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Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

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DESIGN AND ANALYSIS OF BISTABLE COMPOSITE BOOMS

Abstract

The continuous growth and increase of capabilities of nanosatellites has been spurred by key miniaturization technologies that allowed carrying out ever more complex missions while minimizing volume, mass and power requirements. Indeed, the success of these technologies has allowed the blossoming of LEO nanosatellite constellations dedicated to Earth Observation, object tracking, telecommunications, as well as opening the door for deep space missions. In this way, the development of Carbon Fiber Reinforced Plastic (CFRP) ultra-light weight deployable booms represents a critical technology for supporting deployable structures that multiply the effectiveness and capacities of nanosatellites. For instance, deployable booms can be used to support the sail membranes of solar sails for propulsion, drag sails for deorbiting nanosatellites, as well as supporting structures such as parachute-like antennae for nanosatellite telecommunication constellations.

This work presents the design and analysis of bistable CFRP booms for a triangular quadrant solar sail. The main feature of bi-stable booms is their capability to be stable in both deployed and collided states. Poissons ratio and material anisotropy of various layers in the material provide the possibility to tune the bistability. To do so, multiscale structural mechanics approach is used in which the original problem is decoupled into two sets of analyses: a constitutive modelling and a nonlinear macroscopic analysis. The macroscopic analysis can be formulated exactly as a general continuum and all the approximations are confined to the constitutive modelling. The proposed micromechanical finite element homogenization scheme identifies the smallest mathematical building block of the boom and allows to compute the effective viscoelastic properties of the bistable CFRP booms. Then, Abaqus/Explicit is used to simulate the transition from coiled to deployed structure while the mustiscale approach is iteratively implemented to provide the corresponding material properties for each time step. The simulation results are compared against the experimental data found in the literature and proved to effectively predict the deployment process.