TOPOLOGY OPTIMIZATION OF AUXETIC MATERIALS

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1. Introduction

Mechanical metamaterials are material which properties are depended on their macroscopic structure. These properties can be mechanical, optical, acoustic or electrostatic. One of groups of mechanical metamaterials are so-called auxetic materials – which have negative Poisson's ratio. The Poisson's ratio for the homogenous, isotropic elastic solid material is the negative ratio of transverse to longitudinal strain at every point in a body under longitudinal loading. Isotropic materials have Poisson's ratio greater than -1 and less than 0.5. Anisotropic materials haven't these boundaries. To obtain the maximal value of Poisson's ratio are used methods of topology optimization and Finite Element Method. In this paper will be presented the results of topology optimization by means of various methods and the comparison between them.

2. Subject of optimization

The subject of optimization is an area limited by various shapes with boundary conditions: on the top – loading force, on the bottom and left side: roller condition and on the left side – free condition. In the Fig. 1 and Fig. 2 are presented two examples of optimized area.

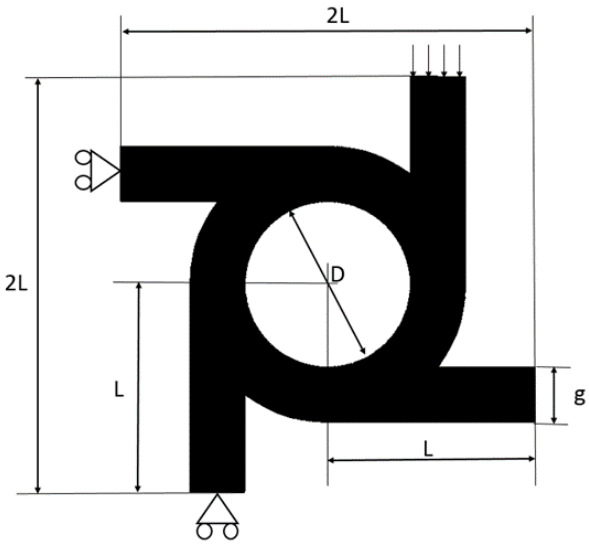

Fig. 1. Anti-tetra-chiral optimized shape

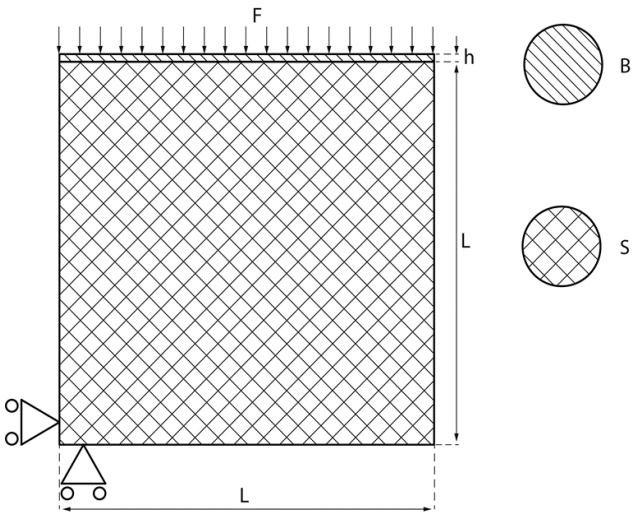

Fig. 2. Optimized square as a core of composite

3. Results

The results of optimizations are found by filling the shape with two materials with positive initial values of Poisson's ratios. Initial parameter of optimization is also the percentage of the first material in the whole shape. In the Fi. 3 and Fig. 4. are shown the examples of results – final shapes built by two materials with minimal effective Poisson's (the colours mean the two materials).

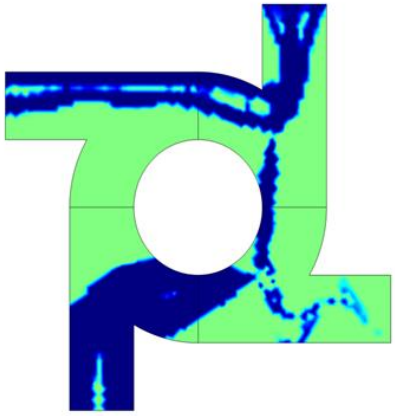

Fig. 3. Optimized anti-tetra-chiral shape

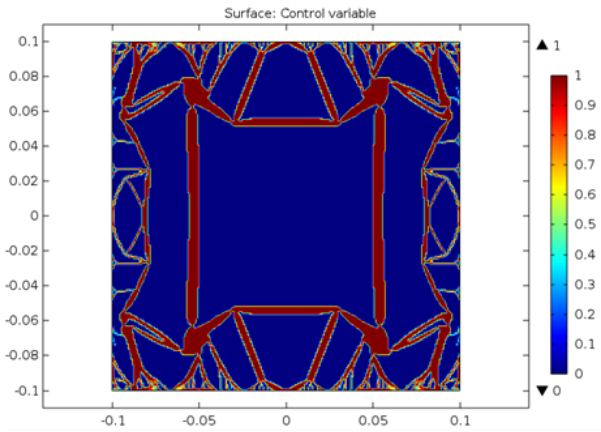

Fig. 4. Optimized square with two materials

4. Summary

The results show that the topology optimization method can lead to obtain the negative Poisson's ratio in the earlier defined geometry. The domain is filled by two materials with initial positive Poisson's ratio. The result can be less than -1.

5. References

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References

[1] M. P. Bendsøe and O. Sigmund. *Topology optimization. Theory, Methods and Applications*. Springer Verlag, Berlin, Germany, ISBN: 3-540-42992-1, 2003.
[2] E. Idczak and T. Strek. *Minimization of Poisson's ratio in anti-tetra-chiral two-phase structure*. IOP Conf. Series: Materials Science and Engineering, 248, 012006, 2017.
[3] T. Strek, H. Jopek, E. Idczak and K.W. Wojciechowski. *Computational modelling of structures with non-intuitive behaviour.* Materials: Auxetic materials 2017 ISSN 1996-1944, 2017.
[4] T. Strek, H. Jopek and E. Idczak. *Computational design two-phase auxetic structures*. Phys. Status Solidi B 253, 1387–1394, 2016.
[5] R. Kutyłowski. *Optymalizacja topologii kontinuum materialnego*. Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław, Polska, 2004.
[6] M. Ameen. *Computational elasticity*, Alpha Science, UK, 2005.
[7] B. Lautrup. *Physics of Continuous Matter, Exotic and Everyday Phenomena in the Macroscopic World*, IOP, Bristol, 2005.
[8] R.S Lakes. *Foam structures with a negative Poisson's ratio* Science 235 pp. 1038-1040. 1987.
[9] K.E. Evans. *Auxetic polymers: a new range of materials*. Endeavour, 15(4), 170-174. 1991.
[10] D. Prall and R. S. Lakes *Properties of a chiral honeycomb with a Poisson's ratio of –1*. International Journal of Mechanical Sciences, vol. 39, no. 3, p. 305-314, 1997.
[11] Y.J. Chen, F. Scarpa, Y.J Liu and J.S. Leng. *Elasticity of anti-tetrachiral anisotropic lattices.* International Journal of Solids and Structures, vol. 50, no. 6, p. 996-1004, 2013.
[12] M. Nowak. *Projektowanie konstrukcji o wysokiej sztywności z zastosowaniem optymalizacji strukturalnej.* Wydawnictwo Politechniki Poznańskiej, 2016.