Gear-Based Topological Mechanical Metamaterials

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The ability to engineer metamaterials with properties and functionalities not found in nature is a revolutionary concept with exciting technological applications. Mechanical metamaterials use mechanisms as fundamental building blocks to achieve novel behaviors. In recent years, topology has transformed our understanding of physics, ranging from electronics to photonics. This project combines these two lines of developments to address the natural question of whether the ideas of topology extend to mechanical metamaterials. In this work, I studied geared mechanical metamaterials. The addition of rotational degrees of freedom expands the basic elements available for designing materials, resulting in new phenomena. I studied metamaterials based on the Martini and Hexachiral lattices. Initially, I optimized the design and manufacturing process, focusing on factors such as cost, production time and repeatability. Then, I conducted a series of experiments to analyze the behavior of these prototypes under various types of deformations. I determined the presence of localized edge zero modes, a key characteristic of topological materials, and investigated how rotational degrees of freedom affect the global stability of the materials. Finally, I determined the compatibility matrices for the metamaterials based on the Martini and Hexachiral lattices and performed a computational study of the effects of varying lattice geometries. My computations revealed the specific geometries at which topological phase transitions occur. The convergence of topology and mechanical metamaterials is a nascent field. The concepts investigated in this work hold great potential for applications ranging from nanomachines to unraveling the intricate mechanisms driving morphogenesis in living organisms.

Awards Won:

Fourth Award of $500

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