Performance of a Guided-Wave SHM System for Launcher Structure Revalidation

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Abstract

The reuse of space launchers is increasingly considered a key strategy to reduce costs and enhance the competitiveness of the space industry. However, this approach requires an efficient and reliable revalidation step before each flight to ensure the mechanical integrity of the structures. Structural Health Monitoring (SHM) offers a promising solution to address this challenge by enabling real-time assessment of structural health through the integration of sensors networks embedded within launcher structures. In this work, we propose the use piezoelectric transducers. With these elements, two SHM strategies can be investigated: active and passive. On the ground, the active-mode SHM system uses guided waves in emission/reception to inspect the structure. During flight, the passive-mode system records acoustic events, such as the emergence of defects, thereby contributing to improved diagnostics.
One of the main challenges facing SHM systems, especially in space applications, is ensuring that they do not introduce damage and assessing their reliability under extreme environmental conditions. The proposed SHM system is bonded to the launcher and experiences the same extreme conditions as the structure itself, resulting in thermomechanical aging of both the launcher being inspected and the monitoring system (1). This aging reduces the SHM system's ability to detect and localize defects on the structure (2), representing a critical challenge for its implementation on reusable launch vehicles (RLVs).

This work focuses on a network of active-mode guided wave piezoelectric wafers bonded to a complex composite structure representative of a launcher vehicle. The objective is to study wave propagation in a complex spatial composite structure and evaluate the ability of the SHM system to detect and localize damage at different aging states. A numerical model is first developed using the finite element method to describe both the SHM system and the structure at a reference state. The numerical model is then validated by comparison with experimental data obtained from wave propagation measurements (using a laser Doppler vibrometer) and electromechanical impedance measurements (using an impedance analyzer). Finally, experimental tests are conducted to subject the SHM system to representative thermomechanical loads. The observed aging trends are injected into the numerical model to

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evaluate the effects of aging on defect detection and localization.

In conclusion, the aging of the SHM system has been demonstrated to significantly impact its ability to detect and localize defects, highlighting the importance of assessing SHM system performance over time when applied to reusable launch vehicles.

References

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