ERG capable of enforcing safety constraints between multiple robots while preserving task performance. The work will build upon an existing multi-robot task and motion planning framework and focus on the execution-level safety and coordination problem.

The student will:

Study safety and coordination challenges in multi-robot systems
Implement predictive safety constraints between collaborating robots
Design a coordination-aware reference governor
Integrate the method into a multi-robot execution framework
Evaluate safety and performance in representative collaborative scenarios

The expected outcome is a robust safety mechanism for coordinated multi-robot systems that enables reliable execution of parallel tasks in shared environments.

Langue	EN (english)

Ouvert à d’autres masters	Yes
Masters concernés	M-IREMR-A, M-IREMR-E, M-IREMR-M
Nombre de sujets	1

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive Dynamic Safety Margin Design for Force-Regulated Explicit Reference Governors

Description

This thesis investigates the design of adaptive safety margins for Explicit Reference Governors (ERG) applied to robotic manipulators operating under external forces and contact constraints.

Explicit Reference Governors ensure constraint satisfaction by predicting future system behavior and evaluating a Dynamic Safety Margin (DSM) that quantifies the distance to constraint violation. In current implementations, safety margins are typically defined using fixed worst-case bounds on modeling uncertainty and force-estimation errors. While this guarantees safety, it often leads to conservative robot behavior and reduced performance.

The objective of this thesis is to develop an adaptive tightening mechanism that adjusts the safety margin online based on measurable uncertainty indicators such as force-estimation residuals, prediction error, or disturbance dynamics. The proposed method will be integrated into an existing force-regulated ERG framework for robotic manipulators.

The student will:

Analyze the baseline ERG and DSM formulation
Design an adaptive uncertainty bound for force and motion prediction
Integrate the adaptive margin into the ERG safety mechanism
Validate the approach through simulation and experimental evaluation
Compare performance against fixed-bound safety margins

The expected outcome is a safer and less conservative ERG controller capable of maintaining constraint satisfaction while improving responsiveness and task efficiency.

Langue	EN (english)
Ouvert à d’autres masters	Yes
Masters concernés	M-IREMR-A, M-IREMR-E

Nombre de sujets	1

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Design and Construction of a Tactile and Proximity Sensing End-effector for Physical Interaction by Contact with a Drone

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f:/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRPtg
When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

Langue	EN (english)
Ouvert à d'autres masters	Yes
Masters concernés	M-IREMR-A, M-IREMR-E, M-IREMR-O
Nombre de sujets	3

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Design, Fabrication and Experimental Evaluation of an Ultra-Fast Racing Drone

Description

Please find the details of the proposal at https://vub-my.sharepoint.com/:f:/g/personal/bryan_convens_vub_be/IgBI9W0iRlpcTYOq0smzEhdEAQ4rkr6I_fYt8wBzDMGZXZs?e=NJRPtg
When interested, please contact bryan.convens@vub.be to discuss the details during a Microsoft Teams meeting.

Langue	EN (english)
Ouvert à d’autres masters	Yes
Masters concernés	M-IRIFS, M-IREMR-A, M-IREMR-E, M-IREMR-O
Nombre de sujets	3

Supervision

Supervisor : Vanderborght Bram (bram.vanderborght@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Study of a high-transmission ratio compliant actuator for robotics

Description

The project aims to improve a high-efficiency Wolfrom gearbox for robotics by adding compliance to enhance safety in human-centered applications.
You will model the gearbox in Simscape, design a compliant element, and determine its optimal placement, followed by experimental validation.
It requires motivation and hands-on skills in CAD design, manufacturing (3D printing/molding), and mechanical assembly

Langue	EN (english)
Ouvert à d’autres masters	Yes
Masters concernés	M-IRELE, M-IREMR-A, M-IREMR-E
Nombre de sujets	2

Supervision

Supervisor : LOPEZ GARCIA PABLO (pablo@ailos-robotics.com)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Human-Aware Velocity Regulation using Explicit Reference Governors for Safe Human–Robot Interaction

Description

This thesis focuses on the development of a safety-aware control mechanism for robotic manipulators operating in environments shared with humans. According to international human–robot interaction standards, such as ISO 10218 and ISO/TS 15066, robot velocity and impact energy must be limited depending on the proximity to the human body and the specific body region involved.

