Homogenized enriched continuum analysis of acoustic metamaterials with negative stiffness and double negative effects

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Abstract

This paper demonstrates the application of a recently developed enriched micro-inertial continuum based homogenization framework towards numerical dispersion and boundary value problem analyses of local resonance metamaterials exhibiting sub-wavelength negative stiffness and double negative effects (i.e. simultaneous negative effective mass density and stiffness). This is a novel development since homogenized structural dynamic analyses that specifically incorporate negative stiffness effects have not yet been extensively explored. The proposed methodology is successful in approximating the negative stiffness effect to a certain degree. Accordingly, an appropriate error estimation procedure based on dispersion analyses is proposed to identify the limits of the reliability of the homogenized model. The resulting methodology provides a highly efficient framework for the analysis of double negative metamaterial problems involving a non-trivial macroscopic loading, the influence of the applied boundary conditions, and a complex unit cell design. This is illustrated through a case study involving the refraction analysis of a double negative metamaterial prism.

Keywords: local resonance, double negativity, acoustic metamaterial, dispersion spectrum, multiscale analysis, homogenization