An in-situ study of ductile fracture using random porous metamaterials

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Abstract

Ductile fracture is a common failure mechanism of metals and alloys. It consists of several stages, which involve the nucleation, growth and coalescence of microscopic voids within the metallic matrix. Over the years, intensive efforts have been made to study this complex fracture process and a variety of theoretical as well as numerical models have been formulated to describe these mechanisms. To assess the faithfulness of model predictions, multiscale experiments that allow for the identification of meaningful physical parameters are needed. In the present work, *in-situ* tensile testing is combined with Finite-Element based Digital Volume Correlation (DVC) to study the mechanisms of ductile fracture at the mesoscale. In particular, the influence of void interaction on plastic localization and damage accumulation is investigated using a novel class of metamaterials in which cylindrical voids (with elliptical geometry) are randomly dispersed into a metallic matrix. Their arrangement and geometry are precisely-controlled from design to manufacturing, by combining a Random Sequential Absorption Algorithm (RSA) with Laser Powder Bed Fusion (L-PBF) additive manufacturing.

The results show that model materials of this type effectively display, in their tensile response, several features of ductile fracture of metals-albeit at the mesoscale. For example, it is found that experimental data for the average void growth agree well with the predictions of McClintock's micromechanical model, when void interactions are small. Conversely, voids grow significantly faster when large defects, such as cracks, are present within the matrix. Defects of this type are known to result from L-PBF manufacturing, and are shown to trigger plastic strain localization. To quantify their influence on the observed strain patterns, a Finite Element Model Updating (FEMU) technique is implemented using locally-damaged meshes, in which pre-existing defects are first identified (from the initial tomography) and removed from the nominal (defect-free) mesh.

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