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Fatigue Performance of Hybrid Surface-Based Additively Manufactured Lattice Structures

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Lattice structures represent one of the most promising and innovative design approaches enabled by Additive Manufacturing (AM). In particular, extensive research has demonstrated the unique advantages of surface-based unit cells derived from Triply Periodic Minimal Surfaces (TPMS) in mechanical applications. Although a substantial body of literature has investigated the elastic properties and energy absorption capabilities of these structures, their fatigue performance remains largely unexplored, thereby limiting their application in critical sectors such as automotive and aerospace.
This work presents the results of the FLIGHT project (Fatigue of Lattices Improved by Generating Hybrid Topologies), carried out within the framework of MOST (National Centre for Sustainable Mobility). The aim of the project was to investigate the fatigue performance of innovative lattice cells obtained through the hybridization of classical TPMS structures.
A comprehensive geometrical study was first conducted to analyze the morphological features of these structures. This analysis, combined with the manufacturability constraints of the chosen technology, enabled the definition of the fundamental cell dimensions. The specimens were fabricated in AlSi10Mg using Laser Powder Bed Fusion (LPBF). Different heat treatments were evaluated to identify the optimal balance between microstructure and residual stresses. In particular, 3D scanning was employed to quantify distortions induced by post-processing.
To perform tensile fatigue tests under a stress ratio of R = 0.1, a dedicated specimen geometry was designed to ensure failure within the gauge region. This design was validated through both Finite Element Analysis (FEA) and preliminary tensile tests on brittle resin specimens. The final specimens were then produced in AlSi10Mg and inspected using micro-Computed Tomography (µCT) to assess manufacturing quality. Additionally, microhardness measurements were carried out to evaluate the influence of thermal gradients along the specimen axis.
Nine different lattice topologies were experimentally tested under both static and cyclic loading conditions. Fatigue tests were conducted on hydraulic testing machines at a frequency of 32 Hz, with runout defined at 10^7 cycles.
The results indicate that the fatigue limit of the investigated structures ranges between 16% and 24% of the static Ultimate Tensile Strength (UTS). Notably, the fatigue data exhibit a remarkable linearity in the double-logarithmic Wöhler (S–N) diagram. This high level of predictability can be attributed to the intrinsic topology of the structures, which appears to retard crack propagation and promote multiple crack paths prior to final failure. This hypothesis is further supported by microstructural analyses of the fracture surfaces performed using Field Emission Gun Scanning Electron Microscopy (FEG-SEM).

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