
Image-based tracking of the crack propagation within regular and irregular architected materials

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Abstract

Architected materials offer disruptive opportunities to combine low density with high toughness or strength. Tuning their architecture allows for further unlocking of features not intrinsic to the base material, such as negative Poisson's ratio, local toughening, and ultra-stiffness. Due to the reduced slenderness of lattice struts, it is challenging to characterize and predict how engineering the topology of lattice materials alters the local stress state and modifies their macroscopic failure. We propose an approach based on digital image correlation (DIC) to unravel the damage nucleation and propagation mechanisms of 2D lattices under mode I loading. To identify the dominant strut failure modes, we 3D-printed compact tension specimens with stretching and bending-dominated topology (triangular, hexagonal, and Kagome). Using FE-based DIC, we measured the nodal displacements of the joints and extracted the strain distribution within the struts by sub-lattice scale meshing. Based on the gray level residuals, we determined failure criteria for the strut in terms of strain thresholding, and we tracked the crack propagation. By using integrated DIC, the fracture toughness and energy release rates were obtained by a priori knowledge of the detected crack path. Leveraging these local measurements, we assessed the influence of heterogeneities on the lattice strain distribution and thus damage nucleation and propagation mechanisms, resulting in increased work to failure. Ultimately, we highlight how image-based characterization approaches enlighten the effects of the topology and its alterations on the local fracture behavior of lattice materials and provide realistic failure criteria for numerical damage modeling. This insight is essential to design architected materials with engineered properties and customized fracture behavior for real-world applications.

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