Digital Holographic Studies on Detection of Defects in Honeycomb Sandwich Structures and Imaging of Stresses in Transparent Objects

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ABSTRACT

In satellite launch vehicles, honeycomb sandwich bonded constructions are extensively being used owing to its high bending stiffness and high specific strength. However reduction in stiffness due to debond and delamination in such structures may result in system failure. Vibration-based damage identification and health monitoring methods are widely used to ascertain proper bonding of face sheets to the honeycomb core. For inspection of such complex structures, the non-contact, whole field, highly sensitive, fast and easy to use optical interferometry techniques based on vibration are being inducted in aerospace industries. A few issues during the application of such optical techniques are addressed and solutions are proposed using one of the recent advancement in the field of interferometry called time average digital holography.

Honeycomb sandwich structures fabricated with curved edges for better structural integrity posed a problem to conventional methods in detecting debonded face sheets at the curved edges. Time average digital holographic method of inspection is proposed and the dynamic response of a debonded face sheet at the curved edge was mapped under a sinusoidal frequency sweep. The resonance frequency of the debonded face sheet at the curved edge was captured through frequency sweep and the feasibility of using time average method is established.

However, the procedure of frequency sweep to capture the resonance is time-consuming and it increases the inspection time. Hence the use of square wave excitation is proposed instead of sinusoidal frequency sweep for fast inspection. The advantage of square wave excitation over random excitation is also demonstrated experimentally. The effect of excitation magnitude and excitation location on the detectability of defects is also illustrated.
Most of the honeycomb sandwich structures are fabricated with potted-inserts to mount hardware ranging from electronic packages to mini-satellites. The effects of geometric and material discontinuities on the dynamic response due to the potted-inserts were studied for the successful application of optical inspection tools. Moreover, the dynamic response of plates with multiple holes and multiple stiffeners were also mapped simulating potted-insert sandwich structures. The above simulation was validated through both experiments and numerical studies. It is proposed that the extent of bonding of face sheet across potted insert can be evaluated at high excitation frequency.

A method to numerically plot holographic fringes, under the square wave and random excitations, is also proposed. The analytical solutions of the characteristic function of time average holography under two or more modes are provided by infinite series of the summation of the product of Bessel functions or by infinite series of probability density functions. However, these solutions under random or square wave excitation become very complex owing to the complex nature of the response under such excitations. A numerical solution through transient response analysis under random or square excitation using finite element method is proposed.

In satellite launch vehicles and space shuttles, transparent materials are being used for chemical storage and windows due to its transparency, high chemical resistance and strength. A study related to the application of digital holography for imaging stress fields in transparent objects was also carried out. A photoelastic digital holographic polariscope is proposed for imaging the stress field in both birefringent and non-birefringent transparent objects. This technique can be used for the inspection of defects in such transparent objects.