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

Author: Mr. Fedorenko Alexey
Moscow Institute of Electronics and Mathematics of National Research University Higher School of Economics (MIEM NRU HSE), Russian Federation, alexey.n.fedorenko@gmail.com

Prof. Eugene Chumachenko
Moscow Institute of Electronics and Mathematics of National Research University Higher School of Economics (MIEM NRU HSE), Russian Federation, mmkaf@miem.edu.ru
Dr. David Dunham
KinetX, Inc., United States, david.dunham@kinetx.com
Dr. Natan Eismont
IKI RAS, Russian Federation, NEismont@iki.rssi.ru

DESIGN OF SPHERICAL SOLAR SAILS FOR SPACECRAFT ATTITUDE MANEUVERS

Abstract

A solar sail is a surface with high reflectance of light. Solar radiation pressure accelerates a spacecraft without any fuel costs and can thus be used to substitute for traditional jets to accomplish many space missions. If the surface has variable reflective characteristics, the solar pressure control can generate rotational torques for attitude control. Consider a solar sail with six spheres attached by mutually orthogonal long rods. The spacecraft's center of mass is located at the point where the rods intersect. All structures are regarded initially as a rigid body. Each sphere's entire surface is divided into pixels and each pixel can be specified in an active or non-active mode. Active pixels reflect most of the radiation while non-active pixels absorb it. In this work, it is shown that pixel reflectance control allows rotation of the entire structure with known moments of inertia around any axis with a predefined angle. At the initial step, no other disturbance except for solar radiation pressure was taken into account. A special program written in C++ was developed that executes an algorithm of rotation around an arbitrary axis and stopping in a predefined orientation. In each time point, it calculates the appropriate pixel configuration, defines attitude, rotation moments, angular velocities and simulates the full structure's rotation. After program testing, analysis results were obtained, including estimation of rotation torques and angular velocity, depending on the space vehicle's geometry and mass parameters, optical coefficients of the material and the pixel size. Using these estimates, further investigations were made adding other torques, for instance, the gravity gradient effect. If the value of this additional rotation moment for the current time point is found, then the program uses it in the rotation algorithm to estimate the length of the rods and the radius of the spheres for achieving a desired rotation, or to hold the structure in a stable position. These parameters can be used to determine the feasibility of executing the rotation maneuver with such a solar sail in a real space mission. Gravity gradient torques on an Earth satellite in various orbital altitudes were considered. The necessary length of the rods and radius of the spheres for the maneuver were determined. It is shown that this control with the described sail design is quite feasible, especially in high orbits with a lower gravity gradient or for satellites with approximately equal moments of inertia.