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ON THE ATTITUDE CONTROL BY THRUSTER OF A SPINNING SOLAR SAIL AND BENDING MOMENT'S EFFECT ANALYSIS

Abstract

The membrane dynamics of spinning solar sails have a special relevance when considering attitude control of the spacecraft. Because of being non-rigid structures, local deformation occurs, changing the overall effect of the Solar Radiation Pressure, which might lead to attitude disturbances and unexpected behavior. Thus, an accurate model and study of such dynamics is needed. Until this point, several researches on the topic have been conducted (Nakano, T., et al., 2005 - Takao, Y., 2018), modeling the membrane as a completely flexible body. However, the deformation observed in IKAROS (a spacecraft developed by the Japan Aerospace Exploration Agency (JAXA) to demonstrate solar sail technology) during its low-spin operation suggested a higher rigidity of the sail than the predicted one (Shirasawa, Y., et al., 2012). The difference between the observed and the predicted deformation of IKAROS is believed to be caused by the bending stiffness present in the membrane.

First, this study shows that the bending moment has strong effects on the attitude of the sail during its spin axis reorientation. Given the difficulty of measuring the actual bending stiffness of the membrane, it is necessary to find a control system capable to perform the same regardless of its value. Therefore, this paper also presents a new control system and its corresponding logic to lower the influence of the bending parameter on this attitude maneuver performance. The sail dynamics are simulated via an adjusted membrane model implemented through the Multi Particle Method (Mori, O., et al., 2013), and the characteristics of the sail are those for the OKEANOS mission (Kawaguchi, J., et al., 2018).

This newly proposed system consists on placing reaction devices in the tip-masses present in the vertexes of the sail instead of in the main body of the spacecraft. This also allows limiting the effect of the coupled dynamics between the hub and the sail, and grants a major control over the vibrations since it acts directly over the membrane. The advantages of this control system with respect to the conventional in-body one are discussed through simulations. Finally, a frequency analysis on the vibrations arising in the membrane for both presented methods when considering different bending stiffness values is done. This last analysis shows the shift in the natural frequencies obtained when compared with the non-bending analyses until the date, remarking the importance of the bending stiffness when considering the dynamics of a mast-free sail.