

Numerical and experimental study of bistable lattice metamaterials for energy absorption

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ABSTRACT

The goal of this work is to study metamaterials with a two-dimensional lattice microstructure and to assess specific geometries that enhance energy absorption efficiency in honeycomb structures. The approach leverages curvilinear beam elements at the unit cell level, exhibiting a non-monotonic stiffness response under compression. This bistable mechanism, comprising coupled curved beams that undergo stable transitions between two equilibrium states, improves the impact protection capabilities of these structures. For the modeling, a geometrically nonlinear two-dimensional formulation of a beam element, originally introduced in a study on Euler-Bernoulli curved beams and later extended to incorporate transverse shear strain [1,2], is adopted. It employs an integrated form of equilibrium equations, combined with kinematic and generalized material equations, leading to three differential equations, discretized using finite differences. The boundary value problem is then transformed into an initial value problem via a shooting-method-inspired technique [3]. Numerical simulations performed on lattices with different shallowness were experimentally validated using 3D-printed specimens subjected to compressive loading. In both experimental and numerical tests, the energy absorption capability of the structures was assessed through parameters such as total energy absorption, mean crushing force, specific energy absorption, and crush force efficiency.

References

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