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ROBUSTNESS ANALYSES OF ATTITUDE SLEW MANOEUVRES FOR SPINNING PENETRATOR SPACECRAFT

Abstract

Spin-stabilisation of spacecraft is considered a simple and relatively effective way of ensuring passive attitude stability and has therefore seen wide application. However, very few spin-stabilised spacecraft are prolate (long and slender), likely due to the fact that spin-stabilising a prolate spacecraft is dynamically unstable in the presence of energy dissipation due to e.g. fuel sloshing. Recently, interest in prolate spinning spacecraft has been rekindled because of mission proposals utilising a penetrator concept for exploration of atmosphere-less celestial bodies such as the Moon. A penetrator is a spacecraft/probe that is designed to impact the body and survive, thereby burying itself in the upper layer, yielding an attractive vantage point for subsurface sensors such as seismometers. A high-level analysis and comparison of attitude slew algorithms using only one thruster has been performed previously in a paper presented at IAC 2010.

This paper aims to give a summary of the comprehensive robustness analysis of seven different single-thruster slew manoeuvres for a rigid, highly prolate spin-stabilised axisymmetric penetrator spacecraft as designed in the MoonLITE mission proposal. This analysis has been performed using both analytical solutions and simulations, except for the Rhumb line algorithm where only simulations could be used. Five different parameters (spin axis moment of inertia, transverse moment of inertia, spin rate, thruster-on time, asymmetry) were perturbed one by one; the impact of different design parameters (moments of inertia, spin rate) on the slew error has also been investigated.

Comparing the analytical solutions with the simulation results it appears that the analytical solutions are quite accurate and require much less computation time. A further advantage of using analytical solutions is that they can be inverted and used to e.g. determine the minimum spin rate given a certain maximum slew time. With respect to the comparison between the slew algorithms, all slews derived from the Half-cone slew algorithm turn out to be highly susceptible to errors in spin rate for a spacecraft of this type; errors in moments of inertia have a much lower impact on the final accuracy. Of the Pulse-train algorithms, the Rhumb line is relatively impervious to a spin rate disturbance but the Spin-Synch is not. These results will benefit the design of a penetrator mission and spacecraft as they allow the designer to improve estimates of a mission's feasibility.