Paper ID: 63778
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IAF ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (2) (9)

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HIGH PRECISION SATELLITE ATTITUDE CONTROL USING DOUBLE-GIMBAL VARIABLE-SPEED CONTROL MOMENT GYRO WITH UNBALANCED ROTOR

Abstract

Variable high inertia satellite requiring precision pointing needs Control Moment Gyros (CMGs) for their actuation and alignment. Double Gimbal Control Moment Gyro (DGCMG) which encounters less singular situations as compared to an array of Single Gimbal CMGs (SGCMGs) can be used for such purpose. Double Gimbal Variable Speed Control Moment Gyro (DGVSCMG), a variant of the DGCMG wherein rotor speed is variable, is a three axes actuation system that is more useful than DGCMG for control purposes. However, all the CMGs create undesirable disturbance such as high-frequency vibration which influences the imaging performance of high-resolution remote sensing satellites making the attitude control a real challenge. These high-frequency vibrations are mainly caused by static and dynamic imbalances of the rotor and rotor bearing. Achieving attitude control with precision orientation and stabilization is necessary for providing an ultra quiet environment for the optical payloads onboard, and requires reduction in vibration propagated into the satellite bus induced by the CMGs. The internal degrees of freedom associated with the DGVSCMG get coupled in a complex nonlinear way with the satellite bus attitude degrees of freedom, and therefore needs to be accounted in modeling of the complete dynamics for precision control. The above issue of a high inertia satellite actuated using a DGVSCMG has been addressed in this paper. The DGVSCMG is modeled in the framework of geometric mechanics to account for the spacecraft large angular motion and the wheel imbalances of the DGVSCMG. The satellite attitude control tracking is accomplished using a proposed novel robust adaptive fixed-time sliding mode control to ensure time bounded convergence independent of the initial states of the system. A novel sliding surface is also proposed to ensure that gimbal rates converge to zero when the attitude and angular speed converge to the desired values. In the controller design procedure, actuator saturation, system uncertainty which contains external disturbances, and inertia uncertainty are also considered. A satellite equipped with a single DGVSCMG for attitude control is considered to validate the proposed control algorithm. Multiple test cases of rest to rest attitude maneuvers are simulated. Results demonstrate efficacy of the proposed controller in driving the satellite attitude from a given initial state to any desired final state within the settling time of 20 seconds with pointing accuracy better than 0.01 degree and stability better than 0.0005 deg/s.