Analysis of an adaptive tensegrity module

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Lightweight self-stressed tensegrity systems, composed of tensioned members (cables) and compressed members (struts), offer an economical and efficient alternative to many classical civil-engineering and aerospace structures. Their implementation is very promising in projects that require active or deployable systems. Tensegrity structures have been intensively studied since first appearing in the fifties and their applications have been extended from art and architecture to other areas that include aerospace structures, robotics and cell mechanics (see monographs [1-4]).

Active tensegrity systems equipped with sensors and actuators provide shape-control potential that adapts to changing loads and environmental conditions [5]. Structural control is carried out by modifying the self-stress state of the tensegrity structure in order to satisfy prescribed reliability criteria due to ultimate and mainly serviceability limit states [6, 7]. Skelton et al. in [8] demonstrated that in contrast to classical structures, tensegrity systems do not need excessive quantities of energy to ensure adequate control. Hence, they are advantageous for active control.

This paper describes a newly developed adaptive tensegrity module which has the ability to alter its geometrical form and pre-stress properties in order to adapt its behaviour to current loading conditions. The novel adaptive structure creates a new aspect presented in the paper. This system contains sensors that sense forces from the environment and actuators that adjust its shape accordingly, depending upon the load applied. The structure, in the form of a truncated pyramid, consists of twelve pre-stressed cables and four compressed struts which are designed to function as actuators. Two types of tests were carried out, namely: a pre-stressing test and a static loading test. Tests confirmed the functionality of the developed adaptive (active) system and the applicability of the proposed equipment, software, computational models and control commands. Responses of the structure obtained numerically are compared with experimental results. A 3D discrete geometrically nonlinear analysis of the adaptive tensegrity module is based on the application of the nonlinear finite element method. The results demonstrate that the behaviour of the adaptive active tensegrity system obtained by tests can in general be closely theoretically predicted. Results confirmed a physical relevance and mathematical correctness of the applied theoretical approaches.

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