Shape optimization of single-layer free-form lattice structures considering both high efficiency and safety

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Abstract

Over the past decades, the emergence of parametric modeling and scripting techniques in architectural CAD applications has enabled a new level of sophistication in free form design, allowing architects and designers to create almost any shape imaginable. Complex free form structure is one of the most striking trends in contemporary architecture. A large number of new building types with fanciful designs and eye-catching shapes have been successfully constructed [1-2]. However, a free form curved structure should not only emphasize the freedom of its form, but also the good quality of its mechanical properties. It is a difficult problem to meet the requirements of architectural and structural engineers at the same time.

The traditional form finding method usually takes the structural total strain energy as the objective function. The optimum shape is obtained if the total strain energy reaches its minimum value. At this point, the axial strain energy is dominated in the structure and the bending strain energy becomes very small. The buckling load of the intact structure become very high, but once the initial geometric imperfections are considered, the buckling load of the structure will decrease significantly. Finally, it cannot obtain the structural shape with high buckling load as the initial geometric imperfection is applied.

Therefore, in this paper, an improved form finding method of free-form lattice structure considering the effect of structural imperfect sensitivity is proposed. Taking the bending strain energy as the constraint and the proportion of bending strain energy is controlled in the method. When the total strain energy decreases, there will still be a certain proportion of bending strain energy in the structure. So, the final shape we find will be insensitivity to the initial geometry imperfection, it is an efficient structure with higher buckling load and lower imperfection sensitivity.

Then, in order to evaluate the redundancy performance of optimized structure, an index called overall redundancy of the structure based on the damage model is proposed in this paper. The damage model is simulated by deleting the key bar of structure and the key bar is determinate according to structural components redundancy which is inversely proportional to their response sensitivity [3]. The results show that the overall redundancy of the structure obtained by the improved method is higher than that obtained by traditional method, and it is an optimal structure.

References

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