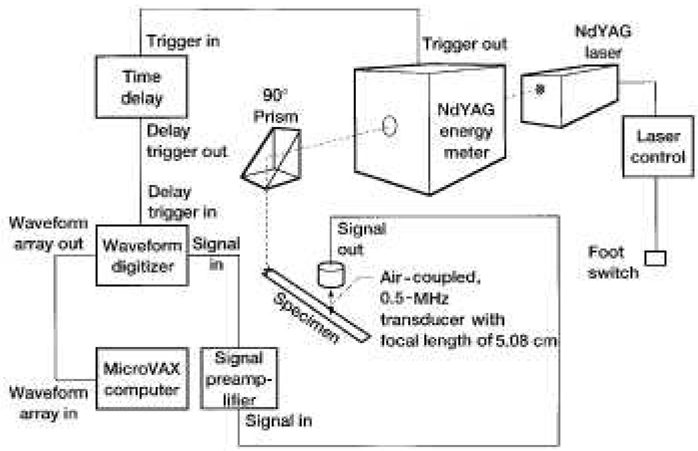
Noncontact Determination of Antisymmetric Plate Wave Velocity in Ceramic Matrix Composites

High-temperature materials are of increasing importance in the development of more efficient engines and components for the aeronautics industry. In particular, ceramic matrix composite (CMC) and metal matrix composite (MMC) structures are under active development for these applications.

The acousto-ultrasonic (AU) method has been shown to be useful for assessing mechanical properties in composite structures. In particular, plate wave analysis can characterize composites in terms of their stiffness moduli. It is desirable to monitor changes in mechanical properties that occur during thermomechanical testing and to monitor the health of components whose geometry or position make them hard to reach with conventional ultrasonic probes. In such applications, it would be useful to apply AU without coupling directly to the test surface.

For a number of years, lasers have been under investigation as remote ultrasonic input sources and ultrasound detectors. The use of an ultrasonic transducer coupled through an air gap has also been under study. So far at the NASA Lewis Research Center, we have been more successful in using lasers as ultrasonic sources than as output devices. On the other hand, we have been more successful in using an air-coupled piezoelectric transducer as an output device than as an input device. For this reason, we studied the laser in/air-coupled-transducer out combination-using a pulsed NdYAG laser as the ultrasonic source and an air-coupled-transducer as the detector.

The present work is focused on one of the AU parameters of interest, the ultrasonic velocity of the antisymmetric plate-wave mode. This easily identified antisymmetric pulse can be used to determine shear and flexure modulus. It was chosen for this initial work because the pulse arrival times are likely to be the most precise. The following schematic illustrates our experimental arrangement for using laser in/air-transducer out on SiC/SiC composite tensile specimens. The NdYAG pulse was directed downward by a 90° infrared prism to the top of the specimen, but at the edge of one end. An energy sensor measured a single pulse at 13 millijoules (mJ) before it passed through the prism, which attenuated 15 percent of its energy. It also provided an output trigger for the waveform time-delay synthesizer.



Experimental laser input/air-coupled-transducer output arrangement for collecting waveforms.

A broadband, air-coupled, piezoelectric transducer was centered nominally at 0.5 MHz and coupled to the air through a buffer that was shaped to focus the ultrasound 5.08 cm beyond its surface. We have shown that, for ceramic matrix composite specimens of the present geometry, this frequency range is very much dominated by the lowest antisymmetric plate mode.

Six specimens each of three layups, 0°/90°, $\pm$45°, and $[0°/+45°/90°/-45°]_s$, of approximately 20-percent porous SiC/SiC were studied. For each layup, eight-ply panels were cut into 1.27- by 15.24-cm rectangular bars with thicknesses of 0.25 to 0.29 cm. Then, the bars, which had a 40-percent fiber fraction, were treated with a seal coating.

In the following figure, the noncontact average plate-wave velocities are plotted against the contact average values. The standard deviation of the 18 sets of velocities was determined. For the noncontact data, the average was 2.8 percent, and for the contact data, it was 2.3 percent, indicating very similar reproducibility. Standard deviation bars are not plotted in the figure so that the correlation between the contact and noncontact velocity can be seen more readily. The laser in/air-coupled-transducer out system can provide data as accurate as that from contact-coupled transducers for determining the velocity associated with the lowest antisymmetric plate mode for SiC/SiC ceramic matrix composites.

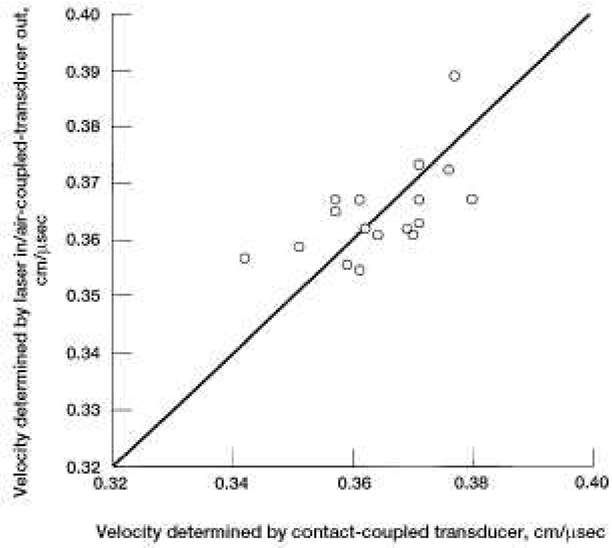


Plate-wave velocities from laser input/air-coupled-transducer output compared with those from contact-plate transducers.

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