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An Integrated Multiphysical Framework for the Design, Optimization and Experimental Assessment of Aerospace Metamaterials

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The growing demand for lightweight, efficient and functionally integrated aerospace structures is driving increasing interest in architected metamaterials. In this context, the present work summarizes the outcomes of a completed research project aimed at developing a multiphysical approach to the design of aerospace-oriented lattice metamaterials. The proposed framework combines theoretical modelling, parametric numerical simulation, multi-objective optimization, additive manufacturing and experimental assessment within a unified research workflow. The project addressed the interaction between structural, thermal, electromagnetic and fluid-structure-related aspects, with the goal of supporting the design of metamaterial solutions characterized by tailored performance and enhanced application potential. Different lattice concepts and geometrical parameterizations were investigated through computational tools specifically developed or adapted for the project, enabling systematic exploration of morphology, response relationships and supporting the identification of promising design strategies under different performance requirements. The numerical activity was complemented by the fabrication of representative prototypes and by experimental testing campaigns aimed at assessing the mechanical response of selected configurations and at comparing experimental evidence with simulation results. This integrated approach made it possible to progress from the definition of reference analytical and numerical models to the consolidation of a design-oriented methodology, thus providing a coherent basis for future application-driven developments. Overall, the project highlights the potential of multiphysical and optimization-based methodologies for the development of advanced metamaterial structures for aerospace applications. The results provide a scalable framework for bridging conceptual design, numerical assessment and experimental investigation, and open the way to further developments focused on robust design criteria, multifunctionality and industrial implementation.

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