Paper ID: 65865
oral
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (1) (8)

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A FUEL-FREE AND AGILE ATTITUDE MANEUVER OF SPINNING SPACE MEMBRANE STRUCTURES USING ELECTROMAGNETIC FORCE

Abstract

This study proposes a method that uses electromagnetic force for the attitude control of spinning space membrane structures. Space membrane structures are thin sheet-shaped devices that provide a large surface area to satellites while remaining lightweight. Taking advantage of this feature, many satellite missions in LEO use membrane structures in applications such as solar power sails, antennas, and aero drag deorbit systems. A membrane structure that utilizes spinning to maintain its deployment is already in use on IKAROS, launched by JAXA in 2010. This type of membrane can achieve larger areas in a more lightweight structure in comparison to boom-supported membranes such as the one used in NanoSail-D2 launched by NASA in 2010. In the utilization of membrane structures, attitude maneuvers are one of the major technical issues. Conventional attitude maneuver methods use thrusters installed on the satellite body. Due to the gyro effect and high moment of inertia of satellites with membranes, greater amounts of fuel are required for attitude maneuvers, thus requiring a larger amount of volume on the satellites. Another attitude maneuver method uses reflectivity control devices (RCDs) that change their reflectance to control the solar radiation pressure (SRP) applied on membranes. Since SRP is weak, this method takes a long time for attitude maneuvers, demonstrated in the IKAROS mission at a rate of 0.5 deg/day. The proposed method in this study installs electric wires on the membrane and applies electromagnetic force by the interaction between electric current and the geomagnetic field. Since this method can apply stronger torques than that produced with RCDs, more agile attitude maneuvers are expected. In addition, this method only consumes electrical power, a resource that can be generated in space. However, since this method applies force to the membrane, attitude maneuvers may be disturbed by the potential deformation or vibrations to the membrane. This study develops an attitude controller of the satellites which suppresses membrane deformation and vibrations. First, the attitude dynamics of the satellite and membrane dynamics are modeled. For membrane dynamics, the multi-particle method (MPM) is employed. Second, an attitude controller considering the effect of gravity is developed. Finally, to evaluate the developed controller, this study conducts numerical simulation and analyses on the attitude and membrane behavior.