The objective of this thesis is to design an Explicit Reference Governor (ERG) capable of detecting human presence in the robot workspace and dynamically regulating robot velocity to ensure safe interaction. The governor will enforce velocity limits derived from safety standards while maintaining smooth and predictable robot motion.

The student will:

Study human–robot interaction safety standards and velocity limits
Implement a perception-based human detection mechanism
Define distance-dependent velocity constraints
Integrate these constraints into the ERG framework
Evaluate safety and performance in simulated human–robot interaction scenarios

The expected outcome is a predictive safety mechanism that ensures compliant and safe robot behavior in the presence of humans while preserving operational efficiency.

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

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master's program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Multi-robot localisation

Description

This thesis topic is a broad collection of subtasks that can be undertaken within multi-robot localisation research.
This includes topics such as:
- Multi-agent SLAM.
- UWB Anchored 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

Human-Aware Velocity Regulation using Explicit Reference Governors for Safe Human–Robot Interaction

Description

This thesis focuses on the development of a safety-aware control mechanism for robotic manipulators operating in environments shared with humans. According to international human–robot interaction standards, such as ISO 10218 and ISO/TS 15066, robot velocity and impact energy must be limited depending on the proximity to the human body and the specific body region involved.

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Implement a perception-based human detection mechanism
Define distance-dependent velocity constraints
Integrate these constraints into the ERG framework
Evaluate safety and performance in simulated human–robot interaction scenarios

The expected outcome is a predictive safety mechanism that ensures compliant and safe robot behavior in the presence of humans while preserving operational efficiency.

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

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Adaptive Dynamic Safety Margin Design for Force-Regulated Explicit Reference Governors

Description

This thesis investigates the design of adaptive safety margins for Explicit Reference Governors (ERG) applied to robotic manipulators operating under external forces and contact constraints.

Explicit Reference Governors ensure constraint satisfaction by predicting future system behavior and evaluating a Dynamic Safety Margin (DSM) that quantifies the distance to constraint violation. In current implementations, safety margins are typically defined using fixed worst-case bounds on modeling uncertainty and force-estimation errors. While this guarantees safety, it often leads to conservative robot behavior and reduced performance.

The objective of this thesis is to develop an adaptive tightening mechanism that adjusts the safety margin online based on measurable uncertainty indicators such as force-estimation residuals, prediction error, or disturbance dynamics. The proposed method will be integrated into an existing force-regulated ERG framework for robotic manipulators.

The student will:

Analyze the baseline ERG and DSM formulation
Design an adaptive uncertainty bound for force and motion prediction
Integrate the adaptive margin into the ERG safety mechanism
Validate the approach through simulation and experimental evaluation
Compare performance against fixed-bound safety margins

The expected outcome is a safer and less conservative ERG controller capable of maintaining constraint satisfaction while improving responsiveness and task efficiency.

Langue	EN (english)
Ouvert à d’autres masters	Yes
Masters concernés	M-IREMR-A, M-IREMR-E

Nombre de sujets	1

Supervision

Supervisor : Vanderborght Bram (Bram.Vanderborght@vub.be)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Dual-motor drive for e-bikes

Description

Dual-motor actuators use two motors to improve control, torque distribution, and efficiency in applications like robotics and e-bikes, enhancing performance and user experience.
This project supports the characterization of the OWURU drivetrain by E2Drives, used in Decathlon BTWIN bikes, leveraging R&MM expertise.
It includes performance testing (torque, speed, efficiency, inertia) and development of a new dual-motor actuator concept.

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

Supervision

Supervisor : LOPEZ GARCIA PABLO (pablo@ailos-robotics.com)

Master’s program offering the topic: EM - Robotics & mechatronics constructions - M-IREMR-M

Studying the relationship between fatigue and torque generation in older adults during tasks of daily living

Description

Context
Age-related mobility impairment is a major challenge for older adults and is strongly associated with reductions in muscle mass and muscle quality. Lower limb exoskeletons have been proposed as a promising strategy to help this population. They can serve as rehabilitation tools that facilitate repetitive, task-specific training and promote muscle strengthening. On the other hand, when used as assistive devices, exoskeletons may enable older adults with mobility impairments to remain physically active in daily life. One of the major challenges in exoskeletons is providing the correct amount of assistance throughout the different activities of daily life. The exoskeleton should be aware of the activity the user is performing (e.g. walking, stair ascent/descent), but also understand when and how much to provide assistance withing this specific activity. Many methods exist for controlling these devices, but each have different drawbacks that should be considered.
Objective
In this thesis the student will develop a controller for a lower-limb exoskeleton (hip-knee). Two control strategies are proposed, but the student can also choose to come up with their own control strategy.

