Discrete models to simulate cellular metamaterials

Igor Berinskii*

* School of Mechanical Enginerine
Tel Aviv University
Ramat Aviv, 6997801, Tel Aviv-Yaffo, Israel
e-mail: igorbr@tauex.tau.ac.il

ABSTRACT

Artificial periodic cellular (lattice) materials attract the attention of researchers due to their outstanding stiffness and strength and enhanced absorption of mechanical energy at relatively small density. Lattice materials can be relatively easy fabricated using modern additive technologies. Computer simulations can help to choose the best cell topology, a number of cells, geometry of struts, material properties. Usually FEM is used for simulations, however, in some cases, discrete models seem to be more applicable. For instance, such problems include big deformations, buckling, and fracture of cellular materials.

In this work, two discrete approaches are proposed to simulate cellular metamaterials. The first approach is based on an elastic network representation of the lattice structure. The two-parametric linear model is used for qualitative analysis. The model describes an interaction between the cells' nodes with axial and torsional linear springs. The homogenization procedure is proposed to determine the effective properties of solid material corresponding to the re-entrant and regular honeycombs. The procedure is based on a comparison of strain energies of the structures and corresponding orthotropic material. The components of the stiffness tensor and Poisson's ratio of the structures are obtained as a function of interaction parameters and the angles between the structural elements.

Although the two-parametric model can accurately describe the properties of the isotropic 2D material, it lacks the accuracy in the anisotropic case. Due to this, the approach based on the use of particles with rotational degrees of freedom is used in a way proposed in [1]. Such an approach is widely used to simulate cohesive interaction between the granular particles Here, linear elastic and enhanced vector-based model (EVM, [2]) is used to simulate the connections between the nodes. Both models consider the solid as a set of particles connected by the potential of interaction. The parameters of the potential are related to linear elastic longitudinal, transverse (shear), bending, and torsional stiffness. As a result, every strut of cellular material is modelled with two particles with an elastic bond of Bernoulli-Euler type. The models are applied to simulate the fracture and wave-propagation in lattice materials. It is shown, that the results are in good correspondence with the experimental and finite element results obtained by the other authors.

REFERENCES

[1] E.A. Ivanova, On the Use of the Continuum Mechanics Method for Describing Interactions in Discrete Systems with Rotational Degrees of Freedom. Journal of Elasticity, 133(2), pp.155-199 (2018).

[2] V.A. Kuzkin, A.M. Krivtosv, Enhanced vector-based model for elastic bonds in solids. Letters on materials 7 (4), pp. 455-458 (2017)