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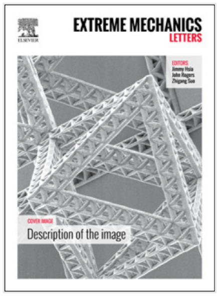

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Can tailored non-linearity of hierarchical structures inform future material development?

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Abstract

An analytical investigation into the non-linear elastic response of helical lattice structures coupled with an elastic medium is presented. Novel composite templates are then obtained to produce bespoke material characteristics by exploiting tuned hierarchy. System behaviour is approximated as a combination of three non-linear "springs", representing the helical lattice, and the axial and circumferential components of the elastic medium via an energy based approach. Non-dimensional parameters governing each component's non-linear load-displacement behaviour are identified, demonstrating tailoring potential. Further tunable parameters that govern the combined system response, involving form factor, geometric and stiffness ratios are identified. In particular, pseudo-ductile responses are observed. The feasible region of pseudo-ductility, as determined by these non-dimensional parameters, is obtained, allowing discussion of viable materials and geometries. Finally, load-displacement behaviour is utilised to obtain indicative effective stress-strain curves, thus showing promise as a model for future material development.

Keywords: Pseudo-Ductility, Analytical Modelling, Non-Linear Elasticity, Hierarchical Structures.

1. Introduction

Structures that present non-linear elastic responses to applied loading have the potential to offer predictable, repeatable, load-displacement behaviour that has favourable characteristics. We describe how a hierarchical structure composed of a helical lattice and elastic medium can be successfully tuned to achieve a set of desired characteristics. In general, the resulting behaviour may be tuned to a variety of responses, however, to highlight one such possibility, we focus on the introduction of pseudo-ductile qualities in the resulting system's elastic stress-strain response. As there is no universally accepted definition of pseudo-ductility, herein, we describe pseudo-ductile systems as those that possess characteristics that mimic the key features of a traditional ductile material via non-linear elasticity, e.g. a softening of the effective modulus following an initially positive region.

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