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Li Guidan, Li Haike, Li Bin

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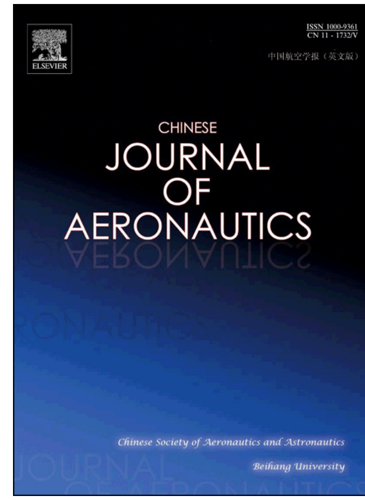

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Spacecraft attitude maneuver control using two parallel mounted 3-DOF spherical actuators

Li Guidan[a,*], Li Haike[b], Li Bin[a]

[a]*School of Electrical Engineering and Automation, Tianjin University, Tianjin 300072, China*
[b]*State Grid Tianjin Power Dongli Power Supply Branch, Tianjin 300300, China*

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Abstract

A parallel configuration using two 3-degree-of-freedom (3-DOF) spherical electromagnetic momentum exchange actuators is investigated for large angle spacecraft attitude maneuvers. First, the full dynamic equations of motion for the spacecraft system are derived by the Newton-Euler method. To facilitate computation, virtual gimbal coordinate frames are established. Second, a nonlinear control law in terms of quaternions is developed via backstepping method. The proposed control law compensates the coupling torques arising from the spacecraft rotation, and is robust against the external disturbances. Then, the singularity problem is analyzed. To avoid singularities, a modified weighed Moore-Pseudo inverse velocity steering law based on null motion is proposed. The weighted matrices are carefully designed to switch the actuators and redistribute the control torques. The null motion is used to reorient the rotor away from the tilt angle saturation state. Finally, numerical simulations of rest-to-rest maneuvers are performed to validate the effectiveness of the proposed method.

Keywords: Attitude maneuver; Spherical actuator; Parallel configuration; Backstepping control; Singularity; Null motion

1. Introduction

Control moment gyros (CMGs) are widely used in spacecraft attitude control, which is attributed to the advantages of high torque capacity and no propellants.[1-3] Especially, the single gimbal CMG (SGCMG) features the torque-amplification-capability. However, complex gimbal structures, large servo parts and commonly required cluster configurations limit their applications to small spacecraft. In contrast, multi-degree-of-freedom (multi-DOF) spherical electromagnetic momentum exchange actuator (SEMEA) has great advantages of reducing attitude control system (ACS) mass, volume and power requirements because of their higher structural integration.[4] Furthermore, its largest asset is that a single device is capable of generating three-axis control torques because the variable-speed rotor can be tilted in any direction, which shows great prospect in 3-axis spacecraft attitude control.[5, 6]

Over the past decades, a variety of structural forms of spherical actuators have been proposed, which commonly have a spherical rotor or a spherical stator. Downer et al.[7] proposed a magnetic rotor suspension system including a magnetic annulus rotor and a spherical stator. An armature is used to induce rotation of the rotor and the spin axis can be gimbaled by selectively exciting the control coils on the stator. A

* Corresponding author. Tel.: +86 22 27890983.
E-mail address: lgdtju@tju.edu.cn.