Investigation of the Fiber/Matrix Interphase Under High Loading Rates

Metin Tanoglu
Giuseppe Palmese, Ph.D.

This research focuses on characterization of the interphases of various sized E-glass-fiberlepoxy-amine systems under high loading rates. The systems include unsized, epoxy-amine compatible, and epoxy-amine incompatible glass fibers. A new experimental technique (dynamic micro-debonding technique) was developed to directly characterize the fiberlmatrix interphase properties under various loading rates. Displacement rates of up to 3000 pmlsec that induce high-strain-rate interphase loading were obtained using the rapid expansion capability of the piezoelectric actuators (PZT). A straightforward data reduction scheme, which does not require complex numerical solutions, was also developed by employing thin specimens. This method enables quantification of the strength and specific absorbed energies due to debonding and frictional sliding. Moreover, the technique offers the potential to obtain the shear stresslstrain response of the interphases at various rates. A new methodology was also developed to independently investigate the properties of the fiberlmatrix interphase. This methodology is based on the assumption that the portion of sizing bound to the glass fiber strongly affects the interphase formation. Conventional burnout and acetone extraction experiments in conjunction with nuclear magnetic spectroscopy were used to determine the composition of the bound sizing. Using the determined composition, model interphase compounds were made to replicate the actual interphase and tested utilizing dynamic mechanical analyzer (DMA) and differential scanning calorimeter (DSC) techniques. The rate-dependent behavior of the model interphase materials and the bulk epoxy matrix were characterized by constructing storage modulus master curves as a function of strain rate using the time-temperature superposition principle.

The results of dynamic micro-debonding experiments showed that the values of interphase strength and specific absorbed energies vary dependent on the sizing and exhibited significant sensitivity to loading rates. The unsized fibers exhibit greater energy-absorbing capability that could provide better ballistic resistance while the compatible sized fibers show higher strength values that improve the structural integrity of the polymeric composites. The calculated interphase shear modulus values from micro-debonding experiments increase with the loading rate consistent with DMA results. In addition, significantly higher amounts of energy are absorbed within the frictional sliding regime compared to debonding. Characterization of model interphase compounds revealed that the interphase formed due to the presence of bound sizing has a Tg below room temperature, a modulus more compliant than that of the bulk matrix, and a thickness of about 10 nm. The results showed that the properties of the interphases are significantly affected by the interphase network structure.