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MULTI INPUT SINGLE OUTPUT ELECTROMECHANICAL IMPEDANCE STRUCTURAL HEALTH MONITORING: HARDWARE IMPLEMENTATION AND APPLICATION TO SPACE VEHICLES

Abstract

Structural Health Monitoring (SHM) plays a pivotal role in ensuring the safety and reliability of space vehicles, which include satellites and other spacecraft. The implementation of SHM to space vehicles aims to minimize structural failures, ultimately contributing to decreased operational costs and increased safety. Monitoring the structural integrity of space vehicles in a systematic manner enables early detection of emerging issues, making it possible to implement proactive in-orbit maintenance and mitigation measures. This proactive approach not only extends the duration and potential of mission but also creates a more cost-effective and secure environment for space exploration and satellite deployment.

A new SHM approach encompassing multi input single output (MISO) electro-mechanical impedance measurements is suggested. In this approach, thin piezoelectric sensors installed on a space structure are simultaneously excited with a harmonic signal. An electromechanical impedance response to this excitation is measured by a single sensor. The obtained electro-mechanical impedance signature includes the structure's dynamic response and can be used to monitor potential damage affecting natural structural frequencies. A mathematical description of the method is provided and laboratory experimental studies supporting application of the method to space structures are discussed.

To implement the MISO approach to SHM of space systems, a new miniaturized hardware system was designed. This hardware utilizes a set of impedance measurement chips and microcontrollers to enable independent multi-channel structural impedance measurements. The collected data is stored on an SD card and could be passed to satellite communication hardware for direct transmission to Earth.

In this contribution, the authors focus on an experiment that utilizes the electromechanical impedance method using thin piezoelectric sensors for SHM of a fixed plate integrated into a 6U CubeSat. The experiment aims to study the effects of the space environment on the plate's structural health and validate the applicability of this method in space. While the electromechanical impedance method has found widespread use in laboratory based SHM, this study endeavors to extend its utility to the challenges posed by complex space structures and diverse space environments. The 6U CubeSat is planned to be deployed into low Earth orbit, where it will be exposed to various space environmental factors such as vacuum, temperature fluctuations, and radiation.

The results of this study will contribute to the development of more robust and reliable space vehicles, and provide a better understanding of the effects of space environmental factors on structures and the performance of SHM methods.