Methods
In this thesis you will try to find a relationship between fatigue and muscle torque generation using biomechanical simulations and earlier obtained data. This data exists of kinematics of different older adults performing activities of daily living (stair ascent/descent, level walking, slope ascent/descent and sit to stand). These activities have been recorded over different self-reported fatigue levels.
Using this data in a biomechanical simulation allows to estimate joint torques in the different lower limb joints. To this end, we will use the open source software OpenSim, to scale a musculoskeletal human model to the size of each participant. You will then use the recorded kinematics data from the inertial measurement units (IMUs) to compute the joint angles of each joint. Finally, we will use these computed joint angles to solve an

optimization problem, that minimizes the difference with the recorded data, in order to predict ground reaction forces, joint torques and even muscle activations. For these simulations, you can use MATLAB, and VUB's supercomputer to speed up the computations.
We hypothesize that as the older adults get more and more fatigued, small changes in kinematics will be observed. These small changes in kinematics can be used to estimate changes in joint torques to determine the relationship between fatigue and torque generation in muscles. By understanding this relationship, we can later adapt assistance appropriately to fatigue.

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

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

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)

Two-phase Flow Mixing Characterisation in an Aero-engine Oil System

Program : EM - Aeronautics - M-IREMR-A

Description

The ATM department develops and operates oil system test rigs for aircraft engine manufacturers. During a recent characterisation test, measurements of two-phases (air-oil) flows have given unpredicted results. The sensors used in the different experimental campaigns are deeply influenced by the flow pattern of the two-phase flow. Different flow patterns can appear at the same pressure and mixture ratio depending on other parameters such as the piping or the existing mixing. It is therefore interesting to investigate the flow patterns and the possibility to impose a determined flow pattern through a correct mixing of the two phases.
The objective of the master thesis is to design and characterise mixing devices such as existing mixers or grids. Through rapid prototyping methods multiple prototypes can be tested and assessed. The mixing of the flow can then be studied through visualisation and image analysis.

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 : Olivier Berten (olivier.berten@ulb.be)

Slip Factor Characterisation in a Two-phases Flow for Aircraft Engine Oil System

Program : EM - Aeronautics - M-IREMR-A

Description

The ATM department develops and operates oil system test rigs for aircraft engine manufacturers. During a recent characterisation test, measurements of two-phases (air-oil) flows have given unpredicted results. One hypothesis is that the flow patterns could be the cause of the variation. Indeed, the same phase ratio can generate multiple flow patterns that behave differently in term of, among others, pressure variation. To characterise the flow pattern, an often-used parameter is the slip factor (phases flow velocities ratio). The objective of this research is to implement and test a device for measuring it experimentally.
The focus of the master thesis is the implementation of an experimental test rig for the characterisation of the slip factor. Then the experimental work will focus on the determination of the different parameters influencing the difference in flow velocities between the two phases. A model can then be drawn from the experimental data and known governing equations.

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 : Olivier Berten (olivier.berten@ulb.be)

Automatic Debris Injection in a Two-phases Flow for Oil Systems

Program : EM - Aeronautics - M-IREMR-A

Description

The ATM department is regularly asked by aircraft engine manufacturer to test prototypes of oil system equipment. A recurring topic is the study of debris carried by the oil, either their effect on mechanical components in the system or the methods to detect and capture them. In both cases, there is a need for a repeatable solution to inject this solid matter into the oil flow. Previous projects have led to a viable prototype for automatic injection into the working oil system test rig. A more rigorous study is needed to experimentally assess its performance. In addition, this research could benefit from a numerical study for optimising the debris injection.

The master thesis focusses on the design and manufacturing of a peristatic pump suitable for the oil system pressure. The performances of this pump for the injection of different debris must be characterised. The debris themselves are of different sizes and materials thus the injection system must be adaptable and work in a large range of conditions. An important parameter influencing the injection is also the angle of penetration between the debris and the existing flow. Therefore, an important part of the experimental study will focus on the injection angle and its integration with the main flow. In parallel with the experimental characterisation and design iterations and review, a numerical study can be implemented. It will be validated through the experimental data and lead to a model like digital twins.

