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Experimental analysis of the strain rate sensitivity and the scale effect in 3D-printed AlSi10Mg auxetic structures

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Extended Abstract

Abstract

Auxetic materials are a class of artificially engineered structures distinguished by their negative Poisson's ratio (NPR), exhibiting the counter-intuitive behavior of contracting and expanding transversely under compression or tension, respectively. These advantageous properties, which include enhanced energy absorption, high fracture toughness, and superior indentation resistance, make them ideal candidates for lightweight energy absorbers and protective barriers in aerospace and military applications. In order to implement these structures in real-world impact-protection systems, it is crucial to understand how their performance scales with size and how they react to different loading velocities. The main objective of this research is to experimentally evaluate the crushing response of 3D re-entrant auxetic structures. This involves a comprehensive strain rate analysis across quasi-static, intermediate, and high rate loading regimes to determine sensitivity. Additionally, the study aims to quantify the scale effect by analyzing how the number of unit cells along the height axis affects structural stiffness and energy absorption efficiency. Low-speed and high-speed cameras were used to capture the deformation process and track the kinematic behavior throughout the tests. Experimental results demonstrate that the AlSi10Mg auxetic structure exhibits negligible strain rate sensitivity over the investigated range, with both peak force and plateau stress remaining consistent across all tested velocities. However, a significant scale effect was observed; structures with a lower number of unit cells along the height axis showed higher stiffness and enhanced energy absorption compared to taller configurations. These findings indicate that, for this specific auxetic geometry and alloy, structural scale is the predominant design factor for tuning and optimizing mechanical performance under both static and dynamic loading.

Keywords:

Auxetic structure 3D-printed AlSi10Mg strain rate Experimental