Element Force Equation Using Multiple Non-stressed Length for Tensegrity Form-finding

Cho Kyi Soe*, H. Obiya[a], K. Ijima[a], M. Nizam b Z[b]

*Graduate School of Science and Engineering, Saga University
1 Honjo Saga, 840-8502, Japan
chokyisoe@gmail.com

[a] Department of Civil Engineering and Architecture, Saga University, Japan
[b] Structures and Material Engineering Department, University of Tun Hussenin Onn Malaysia, Malaysia

Abstract

Tensegrity is a unique geometric morphology which can be stabilized by its self-equilibrium, and therefore, finding its equilibrium shape is one of the key points to design tensegrity structures. In this study, the form-finding problem is carried out by the tangent stiffness method which is quite effective in the geometrical nonlinear analysis due to its strict rigid body displacement of elements. Equation (1) is the general formulation of tangent stiffness method where **U** is the nodal force vector, $\mathbf{K_0}$ is the element stiffness which provides the element behavior in element (local) coordinate, and $\mathbf{K_G}$ is the tangent geometrical stiffness, and **u** is the nodal displacement vector in general coordinate.

$$\boldsymbol{\delta}\mathbf{U} = (\mathbf{K_0} + \mathbf{K_G})\boldsymbol{\delta}\mathbf{u} \tag{1}$$

Since the element behavior inside the local coordinate of element has no concern with the tangent geometrical stiffness, it is possible to define a wide variety of the element behavior and to use the virtual element stiffness freely [1]. In the form-finding process by the tangent stiffness method, the element behavior can be established by defining the measure potentials. The virtual potential functions have the parameters of element measurement and its differential functions as the element force equations prescribing the element behavior. In this study, the element force equation is generalized to be able to have a function of multiple non-stressed length as shown in figure 1. Equation (2) is the defined element force equation and its differential function is as in equation (3) in which, **N** is axial force, **C** is coefficient of stiffness, $\boldsymbol{l_0}$ is the non-stressed length, $\boldsymbol{l}$ is the current length, **n** is the serial number.

$$\mathbf{N} = \mathbf{C}(\boldsymbol{l} - \boldsymbol{l_{01}})(\boldsymbol{l} - \boldsymbol{l_{02}}) \ldots\ldots(\boldsymbol{l} - \boldsymbol{l_{0n}}) \quad (2) \quad , \quad \boldsymbol{\delta}\mathbf{N} = \left(\sum_{i=1}^{n} \frac{1}{l - l_{0i}}\right) \mathbf{N}.\boldsymbol{\delta l} \quad (3)$$

Figure 1 shows the relation between non-stressed length and axial force of the solution whose primary octagonal form is with eight struts and twenty four cables. The shape of each solution is represented by the axial force of each member along with the gradual change of the non-stressed length of softer cables.

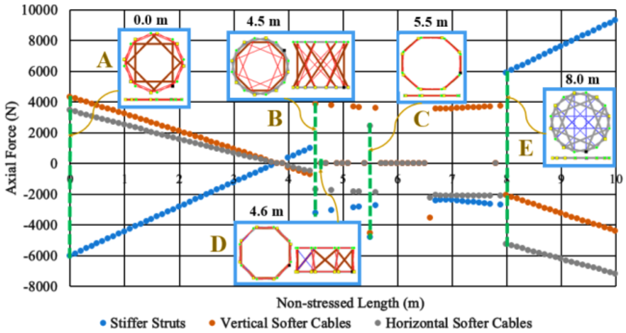

Figure 1. Result of octagonal configuration

Each configuration is resembled by a set of each dot in three colour series respectively. It can be expected to obtain numerous solutions even under the same connectivity of primary form and allows the compression members come to connect each other which is beyond the general sense of tensegrity. Therefore, this research can find out another concept of tensegrity and be applied in more aspects of tensegrity studies.

References

[1] A. Matsuo, H. Obiya, K. Ijima, Z. M. Nizam, "Form-Finding of Extensive Tensegrity Using Truss Elements and Axial Force Lines," in *International Conference on Textile Composites and Inflatable Structures, STRUCTURAL MEMBRANES*, Barcelona, Spain, 2011.