The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Computational homogenization for predicting the macroscopic fatigue life of 3D-printed metallic microlattice materials

F. Mozafari[1*] and İ. Temizer[2]

[1] Department of Mechanical Engineering, Bilkent University, 06800 Ankara, Turkey, mozafari.farzin@gmail.com

[2] Department of Mechanical Engineering, Bilkent University, 06800 Ankara, Turkey, temizer@bilkent.edu.tr

Keywords: *Microplasticity, Entropy, Fatigue, homogenization, Microlattice*

Microlattice materials as custom-architected engineering structures are increasingly used for various applications due to their outstanding tunable properties. However, their heterogeneous microstructures imply built-in complexities in designing and analyzing such materials under fatigue loadings [1]. In this work, we developed a novel micromechanics-based model for fatigue design and analysis of 3D-printed metallic microlattice materials. The key idea is to capture metals' (micro)inelastic deformation of a unit cell in a multiscale setting by employing a recently developed diffused-yielding plasticity theory [2]. The accumulated (micro)entropy generation corresponding to hysteresis (i.e., plastic dissipation) is used as the fatigue indicator parameter (FIP) to predict the onset of fatigue microcracks. A fully-implicit, unconditionally-stable time integration scheme is proposed to implement the constitutive equations into the nonlinear finite element solver. Using experimental data obtained from the three-point bending fatigue test, constitutive parameters are identified for a bulk specimen printed with Selective Laser Melting (SLM) process. The suitably-calibrated model has been employed to conduct a series of microscopic fatigue simulations. It is illustrated that the predictions are in a reasonable accord with the physical experiment data for the macroscopic response, which highlights the quality of our homogenization-based prediction. The experimentally-validated micromechanics-based fatigue model has been verified further by predicting the fatigue life of various topologically-enhanced lattices based on triply periodic minimal surfaces (TPMS) for different relative densities. It is shown that the developed micromechanics-based model provides a versatile framework for fatigue design and analysis of 3D-printed metallic microlattice materials.

REFERENCES

[1] Boniotti, L., S. Beretta, L. Patriarca, L. Rigoni, and S. Foletti, Experimental and numerical investigation on compressive fatigue strength of lattice structures of AlSi7Mg manufactured by SLM.*Int. J. Fatigue*, Vol. **128**, pp. 105–181, 2019.

[2] Mozafari F., Thamburaja P. and Srinivasa A.R., A rate independent inelasticity model with smooth transition for unifying low-cycle to high-cycle fatigue life prediction.*Int. J. Mech. Sci.*, Vol. **159**, pp. 325–335, 2019.