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Topology optimization of metamaterials with negative thermal expansion

Master of Science project

Abstract

This M.Sc. project consists in the computational design and optimization of metamaterials with a negative thermal expansion coefficient. 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.

Thermal deformation is a serious issue in many high-precision machines, so an accurate control of the thermal expansion coefficient would constitute a valuable asset. This project aims at designing the 3D periodic unit cell (PUC) of a metamaterial with a negative thermal expansion coefficient.

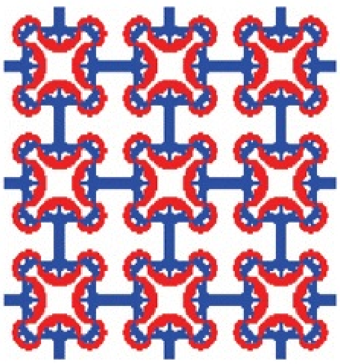

Figure 1: Multimaterial topology optimization of a metamaterial with negative thermal expansion [1]

Tasks *i)* Conducting a thorough literature review on the different methodologies used in the optimization of thermally loaded microstructures and metamaterials; *ii)* Implementing the required formulation within hybrida, our in-house finite element library; *iii)* Executing different design strategies by defining various objectives; *iv)* Manufacturing a prototype that achieves a negative thermal expansion; *v)* 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.