Composite Materials Interface Characterization


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1. Executive Summary

The designs for many of tomorrow's defense systems cannot be implemented with the materials available today. Lighter, stiffer, stronger materials with higher temperature stability are required. A new generation of advanced composites with metal and even ceramic matrices show the greatest promise for satisfying many of these needs. Early attempts at processing these materials met with mixed success. The properties needed have in some cases come close to fulfillment, but other batches of material have been found to exhibit very poor behavior. Micromechanical modeling studies have directed attention to the microscopic interfaces between matrix and reinforcement. Bulk behavior has been predicted to be strongly influenced by the local elastic properties, residual stresses and adhesion of the interface. Techniques to measure these newly perceived quantities of importance do not exist. Thus it is not possible experimentally to (i) confirm the micromechanical model predictions, (ii) explore the relationships between interface properties and processing variables and (iii) ensure acceptable interface properties in materials destined for defense systems.

This research program is directed at developing experimental techniques for characterizing interfaces in composite materials and coupling this expertise to other ONR composite programs to enable optimum interfaces to be designed for the next generation of advanced composites. We have explored two approaches, guided interface waves and acoustic emission. The former refers to a family of ultrasonic techniques with potential for characterizing interface elastic and anelastic properties. The latter utilizes acoustic emission to provide measurements of the adhesion of an interface.
This year, we have achieved the following substantial achievements:

- Formulation of the ultrasonic scattering/interface wave propagation problem for a general interface.

- Theoretical prediction of the suspected existence of guided interface waves at model Al-Fe, Al-SiC, Al-B, and Al-Graphite cylindrical interfaces. The velocity was found to contain both real and imaginary components. The values of both were calculated as functions of frequency and cylinder radius.

- Experimental verification of the theoretically predicted real part of the velocity for model Al-Fe and Al-SiC cylindrical interfaces and detection of leaky radiation due to the non-zero imaginary velocity component.

- Determination of the effect of microstructure and stress upon the velocity of pure Stoneley waves at planar Fe-Ti interfaces.

- Development of an experimental approach using composite single crystals to determine interface and fiber mechanical properties in both metal and ceramic matrix composites.

- Determination of SiC fiber strength and Al-SiC interface shear strengths in model single crystal composites as a function of liquid metal-SiC contact time during processing.

These achievements have, we believe, significantly advanced us toward our goal of determining the elastic properties and adhesion of interfaces in advanced composites. We have begun to devise schemes for implementing these approaches on actual composites. In our future work, we propose to evaluate these methods and develop data from the advanced composites developed in the SDIO/IST Consortium.