Influence of Graded Mechanical Properties on Natural Vibrations of Tensegrity-Inspired Cellular Lattices – Computational Approach

Maciej Kołodziejczak[1,*], **Wojciech Gilewski**[1] **and Anna Al Sabouni-Zawadzka**[1]

[1]Faculty of Civil Engineering, Warsaw University of Technology, Warsaw, Poland
e-mail: maciej.kolodziejczak.dokt@pw.edu.pl

KEYWORDS: *Tensegrity, Graded Cellular Lattice, Natural Vibrations, Computational Approach.*

One unexplored area in mechanics is the design of tensegrity-inspired metamaterials [1, 2] with graded properties, realised by using cells with diverse geometric or physical properties. Modelling dynamic properties of such metamaterials would significantly expand the possibilities of obtaining a variety of extreme properties and improve the controllability of the systems under consideration.

A set of lattices designed from expanded octahedron tensegrity modules [2] with graded mechanical properties is shown in Fig. 1. The lattices are simply supported at the bottom surface. Their dimensions of $6 \times 6 \times 6$ cm correspond to those of planned additively manufactured samples and future experimental studies. Grey cells have struts with a diameter of 1.5 mm and cables of 0.85 mm. Blue cells are thickened with a 4:3 ratio, and red cells with a 5:3 ratio. The green layer consists of rotated cells with significantly lower vertical stiffness.

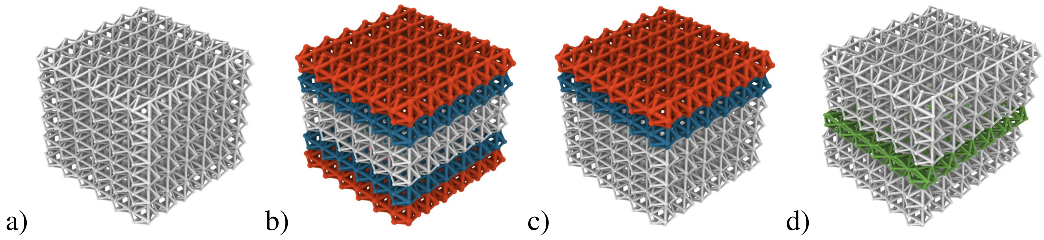

Figure 1. Expanded octahedron lattices: a) periodic, b) top and bottom reinforced, c) top reinforced, d) soft middle layer.

The masses of the lattices are 47.47 g, 87.90 g, 67.69 g, and 48.20 g, respectively. The first six natural frequencies and eigen-modes are analysed. The computational simulations are performed using a 3D frame model in ABAQUS. The natural frequencies of the periodic lattice serve as a reference. These are, respectively, 640 Hz, 663 Hz, 740 Hz, 1833 Hz, 1905 Hz, and 2010 Hz. Mode shapes 1, 2, 4, and 5 correspond to bending in vertical planes of symmetry, with one or two half-waves. Mode shapes 3 and 6 are torsional. Gradation b) does not change the mode shapes, but reduces frequencies 1–3 by approximately 8% and slightly increases frequencies 4–6. The trends are different for gradation c). Mode shapes 1–5 do not change, while mode 6 corresponds to compression/tension in the vertical direction. Frequencies 1–3 decrease by about 25% and 4–6 by about 12%. Gradation d) does not alter the vibration modes and reduces frequencies: 1–3 slightly and 4-6 by about 10%.

An evaluation of lattices designed from other tensegrity modules will be presented at the conference. Computational simulations are promising and indicate the possibility of controlling the level of natural frequencies, as well as the modes of these vibrations, by introducing gradations of mechanical properties.

ACKNOWLEDGEMENT: This research was funded in whole by National Science Centre, Poland, grant no. 2024/55/B/ST8/00475. For the purpose of Open Access, the author has applied a CC BY public copyright licence to any Author Accepted Manuscript (AAM) version arising from this submission.

[1] T.J. Cui, D.R. Smith, R. Liu, Metamaterials: Theory, Design, and Applications, Springer, 2010. https://doi.org/10.1007/978-1-4419-0573-4

[2] A. Al Sabouni-Zawadzka, High Performance Tensegrity-Inspired Metamaterials and Structures, CRC Press, 2022. https://doi.org/10.1201/9781003343202