Simulation of deployable solar sails

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Concept of solar sailing which uses solar energy to propel a spacecraft is becoming popular as a low-cost spacecraft propulsion system, especially for high energy-consuming long-range spacecraft. To capture a sufficient amount of energy these solar sails are orders of magnitudes larger in size compared to space available in spacecraft. Moreover, these solar sails, consist of thin folded membranes supported on a backing structure made of self-deployable booms. Hence these solar sails along with deployable booms will be subjected to very high compaction to store in launch vehicle for transportation. While thin membrane panels are folded by introducing a series of fold-lines, deployable booms made of thin woven fibre composites are commonly used as a backing structure in these applications. Analogous to thin membrane panels, these booms are subjected to very high compact configurations which induce high stresses and curvatures. Hence, an optimized folding mechanism for solar sails is important to fully function during the deployment without failure. Simulation of deployment behaviour of these solar sails along with booms will facilitate the identification of suitable folding mechanism and optimized designs. In this study, idealisation techniques are presented to simulate accurate solar sail deployment. First, a simulation of a selected repetitive unit cell pattern of Miura-Ori folding was performed to develop an idealization method for the intersected creases in a virtual environment. Also, the effect of membrane thickness on the deployment was studied and verified using a series of experiments. Results illustrate that the connection with rotational stiffness gives better idealisation, and the deployment force and shape have a significant influence from membrane thickness and fold-line geometry. Secondly, a simulation of woven fibre composites was performed to capture the nonlinear bending behaviour which is crucial in predicting the accurate behaviour of deployable booms. The numerical model developed can capture accurate moment-curvature response, as observed in experiments, including the non-linear behaviour. This indicates that modelling techniques presented are capable of utilising for simulation of a large-scale solar sail with the backing structure to develop optimised designs.