ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (3)

Author: Mr. Robin Raus
EADS Astrium, United Kingdom, r.a.raus+iac2012@gmail.com

Dr. Yang Gao
Surrey Space Centre, University of Surrey, United Kingdom, yang.gao@surrey.ac.uk
Mr. Mark Watt
EADS Astrium Satellites, United Kingdom, mark.watt@airbus.com

REVIEW AND ANALYSIS OF SINGLE-THRUSTER ATTITUDE CONTROL ALGORITHMS FOR SPINNING SPACECRAFT

Abstract

In the field of attitude dynamics and control, passive spacecraft attitude control by spin-stabilisation can already be considered a venerable technique, almost as old as spaceflight itself thanks to its simplicity. Even today it is still used in a variety of missions, ranging from stabilisation during an orbit boost (the ΔV stage) to deep-space astronomy (the Planck space telescope). Mission concepts have been proposed for spin-stabilised penetrator-like spacecraft targeting non-atmospheric celestial bodies such as the Moon. However, the same gyroscopic stability that resists unwanted disturbance torques also has an impact on the commanded manoeuvres. Several techniques have been developed to take into account and whenever possible benefit from the gyroscopic phenomena exhibited by a spinning spacecraft.

The attitude dynamics and manoeuvre survey in this paper is performed for a mission scenario involving a penetrator-type spacecraft, a semi-rigid axisymmetric prolate spacecraft spinning around its minor axis of inertia, requested to perform a 90° spin axis reorientation manoeuvre. In contrast to most existing spacecraft only one attitude control torque is available, perpendicular to the spin axis. Having only one attitude thruster on a spinning spacecraft could be preferred for spacecraft simplicity (less mass, less power consumption etc.), or it could be imposed in case of redundancy/contingency operations; the proposed Japanese Lunar-A penetrator spacecraft had been designed in this way. This constraint does yield restrictions on the thruster timings, previously unanalysed, depending on the ratio of minor to major moments of inertia.

The attitude dynamics of a spinning rigid body are first investigated analytically, then expanded for the specific case of a prolate, axisymmetric, semi-rigid body. Next two well-known techniques for manoeuvring a spin-stabilised spacecraft, the Half-cone/Multiple Half-cone and the Rhumb line slew, are compared with one newer technique developed by Astrium Satellites. Each technique is introduced and characterised by means of simulation results and illustrations for the penetrator mission scenario and the relative benefits of each slew are discussed in terms of slew accuracy, energy (fuel) efficiency and time efficiency. For example, a sequence of half-cone manoeuvres (a multi-cone manoeuvre) tends to be more energy-efficient than one half-cone for the same final slew angle, but more time-consuming. As another example, the new technique is designed to overcome the specific restriction on slew angle attainable by a half-cone manoeuvre, giving one additional degree of freedom for designers to fine-tune.