Nonlinear multiscale simulation of elastic beam-lattices with anisotropic constitutive models based on artificial neural networks

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Key Words: Beam lattices, multiscale simulation, finite deformations, anisotropic hyperelasticity, machine learning

ABSTRACT

Beyond light-weighting applications, additive manufacturing also facilitates the fabrication of soft and flexible lattice structures and metamaterials, e.g., from polymers or hydrogels. In this work, we present a computational multiscale modelling method for elastic beam-lattices, which are subject to large deformations and microstructural instabilities. For this purpose, we model the unit cells of these cubic metamaterials as beam structures and perform microstructural nonlinear post-buckling analyses with various applied deformations using periodic boundary conditions. These homogenized simulations serve as training data for the calibration of effective, anisotropic hyperelastic constitutive models, which are formulated as artificial neural networks using hybrid theory-based and data-driven approaches that fulfil objectivity and material symmetry requirements. These constitutive models are then employed for the macrostructural finite element simulation of lattice structures subject to finite deformations. We show that these machine learning material models can accurately and efficiently reproduce the effective behaviour of beam-lattices subject to severe nonlinearities such as buckling of struts. Furthermore, they can also be parameterized in terms of material, geometric or topological lattice parameters, which allows design and simulation of graded lattice structures and inverse design or optimization of unit cells.

REFERENCES