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Topology optimization of 3D auxetic metamaterials

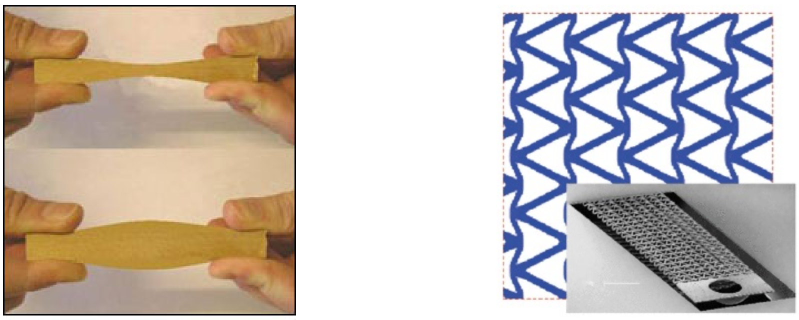
Master of Science project

Abstract

This M.Sc. project consists in the computational design of 3D auxetic metamaterials. The student will implement advanced numerical methods for the optimization of such complex materials within hybrida, a rapidly growing in-house finite element library that is currently being developed at the Structural Optimization and Mechanics (SOM) group.

Introduction Contrary to natural materials, whose behavior is mainly determined by their composition, metamaterials obtain functionality that is not often seen in nature by means of the way they are structured at relatively small length scales. These advanced materials are usually created from a common unit cell that is repeated periodically along orthogonal directions. By means of repetition, the functionality of the periodic unit cell (PUC) is then amplified and thus a larger effect can be noticed at bulk. Metamaterials thus have tremendous potential as they broaden the spectrum of functionalities with new applications that not too long ago were undreamed of. Considering that metamaterials are created from a repeating building block structure, their design and creation present many significant challenges in precision and micro-systems engineering science. The realm of metamaterials has spread out from its origin in the field of electromagnetism, and regarding mechanical metamaterials alone, many new functionalities have been investigated, including energy absorption, acoustic/phononic wave propagation, heat conduction, and negative Poisson's ratio (NPR or auxetics).

This project aims to optimize a periodic unit cell (PUC) for auxetic behavior. Auxetic metamaterials display a range of useful properties, such as a high fracture toughness, indentation resistance and energy absorption, and are therefore advantageous for a vast number of applications.



(a) (b)

Figure 1: Auxetic materials. a) Demonstration of auxetic behavior. The top specimen is compressed, the bottom one is stretched; and b) A topology optimized 2D auxetic structure, taken from [1].

Tasks *i)* Conducting a thorough literature review on the different methodologies for designing auxetic structures; *ii)* Implementing the required formulation within hybrida, our in-house finite element library; *iii)* Executing different design strategies by defining various Poisson ratio objectives; *iv)* Manufacturing an auxetic prototype; *v)* (If time permits) Exploration of tunable auxetics or other mechanical properties; *vi)* Presenting the results and preparing a report that could lead to a peer-reviewed journal publication.

Requirements The student should have modeling experience and basic knowledge of finite element analysis. Python programming experience is recommended.

References

[1] O. Sigmund. Systematic design of metamaterials by topology optimization. In R. Pyrz and J. C. Rauhe, editors, *IUTAM Symposium on Modeling Nanomaterials and Nanosystems*. Springer Netherlands, 2009.