ARCHITECTURED AND ADDITIVELY MANUFACTURED DOUBLE-NEGATIVE INDEX METAMATERIALS

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Metamaterials are artificially engineered materials with periodic microstructures that exhibit properties that are unattainable in traditionally manufactured materials. Most contributions in literature focus on metamaterials that exhibit negative Poisson’s ratio (NPR) or negative thermal expansion (NTE) separately. However, a recent interest has raised in metamaterials coupling both negative indexes, the so-called aneptic metamaterials [1]. Nonetheless, obtaining metamaterials with target properties by the systematic design of their microstructure remains a major challenge to this day. Here, the authors perform Finite Element Analysis (FEA), Topology Optimization (TO), fabrication, testing and characterization of such metamaterials aiming to contribute to the development of a new generation of metamaterials going through an engineering-cycle. The first experimental development of an aneptic metamaterial reported in the literature presents a bi-material polymeric re-entrant truss-like microstructure [1]. To simulate in-silico the experimental results presented in that pioneer work, a microstructural Finite Element Model (FEM) is presented here. In the framework of elastic continua, an auxetic microstructure is designed by homogenization-based topology optimization [2]. The optimal microstructure is then post-processed such that it can be 3D printed and tested using Digital Image Correlation (DIC) techniques. The FEA is performed on optimal microstructure lay-outs and enriched to be effective in predicting the behaviour of the experiments carried out. To that purpose, scale-size effects are studied implying the evaluation of the metamaterial thermomechanical properties which are sensitive to the number of repetitions of a Representative Volume Element (RVE). The design of aneptic microstructures by topology optimization is envisaged as well as the respective experimental validation. The present work emphasizes thus the importance of the engineering-cycle completion, i.e., starting with the systematic and optimal design of metamaterials and ending up in prototype fabrication and its verification.

REFERENCES