Controlling Deformation and Instability of Magnetoactive Metamaterials

Tigernach Feehilly*†[1], Marc Geers[1], Ron Peerlings[1], and Ondřej Rokoš[1]

[1]Eindhoven University of Technology [Eindhoven] – Netherlands

Abstract

Mechanical Metamaterials are materials with exotic behaviours not commonly found in nature, such as negative Poisson's ratio (Saxena, 2016). The material's microstructure, in addition to the choice of base materials, governs these behaviours. Initially, metamaterial designs typically were limited to the small strain regime. However, recent studies have begun to focus more on large deformations, taking optimal benefit of nonlinearities (geometrical and material). Under large deformations, buckling can lead to large changes in the effective metamaterial behaviour. For example, buckling has been used to enhance the vibration of dampening elastic materials while maintaining a high specific stiffness and low density of the material (Dykstra, 2023). However, when fabricating metamaterials, only a single microstructural morphology is typically used; thus, the material's properties cannot be altered during its use.

Creating materials that can alter their properties during use requires methods to interact with the material in a fashion that does not impede the intended use. Including stimuli to actuate the material, such as electromagnetic, chemical, thermal, photo, or pneumatic stimuli, adds new mechanisms for active material control during use. Magnetism is particularly interesting in applications for metamaterials as it allows untethered rapid control and have also recently gained interest in controlling deformation and altering properties (Lu, 2024).

In this contribution, we present a study embedding magnetisation into existing hyperelastic metamaterials to achieve switchable stiffness. In doing so, we can achieve materials with a variable structural stiffness, exploiting the understanding of the coupled effects of magnetic and mechanical loading. We show numerically that with a proper strategy, it is possible to design materials with tuneable critical buckling load under uniaxial mechanical compression, with negligible change in the pre- and post-buckling stiffness. Alternatively, it is also possible to switch post-buckling deformation and alter post-buckling stiffness by up to 10% by application of an externally applied magnetic field. Thus, we demonstrate a class of materials with switchable and tuneable properties without fabricating new microstructures.

References

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*Speaker

†Corresponding author: t.s.feehilly@tue.nl

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