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Hierarchically Designed Shell-Plate Metamaterials with Excellent Isotropic Yield Strength

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ABSTRACT

Hierarchically designed metamaterials can be found in numerous fields such as hard biomaterials and man-made structures. Recently, additively manufactured metamaterials are very promising in meeting the increasing demands for materials providing nearly isotropic yield strength in lightweight engineering as the controlled micro-structures. In this paper, a novel hierarchically shell-plate lattice structures are introduced by placing the plates along the closed shell-based structures. With fixed relative density of 10% for hierarchical metamaterials, the effects of different cell sizes and shell thicknesses of shell lattice structures on isotropy are studied. Based on theoretical analysis, the design map is developed for isotropic plate-shell lattices of cubic symmetry. Numerical models based on finite element method (FEM) are further used to validate the design map and have a detailed computational analysis for the isotropic yield strength. It reveals that through a reasonable decrease in cell size and shell thickness for lattice structures, it is promising to generate a hierarchically designed metamaterial with excellent isotropic yield strength. Additionally, these metamaterials are also confirmed by experiments on fabricated specimens through laser powder bed fusion (LPBF). Due the porous structures and excellent mechanical properties, these hierarchical metamaterials have some potential impact on the application of heat-exchange, thermal insulation, and acoustics fields.

KEYWORDS

Hierarchical metamaterial; additive manufacturing; finite element method; isotropic yield strength

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