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ATTITUDE AND VIBRATION CONTROL OF A FLEXIBLE SATELLITE USING DOUBLE-GIMBAL VARIABLE-SPEED CONTROL MOMENT GYRO WITH UNBALANCED ROTOR

Abstract

Large satellite systems comprise rigid and flexible modules. This natural separation of the structural subsystems of the satellite into two distinct categories is due to the use of large flexible appendages. Attitude maneuver of the satellite results in the vibration of these flexible appendages. Controlling such systems requires first modeling the system dynamics comprising rigid bodies and flexible modes. In this paper, satellite attitude control of such a system is accomplished using a single double-gimbal variable-speed control moment gyro (DGVSCMG). If the DGVSCMG has an unbalanced rotor, this produces undesirable high-frequency vibration, which adds to existing vibration due to the flexible appendages. Simultaneous control of attitude and suppression of vibration for precision pointing or tracking poses a real challenge if the DGVSCMG is faulty, as described above. The presence of a fully flexible appendage on the satellite necessitates significant changes in the formulation of equations of motion, mainly when the relative motion of the satellite and the appendages is subject to closed-loop nonlinear control. This paper addresses these issues for a flexible satellite actuated using a DGVSCMG with an unbalanced rotor. The dynamics of the satellite having large appendages and DGVSCMG with an unbalanced rotor are developed in the framework of geometric mechanics. The coupling of the rotational and the translational dynamics arising due to thrusting is also accounted for in the formulation of the system dynamics. It is shown that the internal degrees of freedom of satellite attitude, unbalanced rotational dynamics of the DGVSCMG, and modal displacement of the flexible appendages are coupled with each other. A fixed-time sliding mode control is proposed for the attitude and vibration control of the proposed flexible satellite system actuated using a single DGVSCMG having an unbalanced rotor. External disturbance torque, uncertainty in the satellite inertia, and thrusting are accounted for in designing the control. Stability proof of the overall closed-loop system is given via Lyapunov analysis. Simulations are carried out for the dynamics and control developed for the above-described system. Simulation results show that when the satellite is thrusted, the vibration of the flexible appendages starts, which then affects the satellite's attitude. However, the proposed attitude controller not only suppresses the vibration caused by the flexible appendages and unbalanced rotor but also drives the satellite from the initial orientation to the final orientation within 40 s, showing the efficacy of the proposed control.