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 : Olivier Berten (olivier.berten@ulb.be)

Wake control mechanism for paired vertical-axis wind turbines

Program : EM - Aeronautics - M-IREMR-A

Description

Wind turbines generate power by extracting kinetic energy from the wind, but in doing so they create wakes with lower wind speed and higher turbulence behind them. These wakes reduce the power output and increase fatigue loads on downstream turbines, so wind farm control strategies such as wake steering are used to improve overall efficiency.

While most research has focused on horizontal-axis wind turbines (HAWTs), vertical-axis wind turbines (VAWTs) are gaining attention because they can achieve higher power densities and improved wake recovery, especially when placed in closely spaced counter-rotating pairs. This project investigates wake control for paired VAWTs, using blade pitch adjustment to deflect wakes away from downstream turbines and enhance wind farm performance.

Link : https://vub-my.sharepoint.com/:b:/g/personal/gabriele_ronchetti_vub_be/IQD3FzjRoodHR5xmdw73nM_mAR_FaNbkDkMjz3czXw9nYTg?e=QE5nzU

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

Supervision

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

Propagating Site Wind-Climate Uncertainty to Wind Turbine Loads
Program : EM - Aeronautics - M-IREMR-A

Description
Accurate prediction of the aerodynamic loads acting on wind turbine airfoil sections is essential for design,
fatigue assessment, and correctly predicting energy output. These loads depend strongly on the turbulent
inflow the rotor experiences, which is inherently variable over the lifetime of a wind turbine.
The standard practice in the wind energy community is to drive aeroelastic simulations (e.g. in Open-
FAST) with stochastic turbulent wind fields produced by TurbSim. TurbSim is typically seeded with a single set of 10-minute statistics representative of the site of interest. While TurbSim introduces variability through its stochastic wind-field generation, the uncertainty in the 10-minute statistics themselves, which can vary considerably across the long-term wind climate of a real site is ignored.
The FLOW research group has developed a synthetic time-series generator capable of producing multiple statistically consistent 10-minute records that match the long-term statistical descriptors of a site derived from multiple years of measurements. By using this tool to draw many different 10-minute input conditions,
it becomes possible to propagate the full upstream uncertainty, from site wind climate, through TurbSim wind field generation, all the way to the aerodynamic loads on the airfoil sections.
The goal of this thesis is to implement and demonstrate this end-to-end uncertainty propagation frame- work for wind turbine airfoil aerodynamic loads, and to quantify how much additional load variability is
revealed when the uncertainty on the 10-minute inputs is properly accounted for.

Link : https://vub-my.sharepoint.com/:b:/g/personal/imran_mohammad_vub_be/IQAQ5hjGv67-Q6XQ33eZviPiAdiJWgP0aAswRRioeEj-K9g?e=E9QhjQ

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

Supervision
Supervisor : Mark Runacres (mark.runacres@vub.be)
Co-supervisor : Imran Mohammad (imran.mohammad@vub.be)

Application of model-based deep reinforcement learning to unsteady flow systems

Program : EM - Aeronautics - M-IREMR-A

Description

The present master thesis aims to combine two highly powerful and modern methodologies: reinforcement learning on one hand, and data-driven modelling on the other.

Reinforcement learning (RL) is a machine learning technique based on an "agentic AI" paradigm where and agent learns to make decisions by interacting with an environment and receiving feedback in the form of rewards. Famous applications include video game and chess, where RL agents have demonstrated superiority over human by autonomously learning how to play. In the field of engineering, control is a natural application. However, RL agents typically require a vast number of interactions with the environment to become effective, which would be impractical for unsteady fluid mechanics applications. Generating such an amount of high-quality data through experiments or simulations would be excessively resource-intensive.

The goal of this master thesis is to overcome these limitations by using data-driven modeling techniques.

Data-driven modeling techniques have been, and continue to be, extensively studied within the FLOW research group. These techniques seek to construct simple, accurate and fast models of complex systems by learning directly from available data rather than explicitly relying on governing equations. A recent example within the group is the work by Damiola et al., who developed a model capable of accurately and rapidly estimating the unsteady aerodynamic loads of a pitching aerofoil from its angle of attack, across a wide variety of pitch rates. Another well-studied system within the group is the oscillating cylinder in cross-flow direction, where the nonlinear and unsteady relationship between force and cylinder position has been successfully modelled.

