Paper ID: 69174
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IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Smart Materials and Adaptive Structures (9)

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EXPERIMENTS OF A ROBUST CONTROLLER FOR ACTIVE VIBRATION REDUCTION OF SPACE STRUCTURES WITH LINEAR AND PATCH PZT DEVICES

Abstract

The interaction between spacecraft structural dynamics and its rigid-body control system is a well-known issue in the space field. Indeed, this phenomenon often leads to the worsening of pointing performance, to unwanted large flexible deformations and even to instabilities or failures. Active Vibration Control (AVC) is a strategy adopted to reduce elastic vibrations in flexible structures, thus mitigating, in case of space systems, the coupling with the attitude dynamics. To this purpose, different actuators can be used, ranging from proof-mass to shape memory alloys, to piezoelectric (PZT) devices. In this research, Offset Piezoelectric Stack Actuators (OPSA) are paired to PZT patch sensors to suppress the elastic vibrations of a space system. In detail, a robust control architecture is implemented to guarantee the desired closed-loop performance, while coping with the presence of several parametric uncertainties of the flexible structure: modal shapes and frequencies, damping factors, sensors and actuators dynamics, structural modeling approximations. In particular, the controller is designed to shape the system desired closed-loop behaviour while accounting for actuating capability limits, input disturbances and sensor noise. To address system uncertainties with an efficient approach and carry out the robust synthesis/analysis, the uncertain state space model is put into a Linear Fractional Transformation (LFT) framework. The efficiency of the proposed AVC framework is verified numerically, by means of structured singular value analysis performed on a finite element model of the controlled system, and then experimentally validated. Two experimental set-ups are realized. The first configuration, used to achieve am initial validation of the proposed approach, consists of a cantilevered panel actuated via an OPSA, with a PZT patch to sense elastic deformations. The testbed is also equipped with an external contactless metrology system, i.e. a motion capture VICON device, used as benchmark for piezo embedded measurements. However, this set-up lacks a key feature of flexible satellites: the interaction between flexible and rigid-body dynamics. Therefore, a second configuration is developed to prove the architecture can be successfully implemented for one or more flexible structures mounted on a free-floating platform, reproducing a flexible satellite attitude dynamics (under single axis rotation hypothesis). The performance in terms of decrease in settling time will be reported, together with an analysis of the power consumption of the sensors/amplifier/actuators chain. Further steps paving the way for a coupled attitude/elastic MIMO control will be suggested.