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DESIGN AND ANALYSIS OF MULTIPLE COMPETING "INERTIAL MORPHING" CONTROL SCHEMES FOR AUTONOMOUS SPINNING SPACECRAFT, ENABLING ATTITUDE ACROBATICS WITH AIMED AGILITY

Abstract

Inertial Morphing (IM) is a concept, first introduced by the authors in 2017 and further expanded in their publications. It implies deliberate manipulation of inertial properties of spinning spacecraft for its attitude control and/or for augmentation of traditional attitude control systems. Installation of the "scissors"-type mechanism, allowing re-position of the working masses, is an example of a method to achieve IM changes. Alternatively, manipulation with deployment of the spacecraft appendages could be used to utilize the associated changes in the inertial properties of the system for attitude control. It has been previously demonstrated that the initial motion of the free spinning systems, being stable spin, tumbling, or unstable flips, could be significantly modified via special IMs, applied at specific instants.

In this paper, the generalized methodology for searching feasible solutions for IMs is presented. It is based on the graphical interpretation of the kinetic energy and angular momentum, expressed in special non-dimensional angular momentum coordinates. For the transformation of the character of the attitude motion of the system, determination and application of the cascaded discrete IMs is explained: each of the IM should force the godograph of the vector of the angular momentum to switch from the old separatrix (or polhode) to a new, specially selected separatrix (or polhode). It is shown, that with the selection of the new separatrix, we arrive at the inverse problem for feasible IMs, which has multiple solutions. In this paper we present analysis of these competing solutions performed in view of the requirement for the agility of the attitude manoeuvre, as each of the separatrices would be characterized with its own period. We also describe in detail the process of selection of the IM at each of segments of the cascaded sequence.

Most significantly, the paper presents reduction of the continuous control actions to paltry number of discrete morphings. Furthermore, we demonstrate how selection of the most feasible separatrices with optimal flipping periods may pave the way for the desired acrobatic scenarios with aimed agility. These would suggest novel spacecraft designs for agile or prolonged manipulations with the spacecraft attitude motion and will allow optimized detumbling of spacecraft, as well as transfer of the rotation from one body axes to another without the need for additional propellant or reliance on reaction wheels. The key expected benefits of this research include ability to design small-size, low-weight, low-energy consumption, low-cost autonomous spacecraft with acrobatic capabilities.