ABSTRACT

The use of composite materials for high-performance structures, particularly in aerospace, wind turbine and automobile industries, is increasing due to several advantages such as high strength to weight ratio and higher resistance to corrosion. It is very important to ensure the reliability of the structures that are susceptible to damages in harsh operating conditions. In recent years, use of Lamb waves has proven to be an effective and efficient method for structural health monitoring, due to their ability to propagate longer distance with less attenuation and having high sensitivity to smaller defects. The accuracy of damage detection using Lamb waves gets affected significantly with the variation of environmental and operating conditions. This thesis is focused on developing a Lamb wave based localization methodology that can compensate the effect of operational and environmental changes. Lamb wave propagation characteristics in composite materials are strongly influenced by material anisotropy and dispersion behavior of the wave. An Effective Stiffness Matrix method (ESM) is proposed to solve the Lamb wave equations without numerical issues. The proposed ESM method offers a simple and mathematically straightforward formulation as it considers the multi-layered laminate as a single homogenous layer with effective stiffness properties. In addition, the directional dependency of Lamb wave propagation characteristic (wave velocity) with laminate configurations is studied, and later incorporated in damage detection procedures.

A new methodology is proposed to calculate the damage residue measure from current state responses which compensate the effect of operational and environmental changes. The proposed damage residue is obtained by comparing the current state responses of the identical paths with the same propagation distance and direction. For damage localization in the structure, a modified delay-sum damage localization algorithm is introduced. The proposed damage residue measure is used along with the modified delay-sum algorithm to identify the damage location in a composite plate. The methodology is tested through simulations based on a finite element model and validated through experiments on carbon fibre cross-ply configured composite plate. The in-sensitiveness of the proposed residue measure with temperature change is demonstrated experimentally. Further, the sensitivity of multi-frequency chirp excitation of Lamb waves is investigated to assess the severity of the damage. The influence of damage size on chirp response and tone burst response is established through simulations and experiments. The work conducted in the thesis and the methods established thereof are expected to result in more reliable on-line defect detection technologies for use in critical structural composites.