Lamb Wave-based Damage Detection of Composite Shells using High-speed Fiber-optic Sensing

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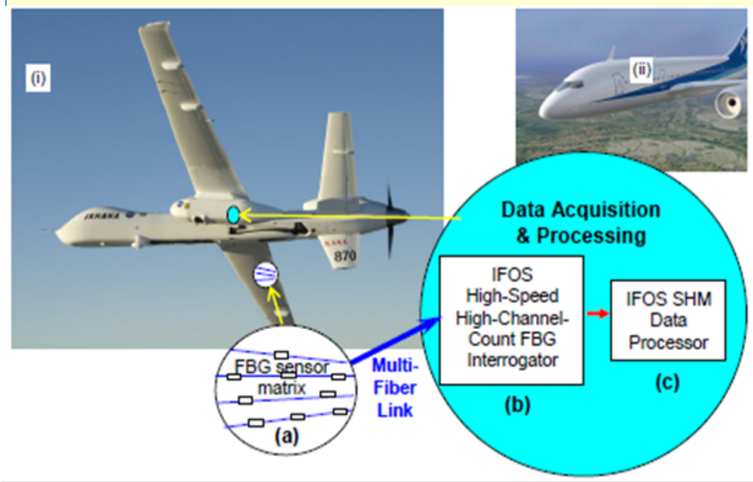
Abstract

A Lamb wave-based damage identification method for composite shells based on piezoelectric actuators and fiber Bragg grating (FBG) sensor arrays is presented. The viability of this method is demonstrated by analyzing numerical and experimental Lamb wave response signals from laminated composite shells. The technique only requires the response signals from the plate after damage, and is capable of performing near real-time damage identification. This study sheds light on the application of a Lamb wave-based damage detection algorithm for curved plate/shell-type structures by using relatively low frequency (≈ 100 kHz) Lamb wave response and a high-sampling rate FBG sensor system.

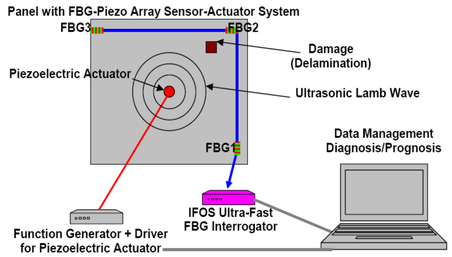


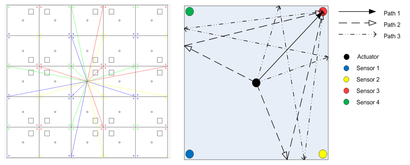
Enabling IFOS Instrumentation

For this program, IFOS developed a robust flight-capable 48-channel parallel processing interrogator with 500 kHz sampling combined with highly distributed sensing (up to 16 sensors simultaneously on a single fiber).

Method

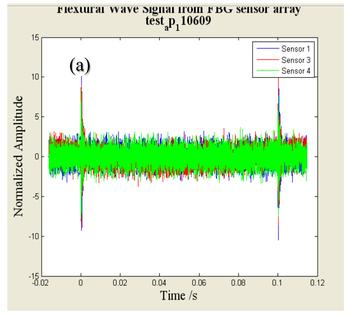
A damage index (DI) is generated from the delay matrix of the Lamb wave response signals, and it is used to indicate the location and approximate area of the damage. A piezoelectric actuator is employed to generate the Lamb waves that are subsequently captured by a fiber Bragg grating (FBG) sensor element array multiplexed in a single fiber connected to a high-speed fiber-optic sensor system. The high-speed sensing is enabled by an innovative parallel-architecture optical interrogation system.

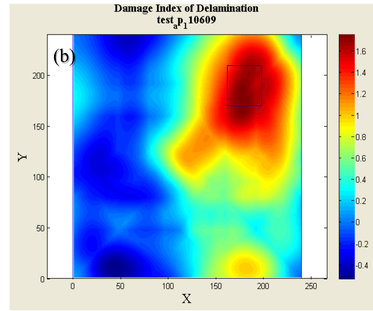




Testing – Flat Plates

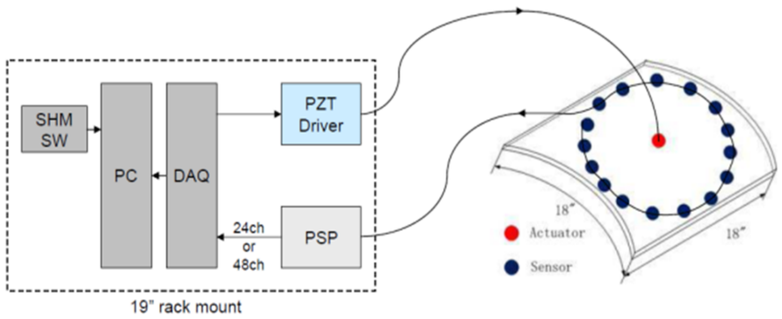
(a) Filtered FBG Signals – The spikes on the left and right show the triggering between which the 4 sensor signals were measured for DI determination of (b). (b) Color Map of Damage Index Using Damage Wave Imaging Technique – The square shows the region where damage (delamination) was introduced and the color map shows the damage index deduced from the piezo-actuator excited FBG measurements.

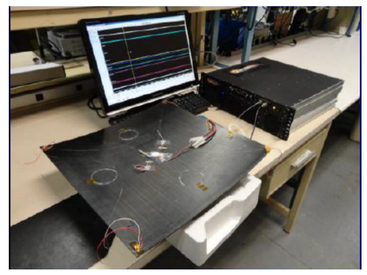


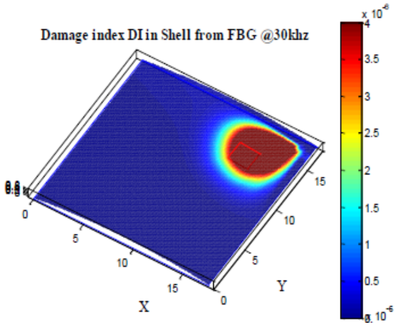


Testing – Curved Shells

Testing was successfully performed on curved shells with excitation by a single centrally placed PZT actuator and sensing with multiple FBG sensor.







Conclusions

The FBG sensor matrices, which are light-weight, EMI-immune and highly multiplexable (many sensors on a single fiber), together with IFOS' broadband (DC to MHz) interrogation provide considerable promise for composite structure SHM. Testing of CFRP shells with integrated system was conducted, and the effect of environment on the system investigated. Results demonstrated that the integrated SHM system is capable of detecting delamination in composite shells and that the operating environment does not have much influence on the system. This integrated miniature-size SHM system has the potential to be implemented for real time and on-board SHM of aircraft structures.

Acknowledgments

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Further Information

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