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Self-Stress Implementation in Tensegrity Grids

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Abstract

Tensegrity systems are composed of any given set of cables connected to a set of struts in which cables connectivity must be able to stabilize the configuration. These systems as kinematically and statically indeterminate pin-jointed systems are characterized by mechanisms and self-stress states. Unlike the other reticulated systems, in tensegrity systems, unilateral behavior of cables causes some problems in determining the basis of compatible self-stress states. At the present study, self-stress implementation in tensegrity grids is presented in which for finding desired self-stress state, linear combination of the independent self-stress states is determined. Experimental study was conducted to verify the accuracy and validity of the numerical method. Considering the results of the present study, the self-stress design of these systems can be improved to obtain specific desired behavior. Also, using supporting constraints, the implementation of self-stress states can be performed in a reduced number of stages.

Keywords: Tensegrity systems, Self-stress design, Force density method, Tension setting

1. INTRODUCTION

Tensegrity systems are composed of any given set of cables connected to a set of struts in which cables connectivity must be able to stabilize the configuration [1].

The first step in the design of a tensegrity structure is to find a self-stressed equilibrium configuration. This step is called form-finding. Generally, form-finding methods of tensegrity structures can be classified into two categories, namely, kinematic and static methods [2]. Kinematic methods are based on the controlling the length of the members and do not require the members to be in a state of pre-stress. In this category, the dynamic relaxation method, introduced by Motro for tensegrity structures, has been reliably applied to tensile structures [3]. Schek presented a kind of static method, namely force density method, which transforms the nonlinear equilibrium equations into a set of linear equations [3]. This method requires priory knowledge of the stress coefficients for all members; and length of the members cannot be controlled.
Averseng and Crosnier [4] demonstrated a simple method for adjusting the whole set of axial forces in tensegrity systems, based on a combination of effects determined from the unit variations of rest lengths for a reduced set of active cables. Tran and Lee [5] presented a numerical method for initial self-stress design of tensegrity grid structures. A discussion on proper division of the number of member groups for the purpose of existence of a single integral feasible self-stress mode has been explicitly given. Tran and Lee [6] also presented a numerical method for initial self-stress design of tensegrity grid structures with exostresses. In this method, auxiliary elements were used to transform the tensegrity grid structure with statically indeterminate supports into self-stressed pin-jointed system without employing the supports.

In recent years, some experiments on tension setting (self-stress implementation) were performed. However, in most of them, specific systems were studied which consist of contiguous cables throughout the joints, and pre-stressing were applied by vertical rods instead of cables. These rods prevent slightly the distortion of system's shape during tension setting. In addition, so far in the studied cases, tension setting was applied in relatively large number of stages. These may cause several questions about tension setting in other types of tensegrity systems: How will be the nature of self-stress implementation of the other systems in which cables are not contiguous throughout the joints? How can we reduce the stages of self-stress implementing?

In this paper, to answer these questions, self-stress design of tensegrity systems is studied numerically and experimentally. In the self-stress design process, for fulfilling the behavior and resistant requirements, a linear combination of self-stress states is determined in such a way that desired compatible self-stress state is obtained. In tension setting process, the variations of element forces during the adjusting process, must be small enough in order to avoid the distortion of system's shape. To overcome this problem, supporting constraints can be used in practical tension setting.