Effects of Material Architecture in Elastic Impact Mitigation

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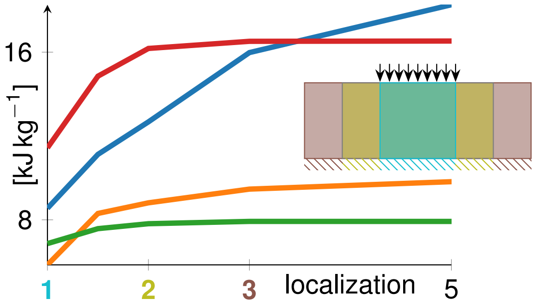

Figure 1: energy intake at 20 % compression and 10 ms^{-1} compression rate

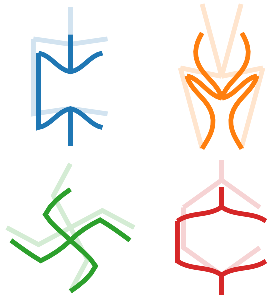

Figure 2: unit cells tuned to $E_y^\star$ = 300 MPa and $\rho_{\text{rel}}^\star$ = 0.1

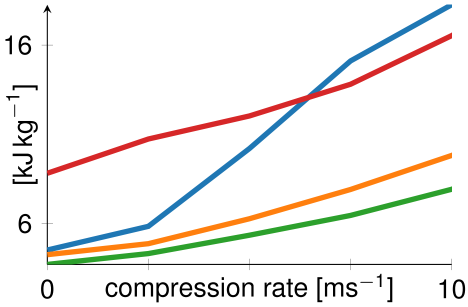

Figure 3: energy intake at 20 % compression and a localization of 5

Introduction

Metamaterials are materials architected to exhibit unique properties based on their microstructure, rather than their constituents. Auxetic metamaterials, materials with a negative Poisson's ratio, demonstrate mechanical properties in the quasi-static regime that present potential for impact protection, provided that these are preserved in the dynamic regime. In this regime, it remains uncertain to what extent the mechanical properties can be preserved by microstructural adjustments, since an impact is typically accompanied by rate and inertial effects with geometric nonlinearities.

Impact Mitigation

At low localizations and compression rates, the regular honeycomb shows the highest energy adsorption. Only the re-entrant honeycomb is able to adsorb more at high localizations (> 3, Figure 1) and compression rates (> 7.5 ms^{-1}, Figure 3). Structures do not exhibit benefits solely based on their auxeticity. Especially the chiral and arrowhead do not generate an advantage. The evolution of elastic properties over deformation modes dominating impact (confined compression and shear) is a better predictor for the impact mitigating qualities of materials.

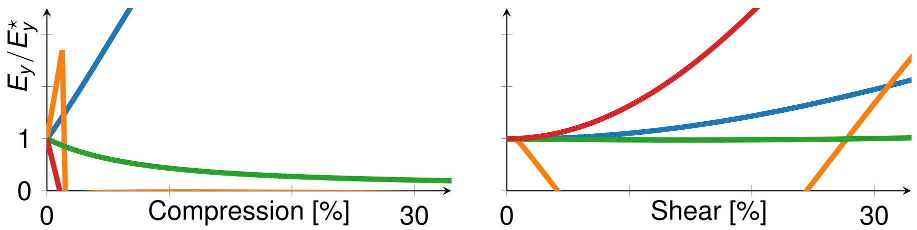

Figure 4: $E_y/E_y^\star$ under confined compression and shear

Property Evolution

Laterally folding materials (re-entrant honeycomb and arrowhead) are orienting their beams towards stretching-dominated behavior. This increases the Young's modulus, but is susceptible to buckling. The honeycomb structures (re-entrant and regular) show both the hightest Young's Modulus throughout deformation (Figure 4) as well as pressure wave velocities c_{P_x} (Figure 5). It is also observable, that the velocities of lateral shear waves c_{S_x} are negligible compared to the pressure waves.

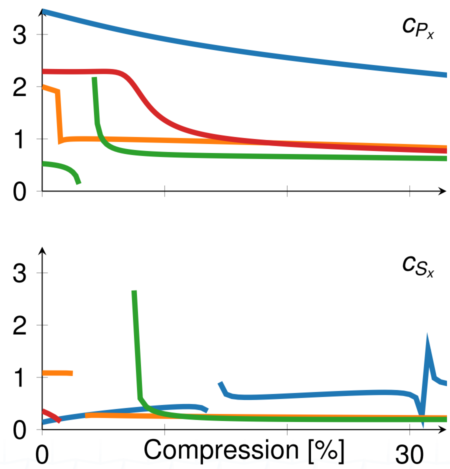

Figure 5: c_{P_x}, c_{S_x} [km s^{-1}] under confined compression

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