

Numerical and experimental investigation of buckling in additively manufactured lattice metamaterials

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Abstract

Lattice metamaterials realised via additive manufacturing represent a promising class of highly tunable structures, whose mechanical response is strongly governed by geometry, material properties and manufacturing-induced imperfections. Among the various mechanical phenomena characterizing these systems, buckling and instability play a key role, especially in beam-like lattice configurations subjected to compressive loading. In this work, a combined numerical and experimental investigation of the buckling behavior of additively manufactured lattice metamaterials is presented. The study focuses on one-dimensional beam-like lattices obtained by the periodic arrangement of selected two-dimensional square unit cells (UCs). The specimens, composed of 5, 10, 15 and 20 UCs, are fabricated in thermoplastic polyurethane (TPU), using two different 3D printer systems and materials characterized by distinct Shore hardness values. The experimental campaign highlights how relatively small differences of constitutive properties are significantly amplified by the manufacturing process, including printer-dependent settings, process parameters and inherent printing-induced imperfections. These effects result in

noticeable variations in the onset of instability and post-buckling response, even for nominally identical lattice geometries. A numerical modeling framework is developed, accounting for geometric imperfections [1]. The results highlight the sensitivity of the global buckling response to both material variability and manufacturing-induced defects, demonstrating that instabilities of additively manufactured lattice metamaterials are governed by a combined effect of lattice architecture, material properties and manufacturing induced imperfections. References: [1] L. Parente, D. Addessi, P. Di Re, C. Gatta, E. Sacco, 2025. Micromechanical buckling analysis of soft lattice metamaterials accounting for randomly distributed imperfections. Mechanics Research Communications.

Keywords:

3D printing TPU lattice metamaterials buckling geometric imperfections