Fatigue Damage Evaluation in Ceramic Matrix Composite Materials for Aerospace Structural Applications

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Carbon fiber/silicon carbide ceramic matrix composites (CMC) are widely used in aerospace structural application because of their superior properties such as low density, high specific modulus/strength and high temperature mechanical properties. Fatigue damages occur in CMC materials due to dynamic loads acting on them during operation. Commonly occurring fatigue damages on CMC are matrix cracking, fibre-matrix debonding, fibre failure, delamination etc. Owing to their inherent limitations, conventional NDE methods such as ultrasonisc, radiography are inadequate to detect damages in CMC materials. Hence to ensure the quality of the product, safety margins and structural performance of these materials an alternate method to detect and evaluate fatigue damages, is of high significance.

Research work, on fatigue damage detection and quantification in CMC materials subjected to various levels of fatigue laoding, presented here is based on Lamb wave parametric characterization. Conventional dog bone type of specimens are prepared from C_f/SiC panels generated through isothermal isobaric chemical vapour infiltration (ICVI) process to carry out the fatigue experiments. The evaluation is carried out based on principle of acousto-ultrasonics by generation of waves on the specimen through bonded piezo actuators and time synchronized detection are done with scanning laser vibrometer.

Variation in Lamb wave parameters, like, wave length, velocity in the CMC specimens at a constant frequency of excitation is quantified to evaluate the fatigue damages. Lamb waves with asymmetric modes within the frequency range of 20 to 100 kHz are employed in this study. Scanning Laser Doppler Vibrometer was used to generate the lamb wave visualization plots on the specimens for various frequencies. Digital image correlation method was used on the lamp wave visualization plots to map the lamb wave velocity on the specimens subjected to fatigue cycles. Early stage fatigue damage was detected with the observation of nearly 5% of localized velocity variation on the fatigue specimens. Observation shows that percentage variation of velocity is increased with increase in fatigue damages.

Key Words: Vibrometer, Lamb Waves, Ceramic Matrix Composites, velocity mapping