In-plane energy absorption characteristics of a modified re-entrant auxetic structure

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1. INTRODUCTION & OBJECTIVE

Auxetic materials possess a unique property of expanding perpendicularly to the applied tensile force, unlike conventional materials that contract sideways under tension [1]. This intriguing behavior, known as the negative Poisson's ratio (NPR), has attracted significant interest for its potential applications in defense, civil sectors, compliant mechanisms, impact resistance, and more [2, 3]. Auxetic materials demonstrate remarkable performance improvements in energy absorption, shear modulus, indentation resistance, damping, acoustics, and crushing [4, 5, 6, 7].

In the context of re-entrant structures, the flexibility at the vertices plays a crucial role in determining the auxetic behavior. However, creating hinge-like connectors can pose challenges, and sharp corners may lead to stress concentrations. To overcome these issues, we propose a modified re-entrant design based on rounded edges. Our proposed designs have the potential to exhibit excellent auxetic behavior with the appropriate fillet radius, while also circumventing the manufacturing challenges associated with hinge-like connections.

The objective of this study is to conduct numerical and experimental investigations of the modified re-entrant structure and compare its results in terms of energy absorption and maximum stress.

2. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

We utilized ABAQUS 6.14 software with an explicit solver to perform numerical simulations capturing the uni-axial loading behavior and shear behavior, thereby examining the deformation process of the modified re-entrant negative honeycomb meta-structures. For tensile/compressive loading, a uni-axial vertical force was applied at the top section of the unit cell, with rotational constraints implemented at horizontal limbs. The material considered in the simulations is PLA, assumed to be linearly elastic, homogeneous, and isotropic. Material properties were obtained through Tensile tests on 3D printed samples, and the Finite Element Method (FEM) simulated results were compared with experimental data, showing good agreement.

From the FEM results shown in Figure 1(a) and 1(b), it is evident that the modified re-entrant auxetic structures exhibited a reduction of approximately 38% in maximum stress when both structures were compressed to an equivalent amount of strain.

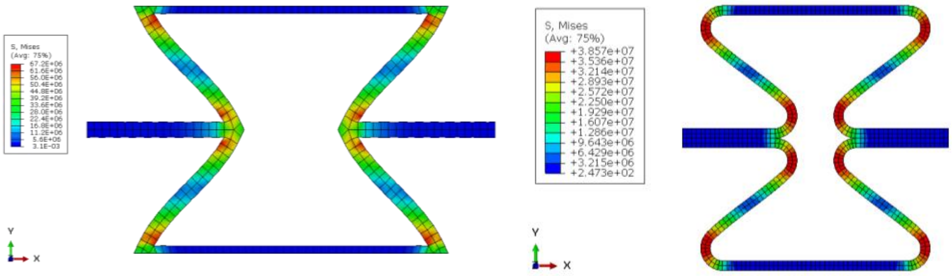

Fig: FEM Simulation of 1(a) re-entrant unit cell and 1(b) modified re-entrant unit cell

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