The objective of the master thesis is to apply reinforcement learning to one of our data-driven models in order to control aerodynamic forces under varying conditions.

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

https://vub-my.sharepoint.com/:b:/g/personal/charly_francois_r_witmeur_vub_be1/IQB2ZOGVGLzKRJzNZPMn1xZOAdqcqHaTCI66UmpUu8wDJio?e=NTfxoQ

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

Supervision

Supervisor : Jan Decuyper (Jan.decuyper@vub.be)

Experimental investigation of the energy exchange between a fluid flow and an oscillating cylinder

Program : EM - Aeronautics - M-IREMR-A

Description
The FLOW research group has developed an experimental setup to study vortex-induced vibration (VIV)
of an oscillating cylinder in the wind tunnel. It is well known that bluff bodies in a fluid flow are subjected to vortex shedding over a large range of Reynolds numbers. When the frequency of vortex shedding is close to the (structural) resonance frequency of the bluff body, the vibration and the vortex shedding tend to
synchronise. Using our set-up, we have studied the phenomenon of synchronisation using forced-oscillation measurements: we impose oscillations at different frequencies (in and around the natural vortex shedding frequency) and for different amplitudes.
In real life, vortex shedding can induce structural vibrations of the bluff body. In this case, there is a net transfer of energy from the fluid flow to the oscillation of the body. In our experiments, we impose the vibration, regardless of whether the oscillating cylinder is giving energy to or receiving energy from the flow.
It is clear that knowledge of the energy transfer is key to use forced-motion experiments to make statements about freely-oscillating cylinders. The objective of this master thesis is to study energy transfer using existing
and new experimental measurements in the wind tunnel.

More information is found in the accompanying document.

https://vub-my.sharepoint.com/:b:/g/personal/tim_de_troyer_vub_be/IQA40mouGotUQoMqc8-491iPAeaGnEYcuqCSsUmdOUOmMkI?e=0ReZ0S

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

Supervision
Supervisor : Tim De Troyer (tim.de.troyer@vub.be)
Co-supervisor : Mark Runacres (mark.runacres@vub.be)

Wind tunnel turbulence characterisation with a multihole probe

Program : EM - Aeronautics - M-IREMR-A

Description

The measurement of wind speed in an experimental facility is typically either pressure-based, temperature-based, or optical. The FLOW research group has a set of different techniques for use in one of its three wind tunnels; this thesis focuses on one pressure-based technique but will require the use of other alternative instruments as well.

At the heart of this thesis topic is the multihole probe (FLOW operates a seven-hole probe, abbreviated to 7HP). This probe consists of a (spherical) head with multiple (in our case 7) pressure taps to measure the pressure distribution around the head. Through calibration, this distribution can be transformed into the incoming flow angle and dynamic pressure, which in turn can be translated into the 3D velocity vector (for limited inflow angles).

In principle, such a probe is designed to measure the mean velocity, not the velocity fluctuations. In practice, however, we hypothesise that the probe allows to measure velocity fluctuations up to 100 Hz, posssibly more. If true, this would turn the 7HP into a device that can measure (low-frequency) turbulence. The objective of this master thesis is to establish to what extent FLOW's 7HP can be used to measure turbulence.

More information is found in the accompanying document.
https://vub-my.sharepoint.com/:b:/g/personal/tim_de_troyer_vub_be/IQB2s1xXD2cmSpVYoRpopgdnAbkh2EIDlngaBtIw3VhXRTI?e=dHJEaE

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

Supervision

Supervisor : Tim De Troyer (tim.de.troyer@vub.be)

Bispectrum-boosted data-driven modelling

Program : EM - Aeronautics - M-IREMR-A

Description

When building models from data, it is useful to embed as much prior knowledge about the system as pos_x0002_sible. One particularly valuable aspect is the nature of the system's nonlinearity. Spectral analysis provides a practical way to extract and leverage this information.

