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DEPLOYMENT DYNAMICS OF A TIGHTLY PACKED MEMBRANE TAKING INTO ACCOUNT MEMBRANE ENTANGLEMENT

Abstract

Membrane space structures are gaining attention as ultra-light and compact alternatives to existing space structures, which can serve multiple purposes including photonic propulsion (e.g. solar sail) and providing power and communications. Since such structures are launched in a folded state, the ability to unfold the membrane into its intended shape (deployment) becomes a crucial aspect of their functionality. However, as such ultra-thin structures are not yet mature, their dynamics are not well understood. Experimental research is challenging, since there are currently no ground test methods that can create low-G environment in the spatial and temporal scale of a membrane deployment, which ranges from a few seconds to a few minutes. Therefore, numerical simulation plays a crucial role in design, verification and validation of membrane-type components, especially pertaining to its dynamics.

HELIOS is one such component needing numerical investigation. An engineering demonstrator featuring a 1m squared ultra-thin membrane that hosts functional devices such as thin-film solar cells and antennae, it is a component of JAXA's RAISE-3 spacecraft (Rapid Innovative Payload Demonstration Satellite 3) scheduled to launch in 2022. This component employs a central motor that extends a set of CFRP booms to deploy its device-laden membrane, making it the first of its kind. The primary concern regarding HELIOS-type deployment is inter-membrane interaction. It is predicted that the presence of rigid devices as well as fold patterns will cause various parts of the tightly packed membrane to interfere with each other's deployment process, i.e., an entanglement.

In this study, the authors simulate the deployment sequence of HELIOS by modeling the membrane as mass-spring systems, i.e. the multi-particle method. The entanglement phenomena and the resulting extra motor loads are explored by modeling membrane-membrane interaction (contact mechanics). Using this numerical model, deployment under different device placement, deployment speed and fold pattern is simulated. Resulting stress on the membrane and on deployment motor, and other quantitative as well as qualitative factors are considered to optimize HELIOS configuration, as well as identify potential complications before launch. The numerical model is verified against ground testing using HELIOS engineering model.