Topology optimization for engineering multifunctional cellular composites with elastic metamaterials

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ABSTRACT

This paper focuses on topology optimization [1, 2] of engineering a kind of functionally graded cellular composites [3] with auxetic metamaterials [4], which includes:

Firstly, we will develop a multi-scale design formulation that is in order to account for both the auxetic behaviour of the microstructure and the stiffness of the macrostructure. The multi-layered artificial composite is tailored to exhibit functionally graded properties for both stiffness and auxetic behaviours, subject to a volume constraint to enable gradient feature over layers.

Secondly, the microstructures for all individual layers to found the macro composite are topologically designed under the consideration of boundary and loading conditions at the macro scale.

Finally, a level set method [5] is used to achieve topological shape changes for each representative microstructure that is used to periodically configure each composite layer, in association with the numerical homogenization method to evaluate the effective properties of the representative unit.

A couple of typical numerical examples are applied to showcase the effectiveness of the proposed design method. The results show that the topologically design cellular composite can systematically integrate the core features of the conventional functionally graded materials and cellular composites, with the elastic metamaterials to deliver a new family of artificial composite materials.

Keywords: Topology optimization, Level set method, Functionally graded materials (FGMs), Cellular composites, Auxetic metamaterials.

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