ASTRODYNAMICS SYMPOSIUM (C1)
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ATTITUDE CONTROL OF AN AGGREGATED MODULAR SPACECRAFT WITH MOMENTUM REACTION SPHERE ACTUATORS

Abstract

Magnetically levitated spherical momentum actuator, usually named reaction sphere (RS) or 3D Wheel, has a spherical rotor magnetically suspended inside the stator. Free from mechanical shaft constraint, a single RS is enough for 3-DOF attitude control without singularities, it possible to reduce the system weight and size. Free from frictions leads to high precision, high rotation speed and long life. The reaction sphere is an attractive solution for aggregated spacecraft ACS module solution, since: (1) The spherical symmetry property of RS makes the alignment issue to mainly a software problem, which drastically reduces the time and cost of the assemble and integration. Also convenient to package into a cube, a very beneficial geometry for building blocks; (2) the one-rotor, 3-DOF controllably feature lead to simple and high function density module design, with redundancy constructible via simply adding additional stator poles. (3) Very flexible yet very simple additive law for synthesis of total control torque among multiple RS actuators; (4) Low-level couplings of actuator gyroscopic momentum to body dynamics, and capability to make direct inter-axis momentum exchange, which benefit the system stability and agility. Up to date, reaction sphere prototypes based on a variety of magnetic suspension and driven principles are developed around the world. However, most literatures are focused on the component level design of the actuator, yet very little discussion on system level application issues is available. In fact, the application strategy is of key important as it's guidelines to the device design and baseline tradeoffs. This paper is an effort on the RS based ACS strategy design, whose contribution is threefold. (1) Proposition of a system level satellite attitude dynamics model with one to multiple reaction spheres, composed of both coupled translational and rotational motion; (2) A comparison of the RS-based, flywheel-based and CMG-based ACS. Through analytical dynamics equation comparison, we revealed the two appealing characters of low-level actuator gyroscopic momentum coupling and simple additive torque synthesis. And numerical simulations are carried to verify that; we also made a physical explanation of the low-level actuator gyroscopic momentum coupling mechanism, and gave some essence of couple effect diminishing principles.

(3)Third, a novel control assignment method for multi-RS based satellite. An inertial referenced RS momentum direction preservation control assignment law is developed, which would be of help in diminishing gyroscopic rotor momentum coupling and relaxing of rotor status measurement requirement.