Since the development of the fast Fourier transform algorithm in the 1960s, spectral analysis has become a cornerstone in many engineering fields, not in the least that of data-driven modelling. The primary quant_x0002_ity of study is usually the energy/power spectrum (sometimes a.k.a. the power spectral density, or PSD).

Despite its many strengths, the PSD has an important shortcoming: it is blind for potential nonlinear rela_x0002_tions between the different frequency components. Therefore, the PSD cannot be used directly to ascertain whether a signal contains traces of nonlinear frequency interactions, or, more broadly, whether that signal has been generated by a nonlinear system.

In system identification, this limitation has been partly overcome by creating dedicated test signals (c.q. the FAST multisine) which allow to quantify the level of nonlinear distortions, and to distinguish between even and odd nonlinear effects. Another alternative, which is to be explored in this master thesis, is the use of higher-order spectra (HOS), in particular
the bispectrum and trispectrum. Contrary to the PSD, the
bispectrum and trispectrum are well suited to detect and analyse non-linearities. The objective of this master thesis is to compare the FAST method to the use of HOS as tools for nonlinear data-driven modelling.

More information is found in the accompanying document.

https://vub-my.sharepoint.com/:b:/g/personal/tim_de_troyer_vub_be/IQCmFwDnOhMhSp0sT4tNqhi5Ae4VA-CAHzIfHiB9CiJ_0Mw?e=NttFEB

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

Supervision

Supervisor : Tim De Troyer (tim.de.troyer@vub.be)

Co-supervisor : Jan Decuyper (jan.decuyper@vub.be)

Gaussian Process-Based Nonlinear Identification of Nano-Drone Dynamics

Program : EM - Aeronautics - M-IREMR-A

Description

The development of agile, miniaturised aerial robots, commonly referred to as drones, is a rapidly growing field with an expanding range of applications. Since these platforms are unmanned and often operate in complex environments, precise control of their dynamics is essential. In particular, model-based control strategies require accurate dynamical models, which can be obtained through system identification. These methods aim to infer system dynamics from data, using physics-based models, purely data-driven approaches, or hybrid combinations of both.

This thesis proposes to investigate Gaussian Process (GP)-based system identification techniques using benchmark data from the Crazyflie 2.1 Brushless nano-quadrotor. Despite its small size, the Crazyflie exhibits complex nonlinear behaviour. It is a multi-input multi-output system, inherently open-loop unstable, and can display strongly nonlinear dynamics under aggressive manoeuvres. These properties make it both a challenging and relevant benchmark for probabilistic identification methods. Gaussian Processes provide a flexible Bayesian framework for learning nonlinear mappings from data. In addition to predicting system outputs, they naturally quantify uncertainty, which is particularly valuable for robust and safe control.

The objective of this work is therefore to assess the ability of GP-based models to capture the dynamics of the Crazyflie nano-quadrotor and to evaluate their suitability for future model-based control applications. Furthermore, the results obtained with the investigated method should be compared to available results from other modelling methods applied to the benchmark data.

https://vub-my.sharepoint.com/:b:/g/personal/gulliver_orian_van_essche_vub_be/IQAKfqFqwKI9R4xCyQmvQAn_AYQnobgHWtduAruR1547tdg?e=TqyTeO

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

Supervision

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Propagating Site Wind-Climate Uncertainty to Wind Turbine Loads

Program : EM - Aeronautics - M-IREMR-A

Description

See document below for context and work description

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

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

Supervision

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Co-supervisor

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Study of reinforced paraffin-based grains for hybrid rocket motor performance enhancement

Program : EM - Aeronautics - M-IREMR-A

Description

The addition of 3D-printed structures in conventional paraffin-based fuel grains are being investigated to improve combustion efficiency and fuel regression rates in hybrid rocket motors, to achieve a reliable performance for launcher and satellite propulsion applications.
A previous final year project focused on the introduction of 3D-printed swirl-inducing surfaces in paraffin grains, investigating how the number of vanes and their angle affected the swirl intensity and the enhanced the mixing of fuel and oxidizer, leading to higher regression rates, increased thrust, and more compact designs.

The thesis focuses on expanding the investigation by performing an extended parametric study on the swirl-inducing parameters of the grain, followed by an experimental test campaign on a small-scale hybrid rocket motor, using gaseous oxygen as oxidizer, paraffin as main fuel and acrylonitrile-butadiene-styrene (ABS), or other polymers, for the 3D-printed structures. Eventually other proposed solutions will be implemented and tested, such as the introduction of diaphragms, mixers or reinforcement structures in the grain.

