Paper ID: 63473
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student

IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Smart Materials and Adaptive Structures (9)

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BATTERY-LESS SOFT SENSOR OF SPACECRAFT VIBRATION WITH ADVANCED PIEZOELECTRIC ENERGY HARVESTER

Abstract

Structural vibration on spacecraft hinders further advanced space explorations with high-sensitivity optical measuring equipment and other sensors. Conventional passive vibration suppression with mechanical dampers cannot meet the severe vibration requirements of the sensors. The excessive weight gain of a spacecraft caused by additional dampers and masses shifting resonance frequency is inappropriate from the viewpoint of spacecraft design. Active vibration suppression can be achieved while minimizing spacecraft weight gain with incorporation of piezoelectric transducers, which have been gaining noteworthy consideration in sensors, energy harvesters, and actuators, as a part of the structural components of a spacecraft. Active control requires three elements: a sensor, a power supply, and an actuator. Mounting sensor hardware on a spacecraft is undesirable because it requires installation space and cumbersome wiring. Power consumption for vibration suppression is also undesirable for a spacecraft with a limited total amount of energy to operate its mission. We proposed a battery-less soft sensor to achieve active vibration suppression on spacecraft. One multifunctional piezoelectric transducer plays three roles, sensing, energy harvesting, and actuation. The voltage generated by the transducer is proportional to the deformation of the spacecraft in which the transducer is embedded, and thus, structural vibration can be sensed. A digital controller driven by the electrical energy harvested by the transducer estimates the spacecraft vibration as a soft sensor with the Kalman filter using only the piezoelectric voltage as the observation value. The piezoelectric transducer suppresses the vibration of the spacecraft based on an appropriate control signal to the transducer with the estimated value. The proposed system is compact because it eliminates an external power supply and sensor hardware. The proposed system can satisfy the strict weight and volume requirements of a spacecraft design. In this study, the proposed system is simulated and operated in a vibration environment caused by broadband disturbance simulating an actual spacecraft. Through the validation experiment, we evaluated three points: the demonstration of self-powered operation, the performance of the soft sensor, and the vibration suppression performance. The experimental result shows the satisfactory sensing performance under the self-powered driven conditions. The technical advantages on space operation of the proposed system have been demonstrated from this experiment.