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DAMAGE ASSESSMENT IN COMPOSITES BY ACOUSTO-ULTRASONIC TECHNIQUE

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OBJECTIVES

The main objective of the research was to develop and refine the acousto-ultrasonic technique to assess damage in composite materials. Specifically, this research was directed toward three goals: (1) to improve the acousto-ultrasonic technique by focusing on the understanding of the relationship between material properties and wave propagation, (2) to establish operational methods for research and industrial applications, and (3) to improve material characterization and damage assessment using the refined technique.

SUMMARY OF RESULTS

Both analytical and experiemental approaches were employed to optimize the acousto-ultrasonic technique. The following topics were investigated in the study:

Calibration of acoustic emission system and preamplifier
Characteristics of the output wave from transducer
Acousto-ultrasonic wave propagation in composite laminates
Evolution of acousto-ultrasonic wave envelope in composite laminates
Propagation of different waveforms
Assessment of impact damage
Assessment of ply cracks
Assessment of cut fibers

The acousto-ultrasonic waves used in the present study were generated by a transducer which was attached on the surface of the composite laminate. Although the generation and propagation of these waves was quite complex, the most dominant of the detected waves could be approximated by a plane Lamb wave because the measured speeds were quite close to the calculated ones.

The acousto-ultrasonic waves were found to be sensitive to all types of damages investigated. Since the involved measurement is rather simple, the technique would be applicable to structures having complex shapes. One drawback is that although higher frequency waves are more sensitive to damages, these waves are more complex to analyze especially in thick laminates. Further results are summarized as follows.

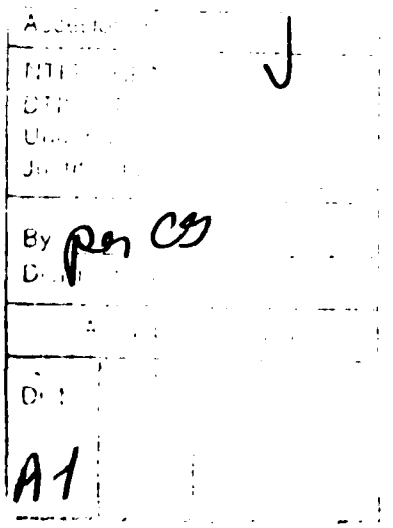
Lamb wave speeds were calculated in the low frequency region for a unidirectional graphite/epoxy laminate. For wave propagation in off-axis directions transverse displacement was Assumed zero. Experimental verification was carried out by measuring the wave speeds on the upper and lower surfaces of the specimen. The changes of the wave velocity and attenuation with frequency were monitored. Fourier spectra of the received signals were obtained using a wave analyzer to study dispersion. It has been found that the dominant AU waves produced experimentally were Lamb waves. The wave velocity changed with the fiber direction in the predicted manner.

The maximum attenuation was obtained in the 22.5 deg. fiber direction while the minimum attenuation was observed parallel to the fibers. (Publication No. 1)

The evolution of wave envelope was studied in an S-2 glass/epoxy cross-ply laminate. A wave packet with fast rise and decay was injected into the laminate. Wave velocities were measured in different directions to the fibers in the contacting ply. To characterize the wave envelope, signal parameters such as peak amplitude, ringdown counts, RMS amplitude, and energy content were measured at different locations. A Fourier analysis was also carried out of the received signals. The wave velocities in the laminate could be predicted by the Lamb wave equations based on the average laminate properties. It was found that the peak amplitude of the received signal might not reveal all the information concerning the damage. Energy should be monitored to obtain additional information. Reflections from the boundaries of the laminate were present to yield higher than true ringdown counts in the received signals. The reflections were delineated by the time and Fourier analyses. The received signals therefore had to be gated to eliminate the reflections. (Publication No. 2)

The acousto-ultrasonic technique was used to investigate ply failure in a S-2 galss/epoxy laminate. The ply failure weas found to decrease signal parameters such as peak amplitude, Fourier spectrum peak amplitude, and energy. The wave speed was also reduced and the Fourier spectrum became broader in the presence of ply failure. (Publication No. 3)

A quasi-isotropic graphite/epoxy laminate was used to study the detectability of impact damage. Damage was induced by impacting the laminate with an aluminum ball. A positive indication of damage was obtained with significant difference in peak amplitudes between the impacted and unimpacted regions. Similar information was extracted from RMS amplitudes, Fourier spectra, stress wave factors, and energy contents. A decrease in wave velocity was found to be another useful parameter in detecting the damage. The severity of damage was correlated with the peak amplitude along the length and width of the laminate. The peak amplitude was inversely proportional to the severity of the damage. (Publication No. 4)



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2. S.M. Moon, H.T. Hahn, K.L. Jerina, "Evolution of the Wave Envelope in Composite Laminates in Acousto-Ultrasonic Technique," Report No. 8815, The Pennsylvania State University, Aug. 1988.

3. S.M. Moon, H.T. Hahn, K.L. Jerina, "Detection of Impact Damage in Composite Laminates by Acousto-Ultrasonic Technique," Report No. 8816, The Pennsylvania State University, June. 1988.

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2. S.M. Moon, H.T. Hahn, K.L. Jerina, "Evolution of the Wave Envelope in Composite Laminates in Acousto-Ultrasonic Technique," Conference on Nondestructive Testing and Evaluation for Manufacturing and Construction, University of Illinois, August 10-12, 1988. (Co-author), To be published.

3. S.M. Moon, H.T. Hahn, K.L. Jerina, "Evaluation of Ply Failure in Glass/Epoxy Cross-Ply Laminates By Acousto-Ultrasonic Technique," SAMPE Technical Conference, Minneapolis, Minnesota, September 27-29, 1988. (Co-author) pp. 667-680.

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