DOI: 10.32604/icces.2025.010448

PROCEEDINGS

Maximizing Sound Absorption in 3D Printed Lattice Structures

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ABSTRACT

Advances in 3D printing have unlocked new opportunities for developing lattice structures tailored for enhanced sound absorption. This work explores methods to maximize sound absorption in microlattice designs by introducing heterogeneity, leveraging dual dissipation mechanisms, and reshaping cavity wall geometries. We present a multilayered Helmholtz resonance (MLHR) analytical model to predict and guide the design of broadband sound-absorbing lattices [1]. Through structural optimization, we demonstrate that heterogeneous microlattices with varying pore and cavity morphologies achieve broadband absorption [2–4], with experimentally validated absorption coefficients exceeding 0.75 across a wide frequency range from 1000 to 6300 Hz.

Beyond MLHR, we introduce hollow-truss metamaterials that harness dual concurrent dissipation mechanisms through their complex truss interconnectivity and hollow interiors [5]. By subtractively introducing a dissipation mechanism through the hollowing of struts, hollow trusses enable additional thermoviscous dissipation within the hollow cavities of the trusses. This internal dissipation arises from acoustic waves interacting with the hollow interiors, operating concurrently with the MLHR dissipation occurring along the outer solid surfaces of the trusses, thereby broadening the effective absorption bandwidth. Results demonstrate that HTMs exhibit superior broadband absorption, achieving a high average absorption coefficient of 0.72 at a low thickness of 24 mm.

Beyond traditional geometric tuning, we also introduce a new concept of reshaping cavity walls to drastically improve thermoviscous dissipation without increasing mass or volume [6]. By strategically positioning cavity walls closer to the pores, additional boundary-layer dissipation occurs at the pore–cavity interface, leading to substantial absorption gains. Experimental results demonstrate that a cuboid cavity with three walls near the pore achieves a 44% increase in maximum absorption compared to a conventional design.

KEYWORDS

Lattice structures; acoustics; optimization; transfer matrix method; finite element analysis

Acknowledgement: The author would like to thank collaborators, Dr Zhai Wei, Dr Yu Xiang, Dr Li Zhendong, Dr Zhao Miao, and Mr. Chua Jun Wei, for their contributions to the research studies referenced to in this work.

Funding Statement: The author would like to acknowledge the Research Support Allowance from Newcastle University that have supported the work.

Conflicts of Interest: The author declares no conflicts of interest to report regarding the present study.

References

1. Li, X., Yu, X., Chua, J. W., Lee, H. P., Ding, J., Zhai, W. (2021). Microlattice metamaterials with simultaneous superior acoustic and mechanical energy absorption. *Small, 17(24),* 2100336.

2. Li, X., Yu, X., Zhai, W. (2021). Additively manufactured deformation-recoverable and broadband sound-absorbing microlattice inspired by the concept of traditional perforated panels. *Advanced Materials, 33(44),* 2104552.

3. Li, X., Yu, X., Zhao, M., Li, Z., Wang, Z., Zhai, W. (2022). Multi-level bioinspired microlattice with broadband sound absorption capabilities and deformation - tolerant compressive response. *Advanced Functional Materials, 33(2),* 2210160.

4. Li, X., Ding, S., Wang, X., Tan, S. L. A., Zhai, W. (2024) Recipe for simultaneously achieving customizable sound absorption and mechanical properties in lattice structures. *Advanced Materials Technologies*, 2400517.

5. Li, X., Yu, X., Zhai, W. (2022). Less is more: Hollow - truss microlattice metamaterials with dual sound dissipation mechanisms and enhanced broadband sound absorption. *Small, 18(44),* 2204145.

6. Li, X., Yu, X., Chua, J. W., Zhai, W. (2023). Harnessing cavity dissipation for enhanced sound absorption in Helmholtz resonance metamaterials. *Materials Horizons, 10(8),* 2892-903.