Computational morphogenesis of free-formed shell

Toshiaki KIMURA[1*]

[1*] Assistant Prof., Dept. of Archi. and Archi. Eng., Kyoto University,
Kyotodaigaku-katsura, Nishikyo-ku, Kyoto 615-8540, Japan
kimura@archi.kyoto-u.ac.jp

Keywords: shell thickness, NURBS, shape optimization, strain energy

1. Introduction

Among various types of structures in civil and architectural engineering, shape of structural components of large span spatial structures has significant effect on their aesthetic property as an architecture. Recently, owing to progress of computer power and technology for construction, architects or designers have been gradually changing their preference from fixed and purely geometrical forms into arbitrary, non-geometrical or organic configurations. However, since the mechanical characteristics of shells with free-form curved surface are very complicated, the way to find the shape of those shells is not simple. Recently, method of computational morphogenesis has been utilized for practical application, however in most of them, only nodal coordinates are adopted as design variable, distribution of thickness is fixed, although simultaneous optimization of shape and cross-sectional areas is not difficult for trusses [1].

In this paper, a method of computational morphogenesis for the shell structures with free curved surface is proposed, where shape and distribution of thickness can be simultaneously optimized [2]. In the proposed method, the shell thickness is discretized in the same manner as the displacement field in a finite element, and Non Uniform Rational B-Spline (NURBS) is utilized by which the number of unknowns can be restricted while the high degree of freedom is maintained for expression of the shape of the curved surface and the shell thickness. Consequently, the shape finding problem of free-form shell structures is formulated as the strain energy minimization problem where coordinates of NURBS control points with respect to both the shape of the curved surface and the distribution of thickness are adopted as design variables.

Effectiveness of the proposed method is demonstrated through numerical example of spherical shell with square plan. The shell is pin-supported at the four corners.

References

[1] M. Ohsaki, T. Nakamura, and Y. Isshiki, Shape-size optimization of plane trusses with designer's preference, Journal of Structural Engineering, ASCE, Vol.124, No.11, 1998

[2] T. Kimura and H. Ohmori, Computational morphogenesis of free form shells, Journal of International Association for Shell and Spatial Structures, Vol. 49, No. 3, pp.149-150, 2008