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ANALYSIS OF LARGE FLEXIBLE SPACECRAFT ELASTIC VIBRATION MODEL AND IMPACT ON ATTITUDE CONTROL SYSTEM

Abstract

Renewed scientific interests in the orbital maneuver of large flexible spacecraft keep growing over the last decade. The large flexible tandem spacecraft is often assembled by single spacecraft through the mission of rendezvous and docking process to form a complex multi-body system.It could generate coupling phenomena with low natural frequencies during the process of orbital maneuver. The dynamics and control of such systems is a challenging task, this is mainly because the dynamic equations are highly nonlinear, especially for the elastic vibration model. The purpose of this study primarily focuses on the analysis of large flexible tandem spacecraft elastic vibration modelling and its impact on the spacecraft attitude control system. Firstly, based on the features of large tandem spacecraft model, we derive elastic vibration equation using finite element method(FEM), and the comparison with other equations is made using the traditional one-dimensional vibrating beam modelling method. Traditional method contains three elastic vibration equations, corresponding to three generalized coordinates qφ, qψ, qγ,separately describe longitudinal bending vibration, yaw bending vibration and axial torsion vibration. These three vibrations distinguish three kinds in the equation, ignoring the coupling between them. The new elastic vibration model using finite element method(FEM) only has one equation, corresponding to one generalized coordinate qi,which could accurately reflect vertical, horizontal, torsion coupled motion characteristics as well as completely describe the arbitrarily complex elastic vibration of the spacecraft. Secondly, Inverse Nyquist Array(INA) method is exhibited according to the multi-input and multi-output system(MIMO). This is mainly due to that the spacecraft vertical, horizontal and torsion motion are fully coupled and coupling matrix is diagonally dominant, which traditional controller design method is no longer applicable. The attitude control system caused by elastic vibration coupling degree between the three-motion is analysed based on the diagonal dominance, then the INA method is used for attitude control system design. Simulation is in the case of large flexible tandem spacecraft,elastic modal is 28 when controller design and time-domain simulation considered.1-9 modes is bend direction of spacecraft in 45 degree of coordinate plane; 10-18 modes is in 135 degree;19-23 is longitudinal vibration modes of spacecraft;and 24-28 modes is torsional modes.Modal damping ratio is taken as 0.005. Time domain simulation with variable coefficients has been carried out 2-160s.Results show that maximum deviation of pitch angle, yaw angle, roll angle is 2.0 degree,1.5 degree,2.2 degree respectively, which verifies the effectiveness of the controller design through the variable coefficient of time domain.