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Author: Prof. Pavel M. Trivailo
RMIT University, Australia, Australia, trivailo@rmit.edu.au

Prof. Hirohisa Kojima
Tokyo Metropolitan University, Japan, hkojima@tmu.ac.jp

AUGMENTED CONTROL OF INVERSION OF THE SPINNING SPACECRAFT, USING INERTIAL MORPHING

Abstract

The paper is aiming to contribute to the attitude dynamics and control of spacecraft and is offering a new method of control of inversion of the spinning spacecraft.

It is well-known that for a rigid body with three distinct principal moments of inertia, its rotation about the intermediate moment of inertia axis is unstable and is associated with periodic inversion of the axis of dominant rotation. This phenomenon, observed in space, is known as "Dzhanibekov's Effect" (discovered in 1985 by V.A.Dznahibekov) and is closely related to the peculiar dynamics of the spinning tennis racket, explained with "Tennis Racket Theorem", published in 1989 by M. Ashbaugh, C. Chicone, and R. Cushman. In the most recent publications by the authors of this paper, a new method of control of this "flipping" motion of the spinning rigid bodies has been presented. It is based on the proposed two strategies (distinct groups of solutions) of the "inertial morphing", during which the selected moments of inertia of the spacecraft are actively changed via controlled mass distribution to influence attitude dynamics in the desired way. The inertial morphing can also be used to activate flipping on a spacecraft, performing initially stable spin, and there could also be two strategies.

In order to improve the efficiency of the inversion, in the current paper we are further proposing to enhance capabilities of the inertial morphing method of control by utilizing an additionally installed on-board torque wheel. It enables not only more precisely control inversion of the spacecraft, but also offers additional capabilities to influence the period of the inversion and more effectively suppress tumbling of the spacecraft during the phases of transition from one axis orientation of the spacecraft to the inverted orientation. Optimal control methods are used to determine changes to the inertial properties of the spacecraft and spin of the torque wheel. This paper presents results of the representative cases simulations. This method is also illustrated with the geometric interpretation, showing associated morphing of the kinetic energy ellipsoids, which (being transient in our cases) is in contract to the traditional methods, employing constant shape ellipsoids.

It is believed that the proposed method, due to its simplicity, low cost of implementation and very small volume requirement of the control components, could be useful in development of new space missions of spacecraft, in particular small satellites and/or enhancement of the small spacecraft formations.