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Author: Dr. Federica Angeletti
University of Rome “La Sapienza”, Italy

Ms. Francesca Callipari
University of Rome “La Sapienza”, Italy
Dr. Marco Sabatini
Sapienza University of Rome, Italy
Mr. Paolo Iannelli
Sapienza University of Rome, Italy
Prof. Paolo Gasbarri
University of Rome “La Sapienza”, Italy

NUMERICAL MODELLING AND EXPERIMENTS OF A VIBRATION SUPPRESSION SOLUTION VIA OFFSET PIEZOELECTRIC STACK ACTUATORS FOR SPACE STRUCTURES

Abstract

Most of modern satellites for Earth and Universe observation are equipped with large flexible antennas, deployable booms and solar panels to achieve their mission objectives. However, the fulfillment of spacecraft pointing and stability requirements may be jeopardized by the undesired elastic vibrations of such flexible parts, due to the coupling between rigid and elastic dynamics. Therefore, control solutions aiming at avoiding disturbances and, at worst, the failure of the mission, are needed. In this scenario, growing interest has been recently devoted to Active Vibration Control (AVC) strategies based on smart materials. Piezoelectric patches are the most studied and tested devices for both actuating and sensing purposes. This paper contributes to this line of research by investigating a different type of actuator, namely an Offset Piezoelectric Stack Actuator (OPSA), obtained by interfacing a multilayered piezoelectric stack at a selected distance (offset) from the structure neutral plane by means of supporting brackets. Despite its promising performance, deriving from the exploitation of the direct piezo coefficient instead of the transverse one (used by the patches), literature related to its space applications is currently scarce.

The objective of this paper is to demonstrate the performance of OPSA devices for damping out elastic vibrations of large space structures. Since the control algorithm should not be considered as the core of this research activity, a classical closed loop feedback control technique is selected.

In order to develop the AVC system, an electro-mechanical coupled Finite Element (FE) formulation is implemented, integrating both sensors and piezo-stack elements on the passive hosting structure. The dynamic model of the active structure, including both electrical inputs/outputs as well as the modified mass and stiffness effects due to the additional piezo devices, is then obtained. A parametric study is carried out to produce the optimal combination of geometrical and physical parameters of the active devices as well as the optimal horizontal/vertical offset of the OPSA device.

This software tool is then experimentally validated in the case of a cantilever plate, representing a scaled solar panel. Special attention is devoted to assess and compare OPSA performance to standard patch actuators. Real-world data will be used not only to verify the expected performance, but also to tune the sensors and actuators parameters of the OPSA FE model, that can be finally integrated in an orbital and attitude propagator to assess the AVC system performance during typical attitude manoeuvres.