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Influence of Controlled Disorder on the Crushing Perfomance of Hexagonal Lattice Metamaterials

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Lattice metamaterials are widely investigated as efficient lightweight energy-absorbing structures because their mechanical response can be tailored through geometry. Among them, out-of-plane extruded hexagonal lattices represent the bechmark configuration against which novel architectures for progressive collapse under compressive loading are evaluated. Most studies focus on periodic or random configurations, and deviations from nominal geometric parameters are treated as manufacturing defect that need to be limited, rather than as a source of controllable design parameter. This limits the understanding of how deviations from periodicity affect collapse mechanisms, stress transmission, and energy absorption.

In this work, controlled disorder is introduced as a design choice, and applied to an extruded hexagonal lattice to assess its influence on the crushing performance of the metamaterial. Starting from a nominal honeycomb configuration, disorder in introduced by perturbing the nominal metamaterial geometry. Disordered variants are generated while preserving the overall footprint, average geometric properties, and relative density. The resulting architected structures are first investigated through numerical simulations, where the full stress–strain response is used to compare the nominal and disordered configurations in terms of peak response, plateau stress, densification behavior, and specific energy absorption. Then, experimental drop-tower tests on additively manufactured nominal and disordered representative configurations are carried out.

The experimental and numerical observations bring evidence that controlled disorder can be introduced to tune the crushing response of metamaterials for energy absorption. The outcome is a mechanical assessment of disorder as a practical design variable for programming energy absorption in lightweight metamaterial structures.

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