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A Finite Element Analysis of Hexagonal Double-Arrowhead Auxetic Structure with Enhanced Energy Absorption Characteristics and Stiffness

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Abstract : Auxetic materials, as an emerging artificial designed metamaterial has attracted growing attention due to their promising negative Poisson's ratio behaviors and tunable properties. The conventional auxetic lattice structures for which the deformation process is governed by a bending-dominated mechanism have faced the limitation of poor mechanical performance for many potential engineering applications. Recently, both load-bearing and energy absorption capabilities have become a crucial consideration in auxetic structure design. This study reports the finite element analysis of a class of hexagonal double-arrowhead auxetic structures with enhanced stiffness and energy absorption performance. The structure design was developed by extending the traditional double-arrowhead honeycomb to a hexagon frame, the stretching-dominated deformation mechanism was determined according to Maxwell's stability criterion. The finite element (FE) models of 2D lattice structures established with stainless steel material were analyzed in ABAQUS/Standard for predicting in-plane structural deformation mechanism, failure process, and compressive elastic properties. Based on the computational simulation, the parametric analysis was studied to investigate the effect of the structural parameters on Poisson's ratio and mechanical properties. The geometrical optimization was then implemented to achieve the optimal Poisson's ratio for the maximum specific energy absorption. In addition, the optimized 2D lattice structure was correspondingly converted into a 3D geometry configuration by using the orthogonally splicing method. The numerical results of 2D and 3D structures under compressive quasi-static loading conditions were compared separately with the traditional double-arrowhead re-entrant honeycomb in terms of specific Young's moduli, Poisson's ratios, and specified energy absorption. As a result, the energy absorption capability and stiffness are significantly reinforced with a wide range of Poisson's ratio compared to traditional double-arrowhead re-entrant honeycomb. The auxetic behaviors, energy absorption capability, and yield strength of the proposed structure are adjustable with different combinations of joint angle, struts thickness, and the length-width ratio of the representative unit cell. The numerical prediction in this study suggests the proposed concept of hexagonal double-arrowhead structure could be a suitable candidate for the energy absorption applications with a constant request of load-bearing capacity. For future research, experimental analysis is required for the validation of the numerical simulation.

Keywords : auxetic, energy absorption capacity, finite element analysis, negative Poisson's ratio, re-entrant hexagonal honeycomb
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