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Space Structures II Development and Verification (Orbital deployable and dimensionally stable structures, including mechanical and robotic systems and subsystems) (2)

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DYNAMIC MODELING AND ANALYSIS OF DEPLOYABLE TELESCOPE TUBULAR MAST (TTM) IN SPACECRAFT SYSTEMS USING HYBRID COORDINATE AND KANE'S METHODS

Abstract

Deployable structures play a crucial role in the design and construction of large spacecraft, offering the advantages of compact storage during launch and subsequent expansion into very large space structures in orbit. The Telescope Tubular Mast (TTM), a representative one-dimensional deployable structure, was specifically developed for space applications, facilitating the positioning of payloads such as solar sails and large antennas outside the main satellites. In this application, generally, a spacecraft system consists of one rigid central hub, one or more deployable TTMs, each one composed of flexible tubes with different radius, which are placed one inside the others before the deployment phase. The structure repeatedly experiences elongation, locking, and restart behavior due to its nested stowed configuration, while the spacecraft bus can be subject to attitude control, controlled spinning, or uncontrolled tumbling motion. This results in a complex system with flexible parts interacting with a central hub while the configurations are time varying, which represents a hard scenario to model. To solve this problem, two distinct modeling strategies are used and later compared: a first one considering the deploying articulated boom as a single body with time varying characteristics (e.g. length and cross-section), and a second one applying a multibody approach, in which each elastic tubular element is modeled as a body of the system. In the first case, the Hybrid Coordinate (HC) method is used, which, starting from the derivation of the system energy, computes the contribution of the morphing boom to the coupled attitude/elastic dynamic equations of this system. On the contrary, the multibody modeling is addressed with the Kane's method, therefore the geometry of the singular tubular elements is pre-defined and remains fixed during the deployment process, leading to a more classical dynamic equation derivation. As a drawback, the number of bodies and associated variables (relevant to attitude, position and modal amplitudes) increases significantly. The two modeling philosophies are cross-validated, and the applicability of each approach is discussed considering modeling complexity, numerical accuracy and computational time. Specific scenarios are simulated to assess the

importance of including flexibility in the two methods during the deployment process: the system dynamics is characterized by time-varying natural frequencies, this presents peculiar challenges compared to classic flexible satellite studies, showing that the use of modeling strategies specifically aimed at this phase are highly recommended.