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Simultaneous Optimization Analysis of Shape and Cutting Pattern for Cable-Reinforced Suspension Membrane Structure

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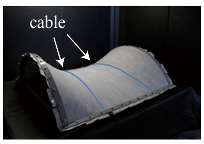
Abstract

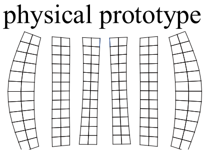
Tension members such as membranes and cables are lightweight and have a mechanical property that transmits only tensile force. Tension structure, for example, the membrane structure is constituted with those structural members, and often used as a structural system for a large spatial structure. The cable-reinforced suspension membrane structure is targeted in this study. Generally, the structural rigidity as the membrane structure occurs by implementing the boundary condition and the initial tension into the tension member (membrane material) existing with no stress in the plane. Therefore, membrane structures require the form-finding analysis and the cutting pattern analysis unlike usual architectural structures [1].

In order to implement the simultaneous optimization analysis of shape and cutting pattern for membrane structures, the finite element technique with coordinates assumption that sets the coordinate value as the unknown quantity has been proposed [2]. Effectiveness of these analysis results has been confirmed by fabricating the scale-down physical prototype of suspension membrane structure and pneumatic membrane structure [3]. However, a converged solution (cutting line) for the cable-reinforced membrane structure is not obtained by the computation procedure that replaces cutting line to the spline curve.

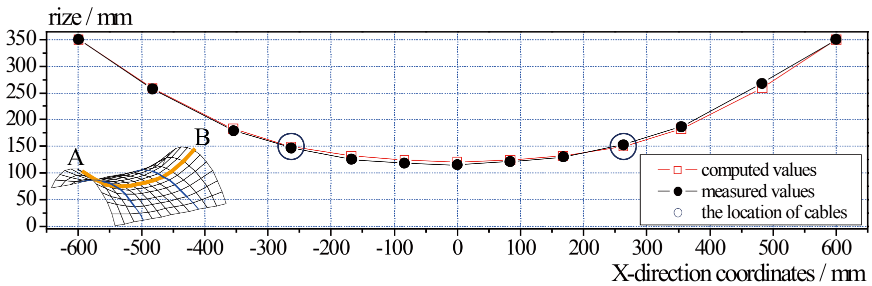
This paper presents the simultaneous optimization analysis of shape and cutting pattern for a cable-reinforced suspension membrane structure. The formulation for simultaneous optimization analysis is derived by applying the finite element technique with coordinates assumption using Lagrange multiplier method [4]. First, we indicate the numerical result of simultaneous optimization analysis of shape and cutting pattern in which Bézier curve surface represent a cutting pattern [5]. Then, the scale-down physical prototype based on the numerical results are fabricated, and the effectiveness and problem of proposed simultaneous optimization analysis are clarified through confirming the form by the measurement. The photograph of a scale-down physical prototype, the cutting pattern and comparison between measurement with a scale-down physical prototype and numerical results of the shape and cutting pattern analysis for cable-reinforced suspension membrane structure on a saddle boundary were indicated in Fig.1 as one example.



Photograph of a scale-down physical prototype



Cutting pattern (numerical result)



Comparison between coordinates measurements and numerical result of A-B line on membrane surface

Fig. 1 Cable-reinforced suspension membrane structure on a saddle boundary shape

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