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Continuous CFRP Composites for Multifunctional Acoustic and Mechanical Metamaterials

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ABSTRACT

The urgent need to achieve "carbon neutrality" drives the development of innovative porous structures that integrate both acoustic and mechanical properties, aimed at reducing energy consumption. However, enhancing these functionalities often results in increased structural weight, which can restrict their application in scenarios where weight is a critical factor. In response to this challenge, we present a groundbreaking structural design that combines carbon fiber reinforced polymer (CFRP) composites with mechanical and acoustic metamaterials for the first time. This novel construction is characterized by its lightweight nature while delivering exceptional mechanical strength and acoustic performance.

The experimental results indicate that with careful design and fabrication, CFRP composite structures can strike an optimal balance among lightweight construction, high strength, impressive energy absorption, and remarkable durability. By incorporating advanced membrane designs and strategically arranged cavities, the structure achieves significant broadband noise reduction through local resonance effects and the impedance matching mechanisms inherent in metamaterials. Notably, the sound insulation performance of this structure transcends traditional mass law principles, leading to an extraordinary sound insulation peak with a bandwidth approaching 1000 Hz. Additionally, its sound absorption capability outperforms that of melamine sponge materials at frequencies below 300 Hz, showcasing superior low-frequency sound absorption. This innovative structure paves the way for the design of multifunctional lightweight superstructures, offering new opportunities for sustainable engineering applications.

KEYWORDS

Auxetic; acoustic metamaterial; composites; negative Poisson's ratio; local resonance; impedance matching

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