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VIBRATION SUPPRESSION OF SPACE STRUCTURES USING CONTROL MOMENT GYROSCOPES AS ACTUATORS

Abstract

Large space structures, such as radar antennas, solar arrays and space trusses have been extensively used in spacecraft for remote sensing, communication and space related research. Vibration suppression of the flexible structures is an essential problem to accomplish the space missions. Control system design for vibration suppression has been a challenging problem for decades because of the large size, low rigidity and the low natural damping of the flexible structures. Choosing appropriate actuators and sensors is first required during the process of designing control system for large space structures. Thrusters can exert active control forces on the structures. Several related problems have been discussed; however, they are not clean actuators and must be refueled for long-term use. Using piezoelectric materials as actuator/ sensor is a powerful method to suppress the vibration and a variety of control strategies have been developed. But the ability of piezoelectric materials to control large structures is limited. Control moment gyroscopes (CMGs) are an efficient mean of generating continuous and precise torques without expending propellant. Therefore, using CMGs in the vibration control of flexible structures offers an attractive option. This drives the motivation of the present study.

This paper presents a new and effective approach for vibration suppression of constrained large space structures. Collocated CMGs and angular rate sensors are adopted as actuators/ sensors for the system. The dynamics of a flexible structure with n CMGs in arbitrary configuration is developed. The dynamics of the CMGs and their interactions between the flexibilities of structure is incorporated in the formulation. Then, the equations of motion are linearized to describe the small-scale movement of the system. The optimal placement problem of the CMGs on the flexible structures is considered first. Two optimization approaches are developed from the perspective of controllability and observability of the system. They both just require calculating the optimization indexes of the candidate locations for the actuators and sensors on the flexible structure. The controller for the vibration suppression is synthesized using only the angular rates of the locations where the CMGs are mounted. In order to keep the gimbal angles small for a long time operation, the control law is designed to guarantee the gimbal angles asymptotically tend to zero reference. The stability of the controller is proofed by Lyapunov theorem.

Numerical examples of several space structures demonstrate the efficacy of the proposed control strategy toward suppressing the vibration.