Propagation of Guided Acoustic Waves in Composite Media

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Abstract

Composite materials are being more widely used today by aerospace, automotive, and a number of other commercial industries because of their advantages over conventional metals. Composites are finding applications ranging from bicycle frames to the proposed High-Speed Civil Transport (HSCT). Determining the response to a variety of damage mechanisms is necessary for a complete understanding of the total use environment of composite structures. The objective of the research presented here is to provide a method of quantifying the amount of damage in composite materials for a number of different damage scenarios. Components which have non-visible damage, but have degraded performance, are of interest. At this level of damage, the safety margin designed into the structure may be compromised.

Nondestructive Evaluation (NDE) is a field of measurement physics where energy is imparted to a material and information is obtained from observing how the energy interacts with the system. Many different forms of energy can be used to obtain useful information from these measurements: acoustic, thermal, x-ray, optical, and electromagnetic. Among the many various techniques available, ultrasonic Lamb waves offer a convenient method of evaluating these composite materials. As a material is damaged, the elastic parameters of the structure change. Since the Lamb wave velocity depends on these properties, an effective tool exists to monitor damage in composites by measuring the velocity of these waves. Additionally, Lamb wave measurements are beneficial because they can propagate over long distances and are sensitive to the desired in-plane elastic properties of the material.

Presented in this study are the results involving the investigation of a variety of damage mechanisms (fatigue, thermal, and thermal-mechanical) using the Lamb wave technique. Two fatigue studies were conducted which showed that the change in modulus and change in velocity of the Lamb wave squared follow the same general trend. The Lamb wave velocity was also observed to decrease with increasing crack density. For the thermal damage study, the results showed that the velocity of the lowest order symmetric Lamb mode dropped significantly for extended thermal damage. When the experimental results were compared to model calculations, good agreement was observed for both fatigue and thermal damage. Finally, for thermal-mechanical damage, it was found that the Lamb wave technique was also able to predict a local defect in a specimen, which was later found to have a large delamination zone.

The Lamb wave velocity is a quantitative measurement and it has been shown by this work to be an effective tool in monitoring different types of damage in composites. Since the Lamb wave velocity depends on a variety of material properties, an ideal technique exists to monitor composites as damage is incurred. With the continued development of damage assessment techniques such as the Lamb wave method, the safety of such structures can be assured.