Objectives:
The primary objective of this thesis is to develop an experimental database of performance parameters of reinforced paraffin-based grains with swirl structures.

- Investigate through a literature study the impact of 3D printed structures embedded in paraffin-based fuel grains on combustion efficiency and fuel regression rates in hybrid rocket motors.
- Expand the previous experimental work on swirl inducing grain geometries by conducting a parametric analysis of swirl enhancing features.
- Design and fabricate paraffin grains incorporating optimized 3D printed structures, as well as thermal protections required for the combustion chamber. Perform thermochemical studies of the mixture to accurately define the theoretical combustion performance values.
- Perform an experimental test campaign on a small scale hybrid rocket motor, operating with gaseous oxygen as oxidizer and paraffin as the primary fuel.
- Quantify the influence of swirl inducing parameters on regression rate, thrust, combustion stability, and overall motor performance.
- Evaluate additional innovative grain internal solutions, such as diaphragms, mixers, or reinforcement structures, assessing their manufacturability and performance benefits.

Methodology:
The student will follow a structured approach involving both theoretical and experimental phases:

- Study of Existing Propellants: Reviewing existing literature on hybrid rocket propellants and their performance characteristics. The student will compare various fuel to be used in combination with gaseous oxygen as oxidizer.

- Analysis of New Geometries: The student will propose various grain geometries to be tested.
- Design of the fuel grains: Design of the hybrid rocket motor fuel grains, as consequence of the preliminary studies, including printing of the structure and casting of the propellants.
- Testing and Validation: The grains will be tested on the motor test bench developed in a previous work.

Requirements for this topic:
The student should have a strong interest in space technologies and rocket propulsion. A good knowledge of thermodynamics and fluid dynamics tools are a must.

Contact: Prof. Aurélie Bellemans and Prof. Patrick Hendrick
Day to day supervision by Dr. Riccardo Gelain and Dr. Mariano Di Matteo

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

Supervision

Supervisor

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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

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Co-supervisor

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

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

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

Supervision

Supervisor
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Co-supervisor
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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

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Torsional Pendulum Micro-Thrust Balance for Electrospray Propulsion Preparation

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

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

Supervision

Supervisor

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Co-supervisor

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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

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Co-supervisor

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

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

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

Supervision

Supervisor

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Electrochromic Coatings for Active Thermal Control in Space : Experimental Assessment

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

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

Supervision

Supervisor

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Co-supervisor

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Experimental assessment of thermochromic coatings for passive thermal regulation in space

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

Supervision

Supervisor

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Co-supervisor

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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

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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

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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)

Testing and analysis of complete UAV (drone) propulsion chain with batteries and H2 fuel cell

Program : EM - Aeronautics - M-IREMR-A

Description

The objective will be to characterize with ground tests a complete electric propulsion chain for a fixed-wing UAV based on a small PEMFC (250 W) feeded with gaseous hydrogen (H2 tank + PEMFC + LiPo batteries + electric motor + propeller).
Based on the results to make an Aircraft Conceptual Design exercise to integrate this propulsion system into a fixed-wing UAV and define its in-flight performance.
MT topic possible for a group of 2 students.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	Possible for 2 students (group of 2).

Supervision

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

Co-supervisor : Adrien Fita-Codina (adrien.fita-codina@ulb.be)

Propagating Site Wind-Climate Uncertainty to Wind Turbine Loads

Program : EM - Aeronautics - M-IREMR-A

Description

See document below for context and work description

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

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

Supervision

Supervisor

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Co-supervisor

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Study of reinforced paraffin-based grains for hybrid rocket motor performance enhancement

Program : EM - Aeronautics - M-IREMR-A

Description

The addition of 3D-printed structures in conventional paraffin-based fuel grains are being investigated to improve combustion efficiency and fuel regression rates in hybrid rocket motors, to achieve a reliable performance for launcher and satellite propulsion applications.
A previous final year project focused on the introduction of 3D-printed swirl-inducing surfaces in paraffin grains, investigating how the number of vanes and their angle affected the swirl intensity and the enhanced the mixing of fuel and oxidizer, leading to higher regression rates, increased thrust, and more compact designs.

