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Design of metamaterial 'pop-up' micro-structures by plate buckling

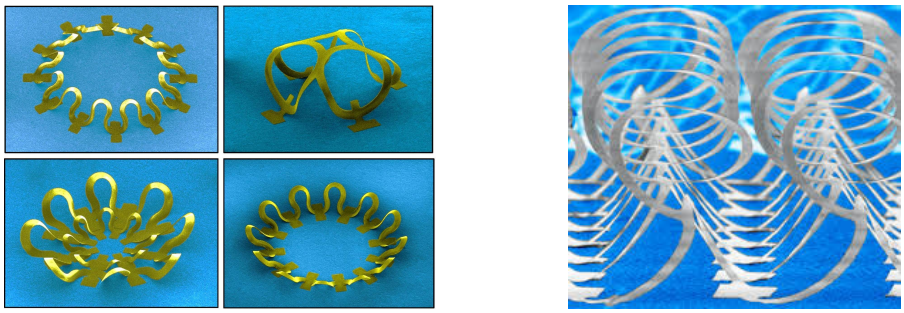
Master of Science project

Abstract

This M.Sc. project consists in the numerical optimization of metamaterial micro-structures whose final configuration is determined by their buckling modes. The student will implement advanced numerical methods for the optimization of such complex structures 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. Metamaterials have tremendous potential as they broaden the spectrum of functionalities with new applications that not too long ago were undreamed of. 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.

Manufacturability of metamaterials is currently considered an important issue as 3D micro-fabrication techniques are not yet fully developed. The use of buckling for the creation of 'pop-up' structures seems to be an interesting approach to overcome this problem. A pattern is made on a highly stretched substrate by lithography in such a way that it is only bonded to the substrate in certain locations. Releasing of the substrate then causes the pattern to buckle up into a 3D structure that can be very complex. The aim of this project is to create a numerical tool for the design and optimization of 2D patterns given a desired shape of a buckled structure.



(a) (b)

Figure 1: Buckled 'pop-up' micro-structures, taken from [1]. a) Various shapes attainable by pop-up buckling; and b) A periodic microstructure made by pop-up buckling.

Tasks *i)* Conducting a thorough literature review on the different methodologies used to include linear buckling analysis of plates in optimization; *ii)* Implementing the required formulation within hybrida, our in-house finite element library; *iii)* Executing optimizations for different objectives to explore the range of viable shapes; *iv)* (If time permits) Performing post-buckling analysis on some of these structures; *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 and basic knowledge of buckling analysis is recommended.

References

[1] X. Sheng, Y. Zheng, K.I. Jang, and W. Huang. Assembly of micro/nanomaterials into complex, three-dimensional architectures by compressive buckling. *Science*, 347:154 — 159, 2015.