MECHANICAL ENGINEERING

DIMEAS - Multiscale Structural Characterization and Multi-Objective Optimization of Additively Manufactured Heat Exchangers

Funded By	Dipartimento DIMEAS
Supervisor	GASTALDI CHIARA - chiara.gastaldi@polito.it
Contact	DELPRETE CRISTIANA - cristiana.delprete@polito.it GASTALDI CHIARA - chiara.gastaldi@polito.it
Context of the research activity	The research will focus on the structural characterization (static and dynamic) of heat exchangers produced by additive manufacturing, combining numerical and experimental activities. The overall goal is to develop predictive, multi-fidelity structural models—validated and calibrated against experimental data—to support robust design and, prospectively, multi-objective multidisciplinary optimization (MDO) jointly accounting for structural integrity, thermo-fluid performance, and process/cost constraints.
	Recent advances in additive manufacturing enable the production of high-performance heat exchangers featuring complex architectures (including lattice-like and porous topologies) that are not achievable through conventional manufacturing. While these solutions can provide significant thermo-fluid advantages, they also introduce critical challenges in terms of structural integrity, fatigue and vibration response, and sensitivity to process variability and operating conditions. Furthermore, the enlarged design space and the computational cost of high-fidelity simulations hinder systematic design exploration. The research activity will be carried out in collaboration with Dumarey within the regional research project AMHPHEX (SWIch 2024). The fellowship will contribute to the development of a comprehensive methodology to: (i) model and characterize structural behavior at micro- and macro-scales; (ii) derive computationally efficient reduced-order / homogenized models trained on high-fidelity data; and (iii) integrate such models into a multi-objective (and robust) MDO workflow, consistent with the project work packages. Numerical activities (main objectives) • High-fidelity structural simulations of complex AM heat exchangers (including lattice/porous regions), under representative static and dynamic loads and boundary conditions. • Multiscale homogenization procedures to identify equivalent properties (e.g., stiffness, damping—eventually simplified strength/fatigue descriptors)

Objectives	starting from unit-cell analyses. • Reduced-order and surrogate model development (physics-based and/or data-driven) trained on a high-fidelity simulation database to enable rapid design iterations. • Uncertainty Quantification (UQ) to account for AM-related variability (material/process scatter, geometric tolerances) and operating-condition uncertainty. • Integration into multi-objective MDO (in coordination with thermo-fluid modelling): generation of Pareto fronts balancing structural robustness, pressure losses, heat-transfer performance, and process/cost metrics. Experimental activities (main objectives) • Development of reliable and traceable measurement procedures for structural response (e.g., FRFs, modal identification, strain/acceleration measurements, monitoring of critical locations for integrity assessment). • Experimental structural characterization of reference heat exchangers and/or prototypes, including testing under multiple boundary conditions and representative vibration profiles (also considering off-design or faulty scenarios to ensure robust characterization). • Validation and calibration of numerical models using experimental data; introduction of data-driven corrections to reduce discrepancies (e.g., tuning equivalent properties, damping, boundary conditions). • Support to the definition of testing metrics and uncertainty evaluation to ensure consistency with downstream model calibration and optimization tasks.

Skills and competencies for the development of the activity	he candidate must have a solid background in structural mechanics (statics, dynamics, vibrations), finite element modelling, and scientific computing/programming (e.g., Python/Matlab) for simulation workflows and post-processing. Experience with model reduction, machine learning for modelling, multi-objective optimization, and/or uncertainty quantification is highly valued. Experimental skills (modal testing, vibration measurements, strain/accelerometers) are a plus