MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

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PASSIVE NONLINEAR ACTUATORS FOR DEPLOYING THE MESH ANTENNAS

Abstract

A mesh antenna comprises a foldable truss, two mirror cable networks, and driving springs and/or motors. Based on a dynamic analysis of a mesh antenna, we revealed from energetic point of view that the energy stored in springs and outputted by motors is transferred into the potential energy of the mesh and truss, which is very low at the initial deployment stage accompanying the relaxed cables, and grows sharply at late stage when and only when the cables are tensioned and truss are compressed. Therefore, the required forces for deploying mesh antenna increase with the process of unfolding, owning negative stiffness. However, the output force of a common passive spring decreases with the process of releasing stored energy, owning positive stiffness. To tackle this conflict, we proposed to develop a new kind of passive nonlinear actuator with nonlinear force-displacement curve to meet the special demand of unfolding mesh antennas. The basic idea is a combination usage of a torsional spring and a convex cam, inspired by compound bow. They two were mounted on the same pivoting axes, and a rope was wound several turns on the cam. The mechanical energy stored in spring rotates the cam, and the force on rope counterbalances the torque from rotational spring. The cam radius corresponding to the small torque is several times smaller than that of the large torque. As a result, the output force of rope increases with releasing of the stored energy in spring. Given a targeting force-displacement curve, the corresponding cam profile was theoretically formulated as an optimization problem, whose solution was got in numerically way. Experimental result confirmed the designed cam could produce the targeting nonlinear force feature. Then, we compared the simulated unfolding processes of a mesh antenna driven by two kinds of springs with same outputted work, one owns positive stiffness while the other one owns negative stiffness. Results confirm that the designed spring with negative stiffness successfully deployed the antenna while the other one fails. Moreover, the passive nonlinear actuators developed here also owns potential to be used in other possible applications where nonlinear force feature are needed.