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Mesoscale Investigation of Ductile Fracture with Random Porous Metamaterials

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Abstract

The continuous investigation of ductile failure mechanisms has pointed out random porous metamaterials as attractive model materials for the study of the failure mechanisms of metals and alloys. These materials enable for mesoscale analyses of void growth and coalescence, thereby providing valuable insights for the development of multiscale models In this work, 3D X-ray tomography is combined with full-field kinematic measurements to investigate the mechanisms of void interaction during ductile fracture. Random porous metamaterials, with different pore arrangements, are employed herein. They are generated using a random sequential absorption algorithm and fabricated via laser powder-bed fusion (LPBF) with different printing orientations, employing two aluminium powders (AlSi10 and AlSi20). These random pore distributions are compared to periodic arrangements to assess differences in the mechanical response and strain localization. The specimens are first scanned using X-ray tomography and subsequently their reconstructed volumes are analyzed to assess morphological characteristics of manufacturing defects, such as internal matrix porosity. Finite element–based Digital Volume Correlation (DVC), applied with mesoscale meshes consistent with pore distributions, is then used to quantify void growth and coalescence during tensile loading. The results show that the random pore arrangements lead to highly heterogeneous deformation patterns and delay the formation of long-wavelength strained bands compared to periodic structures. The influence of manufacturing defects is also investigated, highlighting the detrimental effect of lack of fusion defects.

Keywords:

Digital Volume Correlation (DVC) Ductile fracture Process-induced defects Additive manufacturing Metamaterials