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DAMPING MEASUREMENT AND DEFORMATION VALIDATION OF FLEXIBLE, HIGH AREA-TO-MASS RATIO DEBRIS MODEL

Abstract

Multi-layer insulation (MLI) is thought to be a new type of space debris located in near geosynchronous orbit (GEO). Observation data indicates that these objects have high area-to-mass (HAMR) ratio and their area-to-mass (AMR) ratio changes over time, suggesting a high level of flexibility. As a result, the long term orbital dynamics and rapid attitude motion are substantially affected by GEO perturbations. Previous work by the authors effectively modelled the flexible debris using multibody dynamics. The thin membrane has been modelled as series of flat plates connected via a lump mass. The results of the orbital evolution and attitude motion are coherent with the observation data available. This paper presents a methodology to determine the material dynamic properties of thin membranes and validates the deformation of the flexible model with real MLI materials. Experiments are performed in a high vacuum chamber (10-4 mbar) to significantly decrease air friction. A thin membrane is hinged at one end but free at the other. The first test is a free vibration test to determine the damping coefficient and natural frequency of the thin membrane. In this test, the membrane is allowed to fall freely in the chamber with the motion tracked and captured through high velocity video frames. A Kalman filter technique is implemented in the tracking algorithm to reduce noise and increase the tracking accuracy of the oscillating motion. The final test is performed to determine the deformation characteristics of the object. A high power spotlight (500-2000 W) is used to illuminate the MLI and displacements are measured by means of a high resolution laser sensor. Finite Element Analysis (FEA) and multibody dynamics of the experimental setups are used for the validation of the flexible model by comparing with the experimental results of displacements and natural frequencies.