Mechanical response of modified auxetic re-entrant structure under dynamic compression: A finite element study

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1. INTRODUCTION & OBJECTIVE

The ever-increasing demand for lightweight structures with improved mechanical properties has led to the development of a new class of materials called cellular materials. These materials possess high strength to weight ratio, enhanced specific stiffness and energy absorption characteristics, hence, extensively used in the fabrication of sandwich structures for multifunctional applications. The properties of sandwich structures can be altered by changing the material of core and facesheets or tailoring the topology of the core. Conventional hexagonal honeycomb cores often used in the design of aircrafts, vibration isolation structures, heat insulator, crash boxes, smart structures due to their specific strength, stiffness, energy absorption capacity and out-off-plane behavior[1]. Auxetic structures [2], with negative Poisson's ration are a new class of structures obtained through architecting the topology. These structures shrinks or expands laterally under compression or tension respectively and have gained widespread attention due to their better energy absorption capabilities, damage tolerance, improved fracture toughness, indentation resistance, enhanced shear rigidity and synclastic nature[3]. Among the various classes of auxetics with different core geometries, the re-entrant structure is widely studied due to their simplicity, degree of freedom offered to control auxetic nature and performance.

The performance of sandwich structure with honeycombs can be tailored by changing the core topology, cell wall thickness, length, and other geometrical parameters. A comparative study carried out by Hou et al. (2016) on conventional and auxetic hexagonal honeycombs showed that the plateau stress is higher in auxetic core, and they have better energy absorption ability. Similarly, other studies have compared the performance of honeycombs with hexagonal topology[4], double arrow headed structure[5], Re-entrant[6] and re-entrant star shaped cores under dynamic compression loading. The studies discussed crashworthiness characteristics, energy absorption, failure modes and their effects on core geometry. The results show that the energy absorption and crashworthiness are sensitive to core length than height in the case of hexagonal topology, while the crushing strength and deformation modes are sensitive to velocity in double arrowhead cores. Also, the auxetic nature is influenced by cell wall angle, crushing velocity and strain for re-entrant structures, and for the same wall thickness auxetics absorb more energy than conventional honeycombs.

Primitive re-entrant structure originally proposed has good in-plane compliance and out-of-plane compressive strength but lacks out-of-plane compliance. Huang et al. [7] proposed a modified re-entrant model to improve the out-off-plane compliance, but the performance of the model was demonstrated only for in-plane quasi static load. However, as auxetic structures are mostly used in energy absorption applications, characterizing their energy absorption characteristics under dynamics loading is important. Hence, this study focuses on characterizing the dynamics response of the modified re-entrant structure under dynamic compression loading.

2. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

The study investigates the in-plane dynamic response and crashworthiness of the modified re-entrant core (Fig.1) using the finite element method for compression velocities ranging from 1-100 m/s. The deformation modes, Poisson's ratio, energy absorption and their variation with loading were evaluated for all loading cases and compared with primitive reentrant geometry. The proposed structure is expected to show better energy absorption, reduced peak load and gradual collapse modes under dynamic compression. The results of this study can be used to design efficient energy absorbers with auxetic geometries for various engineering applications.

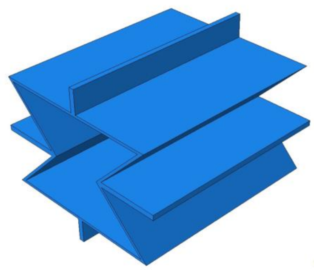

Figure 1. Modified re-entrant unit cell.

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