Optimization of tensegrity lattice with truncated octahedral units

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Abstract
Tensegrity structures are a class of self-standing pin-jointed structures consisting of continuous tensile members (cables) and discontinuous compressive members (struts), and are stabilized by the introduction of cable prestress. Although most implemented applications of tensegrity structures are on small monumental structures, they can also be applied with additional supports to structures for architectural roofs, retractable structures in space, etc., and even as models in biomechanical engineering. The first and second authors have investigated forms and mechanical properties of tensegrity structures based mainly on the force density method and a group-theory approach [1, 2]. The fourth author developed the first known 3-dimensional tensegrity lattice [3] as well as a reduced-order model for studying their nonlinear behavior [4].

In this study, we propose an optimization method for tensegrity lattices consisting of eight truncated octahedral units. Buckling of strut is simply modeled by bilinear nonlinear elastic relation between axial deformation and axial force. The objective function is the stored energy for specified vertical deformation, which is to be maximized. The ratio between force densities of cables and struts are incorporated as parameter, and the design variables are the cross-sectional areas of cables and struts, level of prestress, and the scale of horizontal size of the lattice. A constraint is given for the total volume of material. The problem is formulated as a nonlinear programming problem, which is solved using the package ‘fmincon’ available in the optimization toolbox of Matlab. It is shown in the numerical example that a nonlinear vertical force-displacement relation with degrading stiffness can be obtained as a result of optimization.

References

[1] J. Y. Zhang, M. Ohsaki and F. Tsuura, Self-equilibrium and stability of regular truncated hexahedral and octahedral tensegrity structures, *Int. J. Solids Struct.*, 2019.

[2] J. Y. Zhang and M. Ohsaki, *Tensegrity Structures: Form, Stability, and Symmetry*, Mathematics for Industry 6, Springer, 2015.

[3] J. J. Rimoli and R. K. Pal, Mechanical response of 3-dimensional tensegrity lattices, *Composites Part B*, Vol. 115, pp. 30–42, 2017.

[4] J. J. Rimoli, A reduced-order model for the dynamic and post-buckling behavior of tensegrity structures, *Mechanics of Materials*, Vol. 116, pp. 146–157, 2018.