Design and fabrication of bioinspired self-similar and non-self-similar metamaterials

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Résumé

Hierarchical structures with constituents organized across multiple length scales are commonly found in natural materials such as bones, shells, and spider silk. These materials exhibit remarkable quasistatic mechanical properties, including high specific strength, stiffness, and toughness. However, the impact of hierarchical organization on the dynamic behavior of metamaterials remains relatively underexplored compared to its static counterparts.
This presentation examines the influence of bioinspired hierarchical architectures-accounting for viscoelastic effects-on the wave attenuation properties of phononic crystals and elastic metamaterials. Both self-similar and non-self-similar unit cells with varying hierarchical levels and configurations are analyzed.

Key findings highlight the advantages and trade-offs associated with structural hierarchy:

Advantages:

- Hierarchically induced band gaps emerge alongside those found in corresponding non-hierarchical structures, providing enhanced control over wave propagation.

- Hierarchical designs enable tuning of band-gap frequencies to lower ranges while significantly reducing overall structural weight.

Trade-offs:

- Due to the specific design approach (holes within a matrix), structural rigidity may be compromised.

The results, supported by numerical simulations and experimental validation, emphasize the critical role of even small viscoelastic effects in shaping attenuation behavior, particularly between band gaps. These findings underscore the potential of hierarchical designs for advancing the dynamic performance of metamaterials.

1. Design and fabrication of bioinspired hierarchical dissipative elastic metamaterials -M Miniaci, A Krushynska, AS Gliozzi, N Kherraz, F Bosia, NM Pugno
Physical Review Applied 10 (2), 024012, 2018

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2. Bio-inspired non self-similar hierarchical elastic metamaterials
M Mazzotti, A Foehr, OR Bilal, A Bergamini, F Bosia, C Daraio, NM Pugno, International Journal of Mechanical Sciences 241, 107915, 2023