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FATIGUE OF ADDITIVELY MANUFACTURED METAMATERIALS: EXPERIMENTS, MODELLING AND DESIGN

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ABSTRACT

Additive manufacturing enables the fabrication of mechanical metamaterials whose effective properties can be tailored through their architecture, opening new opportunities for lightweight structures, biomedical implants and multifunctional components. However, their reliable application under cyclic loading remains challenging. Fatigue performance emerges from the interaction between architectural features, constituent material behaviour and manufacturing imperfections. Local stress concentrations, surface roughness, internal defects and residual stresses can influence damage initiation, while load redistribution and interactions between neighbouring cells govern damage evolution and structural failure.

This invited session aims to bring together researchers investigating the experimental characterization, numerical modelling and fatigue design of additively manufactured metamaterials. Particular attention will be devoted to connecting local damage mechanisms at the strut, wall and junction scales with the macroscopic cyclic response of architected structures, including lattice, triply periodic minimal surface and graded architectures.

Contributions addressing cyclic deformation, crack initiation and propagation, progressive damage and fatigue life under uniaxial, multiaxial and variable-amplitude loading are encouraged. The session also welcomes advanced experimental techniques, computational approaches and strategies for improving fatigue resistance through architectural optimization, manufacturing control and post-processing. By integrating experimental evidence with predictive models, the session seeks to support the development of reliable fatigue assessment methods and design criteria for engineering applications.

The main topics include, but are not limited to:

- Influence of topology, relative density, cell size, architectural orientation and grading on fatigue performance;
- Effects of microstructure, surface condition, manufacturing defects, residual stresses and post-processing;
- Experimental characterization and in situ monitoring of cyclic deformation, crack development and progressive failure;
- Local fatigue criteria, fracture mechanics, homogenization and multiscale modelling linking constituent behaviour to structural durability;
- Fatigue under multiaxial and variable-amplitude loading, including mean stress and environmental effects;
- Fatigue-informed design and optimization, uncertainty quantification and transfer of laboratory results to engineering components.