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SHM OF SPACE STRUCTURES: USE OF POLARIZATION-MAINTAINING FIBERS TO DECOUPLE THE THERMO-MECHANICAL EFFECT ON FIBER BRAGG GRATING SENSOR MEASUREMENTS

Abstract

Recent advancements in sensing and actuating technologies have facilitated significant strides in the development of smart structures. The foremost requirement in smart structures entails the incorporation of sensing capabilities within structural components. Consequently, considerable research endeavors have been directed towards the development os sensors and sensing methodologies for integration into engineering structures.

Fiber Bragg Grating (FBG) sensors have indeed become increasingly popular in space applications, especially for monitoring temperature and internal strain in composite structures. Their ability to provide accurate, localized measurements of temperature and strain helps ensure the integrity and safety of critical components in space. In addition, FBG sensors operate based on the principle of optical interference, making them immune to electromagnetic interference. This is particularly important in space environments where electromagnetic radiation from solar flares, cosmic rays, and other sources can interfere with electronic sensors. Furthermore, FBG sensors have the potential for mass production compared to alternative optical fiber sensor variants. This scalability makes them cost-effective for large-scale deployment in space missions and facilitates the integration of multiple sensors for comprehensive monitoring systems.

Embedded FBG sensors are often subject simultaneously to temperature variations and mechanical stresses. In order to distinguish these two contributions on measurement accuracy, various methods have been explored in literature, such as: core dopants, calibration and combined measurements with embedded thermocouples, and encapsulated sensor configurations.

In a bid to surmount the constraints inherent in extant measurement techniques, ongoing research aim to harness intrinsic decoupling methodologies. Notably, this entails the utilization of FBG sensors inscribed within birefringent or polarization-maintaining optical fibers.

These specialized fibers exhibit distinctive refractive index distributions across their cross-section, facilitating dual principal axes along which light propagates at different velocities. This unique attribute enables the generation of two discrete peaks from a singular sensor, each manifesting distinct responses to variations in deformation and temperature. Leveraging this property, thermo-mechanical measurements can be effectively decoupled utilizing solely the fiber itself, thereby providing localized insights into temperature and strain at the same measurement point. This innovative measuring system amplifies sensing capabilities without necessitating additional components.

Overall, the lightweight, compact, and reliable nature of FBG sensors, coupled with their immunity to electromagnetic interference and ability to provide accurate, distributive measurements, make them

highly desirable for a wide range of space applications where temperature and strain monitoring, in harsh environments, are critical for mission success and astronaut safety.