Paper ID: 75525
student

IAF SPACE SYSTEMS SYMPOSIUM (D1)
Innovative and Visionary Space Systems (1)

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SPACECRAFT ATTITUDE CONTROL USING INERTIAL MORPHING

Abstract

The aim of this paper is to present the application of the novel concept of "Inertial Morphing" (IM) introduced by P.M. Trivailo and H. Kojima in 2017. As per their research, IM is deliberate change of inertial properties of the rigid body system in real time specifically applied as controls of the attitude of the spacecraft with a spin. This concept can be expected to replace or enhance the current gyroscopic systems to manoeuvre the spacecraft, saving mass and energy.

The concept of "IM" was prompted by the observation of rigid bodies in space performing the intriguing flipping motion. The phenomenon was first observed in space by famous US scientist-astronaut Owen Kay Garriott on-board Skylab in 1973, but later publicised by USSR cosmonaut Vladimir Dzhanibekov as "Dzhanibekov's effect" during his space flight in 1985 by observing the flipping of a spinning wing nut. The resulting flipping motions of rigid bodies with various shapes can be explained by the Euler equations, derived in 1785 for rigid bodies with fixed area moments of inertia.

This paper presents results for complex cases of rotational motions of the bodies, which are not "rigid bodies" as defined in classical mechanics but are rather systems with the variable area moments of inertia. The results are a part of the PhD research project, dedicated to the design of a conceptual spacecraft prototype that can perform Inertial Morphing changes in real time. Autodesk's® Fusion 360™ is a capable CAD software and was used to design a very accurate CAD model of the integrated system. The design involves a unique mechatronic sub-system that is compact and requires minimum movements to perform IM and complies with all the requirements of ESA's parabolic flight to possibly perform the test in micro gravity in the future.

With this system it is possible to change the inertial properties in all three axes while in unconstrained flight. The prototype not only gives options to initiate the flipping motions with varying periods or completely cease flipping motion, but even allows to perform transfer of the system's initial regular spin to the spin about different nominated body axis. This would enable a spacecraft to perform various acrobatic attitude manoeuvres and this paper will provide details on the proposed innovative concept of spacecraft conceptual prototype design. Simplicity of utilised control method and energy efficiency of the system's design show promise for the application in autonomous spacecraft missions.