Towards the Design of Re-Entrant Auxetic Structures with Magnetoactive Mechanical Behavior: A Hierarchical Experimental and Numerical Investigation

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Abstract

Auxetic metamaterials are a class of periodic metamaterials characterized by spatial arrangements of topologically interlinked unit cells capable of counterintuitive lateral deformation under the action of external loads. With the advent of additive manufacturing technology, it is now possible to realize auxetic metamaterials with complex and intricate unit cell designs and to construct architectures composed of combinations of multiple materials with varying mechanical behavior. This fact has been utilized to create adaptive metamaterials that are sensitive to changes in external stimuli such as temperature, pressure, and electromagnetic fields. The parametric nature of the geometric auxetic unit cell leads to the formation of an expansive structure-property design space, which can be exploited to realize auxetic metamaterials with bespoke mechanical behavior. Although several field-driven adaptive metamaterials have been experimentally demonstrated, parametric studies elucidating the effect of the external field on the expansion of the structure-property design space of an adaptive metamaterial are limited. These investigations are crucial in uncovering novel adaptive metamaterial configurations that could be utilized in various engineering fields. In this work, we address this shortcoming through experimental and numerical experiments of a vascular reentrant honeycomb auxetic metamaterial that is composed of magnetorheological fluids. Custom test fixtures are developed to characterize the behavior of these auxetic structures under compressive loading and varying magnetic field strengths. Beginning with the composite struts that constitute the auxetic metamaterial, we develop a simplified analytical model that accounts for the influence of the external magnetic field on the mechanical response of the adaptive auxetic metamaterial. We perform a suite of numerical simulations to explore the expanded field-structure-property design space to uncover the influence of various geometric parameters on the mechanical response of the metamaterial. The presented class of adaptive auxetic metamaterials can find application in energy absorption technologies such as protective armor.

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