Design and mechanics of 3D intertwined helix-based architected materials

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Abstract

Helix-based intertwined architected materials belong to a newly class of metamaterials created from a lattice structure whose trusses are hierarchically made by helices. The generated material is hence composed by a complex network of structured filaments, which suppress stress concentration, giving rise to interesting properties such as high compliance, increased strain at failure, high energy dissipation. One of the novelties of this work relies in the design of such periodic structures, which is tackled first from a topological description of the unit cell, followed by an optimization of the spatial features of the fibres. A thorough study of the topology of the unit cell involving tools from computational combinatorics allows to span the whole range of possible connections amongst intertwined filaments. Then, optimization of the spatial features of the fibres completes the unit cell geometry, resulting in lower density and improved initial and contact-induced stiffness for each given topology. A wide spectrum of the generated intertwined material designs is tested within an in-house finite element variational framework, which includes a novel implementation of frictional contact, being it at the core of the interaction between filaments. This allows to find a clear relation between the topological description and the mechanical response of the material, paving the way to manufacture 3D intertwined structures with tailored properties.

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