High Bulk Modulus Pentamodes: the Three-Dimensional Metal Water

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Abstract

Over the last two decades, considerable effort has been devoted to the development of acoustic metafluids: engineered solid structures that mimic the properties of fluids to manipulate sound waves. A key player in this field is the pentamode metamaterial, which mimics fluid behaviour due to its singular elasticity tensor. Designing a 3D version of these metamaterials that mimics the behaviour of water holds great promise for underwater applications such as perfect lenses and cloaking (1). Excellent results have been demonstrated for the 2D approximation (2), but existing 3D geometries face limitations in density and stiffness due to their lattice structures (3, 4, 5).

In this study, published in (0), we introduce a novel pentamode lattice that builds on existing mechanical networks. By extending the concept of double cones and addressing theoretical limitations related to bulk modulus, we propose an alternative shape for lattice links to overcome these constraints. A link based on parallel fibres, acting as an ideal slider, allows lower shear and higher axial stiffness to be achieved, effectively removing the upper limit on the ratio of bulk to shear modulus.

In this way, we model the primitive unit cell of 3D metallic water: using low-frequency homogenisation, we obtain an effective elastic solid with a satisfactory bulk modulus and minimal shear-to-bulk ratio. The dynamic behaviour of the lattice is also investigated, revealing two band gaps where only compressional waves propagate, further enhancing the potential of the material for practical applications.

The presentation will discuss preliminary fabrication results and experimental validations.

References

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