Politecnico di Torino

AEROSPACE ENGINEERING

DIMEAS - Multi-Scale Thermal Behavior of Aerospace Structures

Funded By	Dipartimento DIMEAS

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Context of the research activity	The research investigates multi-scale thermal behavior in thin-walled aerospace structures by integrating classical and advanced physics. The project develops models that describe heat storage and transport across micro- and macro-scales, enabling accurate prediction of thermally induced stresses and deformations. The activity is conducted within the AMPERE project, funded under the MUR FIS 2 programme.

Objectives	The objective of this PhD activity is to develop advanced multi-scale models for understanding and predicting the thermal behavior of thin-walled aerospace structures. Future aircraft and spacecraft, including hybrid-electric aircraft and next-generation satellites, operate under highly variable thermal environments. Thin-walled components such as fuselage panels, wing skins, stiffened composite shells, and payload-support structures exhibit strong sensitivity to thermal gradients, often leading to deformation, instability, and thermoelastic disturbances. Existing models based on classical heat conduction, convection, and radiation provide limited fidelity when applied to heterogeneous, anisotropic, multifunctional, or nano-structured aerospace materials. The research will focus on integrating classical thermal transfer theories with physics at micro- and nano-scale, including phonon transport, electron-mediated conduction, rarefied-gas convection, and radiation in non-ideal geometries. These models will be tailored to the structural mechanics of thin-walled systems, using shell and plate formulations capable of capturing thermally induced distortions and stresses. The work includes: multi-scale formulation for heat storage and transmission in thin-walled structures; incorporation of material heterogeneity and anisotropy typical of advanced composites; coupling between thermal fields and structural responses governed by thin-shell theories; numerical implementation and validation through dedicated aerospace test cases;

	integration into the digital twin framework of AMPERE. Applications concern hybrid-electric aircraft (thermal gradients from batteries, electric motors, power electronics) and space structures (thermoelastic deformation, thermal fatigue, thermal flutter). The research will provide a unified, high-fidelity thermal modelling framework essential for next-generation lightweight aerospace structures.

Skills and competencies for the development of the activity	Strong background in structural mechanics, thermodynamics, and heat transfer. Knowledge of thin-walled structures, finite element analysis, and composite materials is desirable. Programming skills (Python, MATLAB, Fortran, C++ or similar) and interest in multi-scale modelling are beneficial.