The thesis focuses on expanding the investigation by performing an extended parametric study on the swirl-inducing parameters of the grain, followed by an experimental test campaign on a small-scale hybrid rocket motor, using gaseous oxygen as oxidizer, paraffin as main fuel and acrylonitrile-butadiene-styrene (ABS), or other polymers, for the 3D-printed structures. Eventually other proposed solutions will be implemented and tested, such as the introduction of diaphragms, mixers or reinforcement structures in the grain.

Objectives:
The primary objective of this thesis is to develop an experimental database of performance parameters of reinforced paraffin-based grains with swirl structures.

- Investigate through a literature study the impact of 3D printed structures embedded in paraffin-based fuel grains on combustion efficiency and fuel regression rates in hybrid rocket motors.
- Expand the previous experimental work on swirl inducing grain geometries by conducting a parametric analysis of swirl enhancing features.
- Design and fabricate paraffin grains incorporating optimized 3D printed structures, as well as thermal protections required for the combustion chamber. Perform thermochemical studies of the mixture to accurately define the theoretical combustion performance values.
- Perform an experimental test campaign on a small scale hybrid rocket motor, operating with gaseous oxygen as oxidizer and paraffin as the primary fuel.
- Quantify the influence of swirl inducing parameters on regression rate, thrust, combustion stability, and overall motor performance.
- Evaluate additional innovative grain internal solutions, such as diaphragms, mixers, or reinforcement structures, assessing their manufacturability and performance benefits.

Methodology:
The student will follow a structured approach involving both theoretical and experimental phases:

- Study of Existing Propellants: Reviewing existing literature on hybrid rocket propellants and their performance characteristics. The student will compare various fuel to be used in combination with gaseous oxygen as oxidizer.

- Analysis of New Geometries: The student will propose various grain geometries to be tested.
- Design of the fuel grains: Design of the hybrid rocket motor fuel grains, as consequence of the preliminary studies, including printing of the structure and casting of the propellants.
- Testing and Validation: The grains will be tested on the motor test bench developed in a previous work.

Requirements for this topic:
The student should have a strong interest in space technologies and rocket propulsion. A good knowledge of thermodynamics and fluid dynamics tools are a must.

Contact: Prof. Aurélie Bellemans and Prof. Patrick Hendrick
Day to day supervision by Dr. Riccardo Gelain and Dr. Mariano Di Matteo

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

Supervision

Supervisor
Aurelie Bellemans (aurelie.bellemans@vub.be)

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

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

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

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Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

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

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

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

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

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

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

The student will first review the principles of electromagnetic shielding, including reflection, absorption, multiple internal reflections, conductivity, magnetic permeability, skin depth, and frequency-dependent attenuation. The experimental work will then focus on defining a repeatable measurement protocol in which a material sample is placed between or near transmitting and receiving probes. Measurements with and without the sample will be used to estimate attenuation as a function of frequency, for example through relative changes in transmission parameters such as 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)

Torsional Pendulum Micro-Thrust Balance for Electrospray Propulsion Preparation

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

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

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

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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)

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

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

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

Supervision

Supervisor

Axel Coussement (axel.coussement@ulb.be)

Co-supervisor

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Electrochromic Coatings for Active Thermal Control in Space : Experimental Assessment

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

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

Supervision

Supervisor

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Co-supervisor

Carlo Iorio (carlo.iorio@ulb.be)

Experimental assessment of thermochromic coatings for passive thermal regulation in space

Program : EM - Aeronautics - M-IREMR-A

Description

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

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

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

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

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

Supervision

Supervisor
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Co-supervisor
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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)

Testing and analysis of complete UAV (drone) propulsion chain with batteries and H2 fuel cell

Program : EM - Aeronautics - M-IREMR-A

Description

The objective will be to characterize with ground tests a complete electric propulsion chain for a fixed-wing UAV based on a small PEMFC (250 W) feeded with gaseous hydrogen (H2 tank + PEMFC + LiPo batteries + electric motor + propeller).
Based on the results to make an Aircraft Conceptual Design exercise to integrate this propulsion system into a fixed-wing UAV and define its in-flight performance.
MT topic possible for a group of 2 students.

Language	EN (english)
Open to other master's programs	No
Eligible master's programs	
Number of topics	Possible for 2 students (group of 2).

Supervision

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