Multilayer Composite Insulation for Advanced Onboard Performance Monitoring System of Spacecraft Structures in Extreme Temperature Environments

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Abstract

A successful operation of any space mission requires an accurate performance monitoring of the associated spacecraft which depends on various sensors to provide critical structural health information during fabrication, testing and service lifetime. NASA has long recognized the significance to have performance monitoring for spacecraft and a large number of NASA programs focus on the development and application of performance monitoring systems. Several advanced performance sensing system have been successfully flight-tested for space shuttles. Structural performance monitoring is expected to be of increasing importance to NASA as we address the requirements of the National Vision for Space Exploration. However, characterized by the properties of microgravity, vacuum, presence of radiation, large thermal variations, mechanical vibrations and shock resulting from the launch, space is well-known as one of the most challenging environment for any sensing system. One of the major requirements to perform spacecraft's health monitoring is to operate the sensors in extreme temperature environments with large temperature variance. Most structural performance sensors, such as electrical resistance gauges, are designed to be working in room temperature. An extreme temperature challenges the dynamic range of most temperature sensors and significantly influences other performance sensor's accuracy, reliability, and durability. To enhance the reliability of the spacecraft's performance monitoring system, the easiest way is to coat the onboard sensors with a layer of suitable material to insulate the temperature effects. In this talk, appropriate multilayer insulation coatings are described to help to eliminate the environmental effects and ultimately adjust the sensitivity the sensors towards the parameters needed to be sensed. The developed composite insulation in this study takes the advantages of innovative layer configurations including metal and nonmetal layers in a single insulation. This will be accomplished by guiding the composite insulation configuration through theoretical and numerical modeling analysis of heat transfer and thermal stress progressing. Detail theoretic, numerical, and experimental analysis proved the feasibility of the proposed multilayer structure of the insulation to work up to 1,000°C without inducing significant deformation on the top of sensor surface from heat. The developed multilayer composite insulation, if applied, for structural performance sensing systems of spacecraft, thus, enables their accurate monitoring capability in harsh service environments.