# High-Performance Acousto-Ultrasonic Scan System Being Developed

Acousto-ultrasonic (AU) interrogation is a single-sided nondestructive evaluation (NDE) technique employing separated sending and receiving transducers. It is used for assessing the microstructural condition and distributed damage state of the material between the transducers. AU is complementary to more traditional NDE methods, such as ultrasonic c-scan, x-ray radiography, and thermographic inspection, which tend to be used primarily for discrete flaw detection. Throughout its history, AU has been used to inspect polymer matrix composites, metal matrix composites, ceramic matrix composites, and even monolithic metallic materials. The development of a high-performance automated AU scan system for characterizing within-sample microstructural and property homogeneity is currently in a prototype stage at NASA. This year, essential AU technology was reviewed. In addition, the basic hardware and software configuration for the scanner was developed, and preliminary results with the system were described.

Mechanical and environmental loads applied to composite materials can cause distributed damage (as well as discrete defects) that plays a significant role in the degradation of physical properties. Such damage includes fiber/matrix debonding (interface failure), matrix microcracking, and fiber fracture and buckling. Investigations at the NASA Glenn Research Center have shown that traditional NDE scan inspection methods such as ultrasonic c-scan, x-ray imaging, and thermographic imaging tend to be more suited to discrete defect detection rather than the characterization of accumulated distributed microdamage in composites. Since AU is focused on assessing the distributed microdamage state of the material in between the sending and receiving transducers, it has proven to be quite suitable for assessing the relative composite material state.

One major success story at Glenn with AU measurements has been the correlation between the ultrasonic decay rate obtained during AU inspection and the mechanical modulus (stiffness) seen during fatigue experiments with silicon carbide/silicon carbide (SiC/SiC) ceramic matrix composite samples. As shown in the figure, ultrasonic decay increased as the modulus decreased for the ceramic matrix composite tensile fatigue samples. The likely microstructural reason for the decrease in modulus (and increase in ultrasonic decay) is the matrix microcracking that commonly occurs during fatigue testing of these materials. Ultrasonic decay has shown the capability to track the pattern of transverse cracking and fiber breakage in these composites.
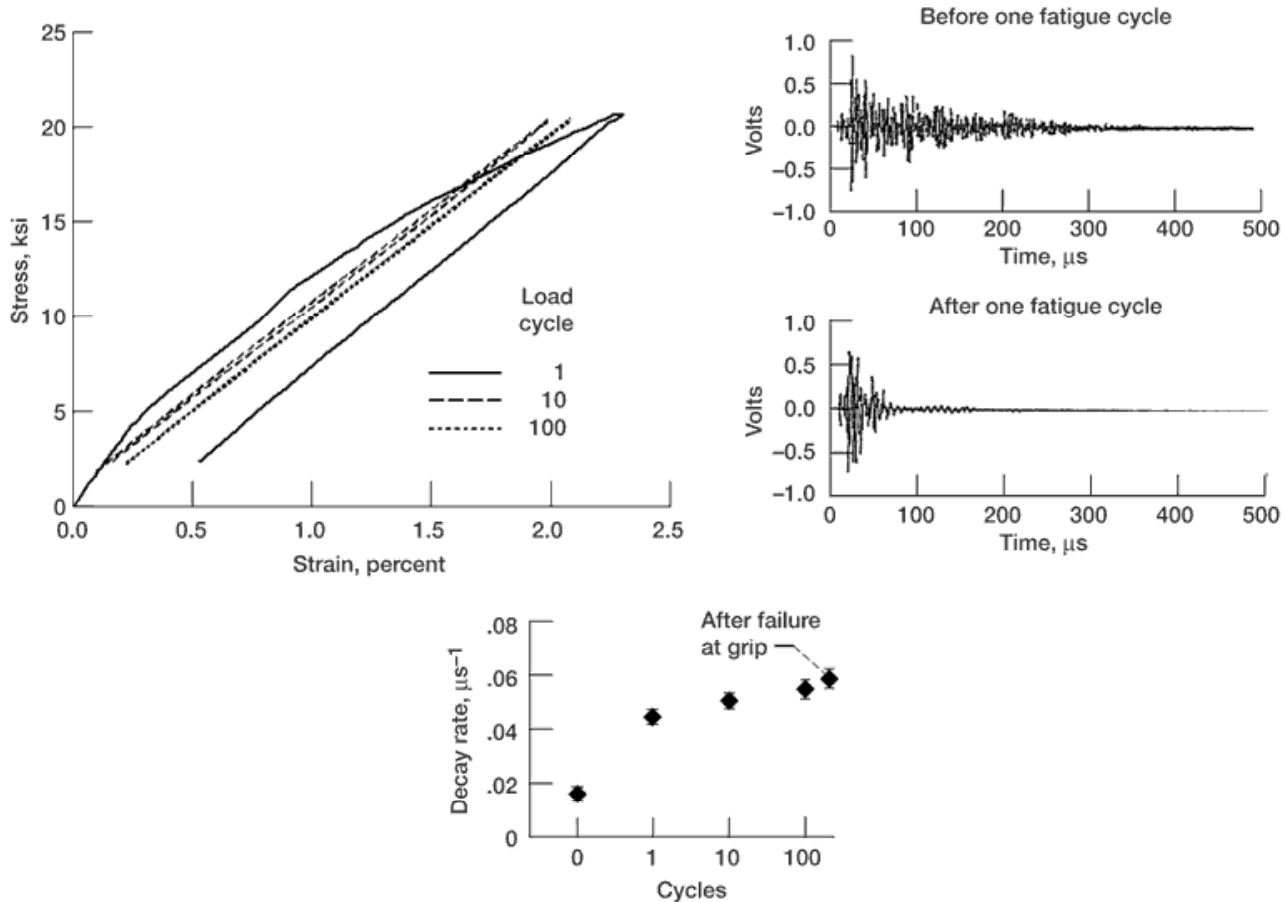
Top left: The stress-strain curves show the decrease in modulus (slope) with increase in strain upon application of the first cycle (note the curvature); subsequent fatigue cycle loading shows moduli similar to that after 1 cycle (note that the slopes of the different stress-strain curves are nearly parallel). Top right: Acousto-ultrasonic wavetrains before and after one fatigue cycle loading show a dramatic change correlating with the decrease in modulus. Bottom: Ultrasonic decay rate derived from waveforms in the top right graph shows a large increase after one fatigue cycle loading and only a moderate increase upon subsequent loading, in agreement with load curves in the top left graph.

The data in the figure were obtained over a small region of a specimen. Scanning capability would allow researchers and practitioners to focus in on exactly where damage is and is not occurring in samples and components that that have been mechanically and thermally loaded. The AU scan system is planned to have both automated scan and interactive point measurement capabilities within one system. All functions will be automated with software interfaces replacing hardware instrument interfaces where possible. The scan capability is close to completion with regards to the basic operations of motion control, load control, data acquisition, online presignal and postsignal processing, and waveform data and image recording and saving. Currently, images of 18 different parameters (including ultrasonic decay) of the AU signal are formed in real time. Detailed system specifications are available upon request. We plan to develop the system to scan curved as well as platelike components.

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