DESIGN AND OPTIMIZATION OF DISSIPATIVE ELASTIC METAMATERIALS AND THEIR APPLICATIONS FOR BROADBAND BLAST AND SHOCKWAVE MITIGATION

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ABSTRACT

Elastic/Acoustic metamaterials comprise a new class of composite materials that possess unique effective material properties owing to their locally resonant substructures. Because of the inherent local resonance mechanism, elastic metamaterials have the ability to completely stop the propagation of elastic/acoustic waves over specific frequency regions (band gaps). However, the band gap regions of non-dissipative metamaterials are fixed, and therefore, broadband absorption is not possible. This draw back can be overcome by incorporating dissipative components into metamaterial substructures. Furthermore, the elastic/acoustic wave absorption can be enhanced through optimization of the metamaterials structural topology and constituent material properties. In this study, a dissipative elastic metamaterial with a multi-resonator substructure capable of broadband acoustic/elastic wave absorption is analyzed. Investigation of the wave absorption properties over a broad frequency range is then carried out via dispersion relations obtained from an analytical model as well as numerical modeling using the finite element method. Then, a biological evolution inspired algorithm is employed in order to carry out parameter optimization. By optimizing the dissipative metamaterials structural geometry and constitutive material properties, the absorption amplitude is significantly enhanced over a broad frequency range. A continuum microstructural design of the dissipative elastic metamaterial is then proposed and numerical simulations are conducted where the absorption/attenuation of elastic stress waves is used as the measure of performance. Finally, two optimal designs are chosen for fabrication using hybrid 3D printing and injection molding manufacturing methods.