Metamaterials in Sound/Vibration Applications

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Abstract

Metamaterials exhibiting unusual properties were initially developed in the fields of electromagnetism and optics, and later extended to acoustics and elasticity. Those metamaterials can generate bandgaps through local resonance (LR) mechanism. Based on the concept of local resonance (LR), we developed various LR units, including spring–mass systems, membrane-type structures, and double-spiral systems, which are embedded in the host medium for use in engineering vibration control applications. By altering the geometric parameters of the LR cell, the bandgap characteristics can be readily tuned. The integration of smart materials into metamaterials enables more flexible tuning of bandgap properties without altering the structural geometry. The use of a negative capacitance resonant shunt can shift the bandgap to lower frequencies as well as broaden the gap width. Lightweight membrane-type acoustic metamaterials (MAMs) also can be used for sound isolation. Unlike traditional porous or fibrous materials that perform effectively in the high-frequency regime, MAMs overcome the mass-law limitation and operate effectively at low frequencies. Adjusting the physical properties of MAMs enables tuning of the transmission loss (TL) band. To generate multiple TL peaks, asymmetrically arranged masses were adopted. Helmholtz resonators have also been considered effective alternative noise reduction filters, but their bulky size limits their application in the low-frequency regime. We employed the concept of coiling up space to construct two-dimensional coplanar Helmholtz resonators for absorbing low-frequency sound. With two resonators assembled in parallel, sound absorption band can be effectively broadened.