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Isolating Low-Frequency Vibrations via Lightweight Embedded Metastructure

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ABSTRACT

Lightweight engineering structures often suffer from low-frequency vibrations that are not limited to single polarization. The emerging field of metastructures offers a practical solution for the low-frequency vibration isolation without introducing extra structures having gigantic size or heavy weight. In this research, an embedded metastructure is proposed for honeycomb-based lightweight structures, which can suppress low-frequency vibrations with different polarizations by strategically positioning locally resonant microstructures while keeping its load-bearing capacity. By using 3D printing technique, the subwavelength microstructure can be easily fabricated with its geometrical parameters precisely controlled. First, the band structure with polarized bandgap of the metastructure unite cell have been analysis by numerical simulation and the vibration isolation capability of the metastructure beam under vibrations with single-polarization and multi-polarizations have been validated by experiments. However, this simple design is difficult to be effective for ultra-low frequency vibration while maintaining lightweight. To solve this problem, a microstructure with ultra-low stiffness is designed by using quasi-zero stiffness (QZS) mechanism. The microstructure consists of a curved beam that produces the negative stiffness and a straight beam that produces a positive stiffness. By adjusting the geometric parameters, the overall stiffness of the microstructure can be close to zero when the curved beam buckled. The assembly stress can make the curved beam buckle when the microstructure is embedded. Finally, we fabricate the ultra-low-stiffness microstructure with 3D printer and experimentally study its static as well as dynamic properties. The comparison between numerical and experimental results are also provided to validate our metastructure design.