Comparison of the Nonlinear Elastic Behavior of Auxetic Lattice Architectures

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Introduction

Mechanical metamaterials are man-made materials which derive their unusual properties from the geometry of their microstructure rather than their constituents. Auxetic metamaterials (materials with a negative Poisson's ratio) exhibit mechanical properties in the (quasi) static regime that are potentially promising for impact protection, given these properties are preserved in the highly dynamic regime. In this regime it is an open question to which extent the mechanical properties are retained and can possibly be maintained by adjustments in the microstructure, since the highly dynamic impact regime is typically accompanied by rate and inertia effects with geometrical nonlinearities as well as large plastic deformations and material nonlinearities.

Study

In a first step the geometrically nonlinear, elastic behavior of different auxetic architectures is investigated. The architectures shown in Figure 1 are all designed to posses the same Young's modulus of 20000 Pa and the same density of 1570 $kg\ m^{-3}$ and are subsequently compared for impact velocities ranging from quasi static (0 s^{-1}) up to strain rates of 10000 s^{-1} and for compression up to 30%. In Figure 2 the quasi-static responses of the different architectures with the given linear properties for large compression can be seen. The same architectures undergoing different strain rates are displayed in Figure 3.

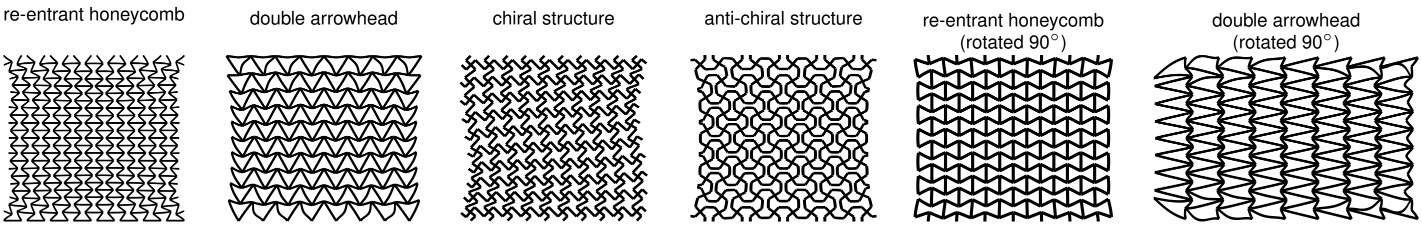

Figure 1: different architectures considered at 10% compression

Results

With the increase in strain, re-entrant honeycomb (rotated 90°) and double arrowhead architectures show an increased stiffness (see Figure 2), since here vertical beams are carrying the load. At higher strain levels, these structures are buckling and thus rapidly losing stiffness. Other structures exhibit a reduced stiffness from the start, due to a more horizontal orientation of the beams leading to longer leverage effects.

When looking at high strain rate cases a plateau stress is reached (compare Figure 3), which shows the maximum amount of resistance for the architecture. Whilst this plateau stress is independent of the velocity in most structures, it shows dependency on the velocity in re-entrant honeycomb (rotated 90°) and reduced resistance in the chiral structures architecture.

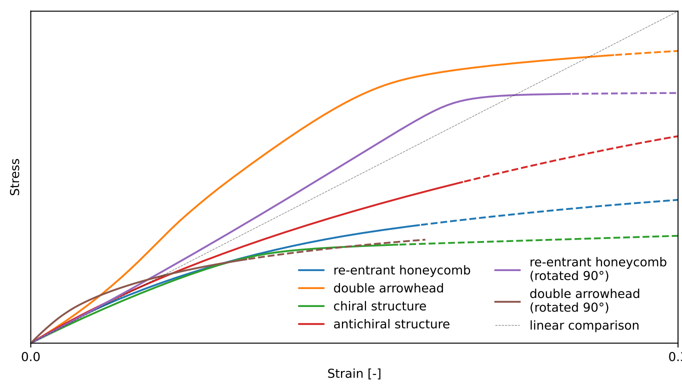

Figure 2: finite strain applied to the different architectures (dashes indicate not modeled self-contact in the structures)

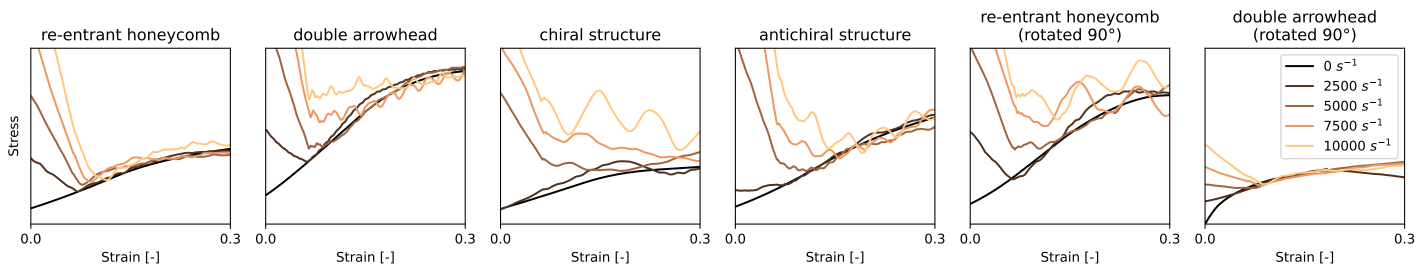

Figure 3: comparison of the effects of high strain rates on different architectures

PhD progress

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