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STATIC AND DYNAMIC ANALYSIS OF PARTIALLY WRINKLED MEMBRANES FOR TETHERED SPINNING SOLAR SAIL APPLICATIONS

Abstract

Soar sails are of interest for near and future space exploration missions. The recent successes of the Japanese IKAROS and the American NanoSail-D2 have shown the feasibility of solar sail as a cost effective source of propellant-less propulsion space system. Among many solar sail concepts available, a tethered spinning solar sail design is of particularly attractive . Conventional solar sail designs utilized large booms to deploy and support ultra-large thin reflective film. Those boom-supported configurations are limited in size due to the penalties involved in the boom mass when the sail area becomes very large. Removing these rigid support booms and using tensioned tethers instead is the apparent advantage of the tethered spinning solar il design. In this paper, structural analysis of a tethered spinning solar sail with ultra-thin film and tensioned cables is performed. The aim of this paper is to study the effect of tether tension and the number of connection points between the cables and sail film, on the sail structural deformations and vibration frequencies. The commercial finite element software ABAQUS are used. The analysis is performed on a full-scale solar sail in free flight condition. Shell S4 and S3 elements are used to model the thin-film. The cables are models by T3D2 truss elements. The central hub and tip masses are modelled as lump mass elements. A multistep analysis method is present. First, pre-stress in cable is applied to pre-tension the whole solar sail membrane. A linear buckling eigenvalue analysis is run to extract the first several global buckling modes. An initial imperfection is formed from the calculated buckling modes and added to the original finite element mesh to produce a perturbed mesh configuration. Then, nonlinear static analysis is performed to determine structural behavior at different incidence angles of the incoming solar radiation. Vibration modes and frequencies are analyzed from the pre-stressed structure. The displacement, stress results and the first vibration modes are obtained. It is found that the vibration modes are closely spaced. The structural deformation is strongly affected by the number of cable-film connections points and cable pretension. An optimum spin rate is needed to keep pretension of sail films and reduce structural local stress concentration. Overall, this work gives reference results for preliminary structural design of a tethered spinning solar sail membranes.