# Form-finding of tensile structures based on particle swarm optimization and integral self-stress states

Yao CHEN*, Pooya SAREH [a], Jian FENG

* National Prestress Engineering Research Center, Southeast University, Nanjing 211189, China
chenyao@seu.edu.cn

[a] Creative Design Engineering Lab, Division of Industrial Design, School of Engineering,
University of Liverpool, London Campus, EC2A 1AG, UK

## Abstract

Tensile structures, which consist of tension cables and/or compression struts, have some interesting structural properties and geometric configurations. Examples include tensegrity structures, cable domes, cable nets, and cable-strut structures. A tensile structure is generally regarded as a mechanism before being prestressed. Under the action of initial prestresses, the internal infinitesimal mechanisms can be rigidified, resulting in achieving the desired structural stiffness. Thus, either developing novel tensile structures or investigating the existing ones require a form-finding (also known as force-finding) analysis.

Form-finding of tensile structures has attracted considerable attention in various fields. Several deterministic form-finding methods and heuristic approaches based on optimization algorithms have been presented to solve the involved problems. However, it is frequently difficult to find simultaneously the prestress forces and the geometric configuration of a given geometry, because the final configuration of a tensile structure is, in general, strictly dependent on the initial prestresses. Therefore, more efficient computational methods are necessary to facilitate effective structural form-finding for such structures.

In this study, an optimization method is presented to determine the optimal feasible prestress modes of cable-strut tensile structures with predefined geometry and multiple self-stress states. Established in the symmetry-adapted coordinate system, the first block of the equilibrium matrix and the integral self-stress states with full symmetry are obtained. Subsequently, an optimization model based on the integral self-stress states is presented to compute the optimal feasible prestress modes. Thereafter, the original multi-objective optimization problem is converted into a single objective optimization problem by the weight coefficient method, and the particle swarm optimization algorithm is applied to find feasible solutions. Illustrative examples verify the feasibility of the presented optimization algorithms to calculate the feasible prestress modes. In comparison with the conventional fminsearch optimization method (based on the Nelder-Mead simplex algorithm), the proposed method shows improved accuracy and efficiency.

## References

[1] J. Zhang, and M. Ohsaki, "Adaptive force density method for form-finding problem of tensegrity structures", *International Journal of Solids and Structures*, 43(18-19), pp. 5658-5673, 2006.

[2] Y. Chen, J. Feng, R. Ma and Y. Zhang, "Efficient symmetry method for calculating integral prestress modes of statically indeterminate cable-strut structures", *Journal of Structural Engineering*, 141(10), 04014240, 2015.

[3] S. Lee, B.S. Gan and J. Lee, "A fully automatic group selection for form-finding process of truncated tetrahedral tensegrity structures via a double-loop genetic algorithm", *Composites Part B Engineering*, 106, pp. 308-315, 2016.

[4] X. Xu and Y.Z. Luo, "Force finding of tensegrity systems using simulated annealing algorithm", *Journal of Structural Engineering*, 136 (8), pp. 1027-1031, 2010.

[5] K. Koohestani and S.D. Guest, "A new approach to the analytical and numerical form-finding of tensegrity structures', *International Journal of Solids and Structures*, 50 (19), pp. 2995-3007, 2013.