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Improved understanding of the dynamic response in anisotropic directional composite materials through the combination of experiments and modeling[1]

C.S. ALEXANDER, Sandia National Laboratories

Recently there has been renewed interest in the dynamic response of composite materials; specifically low density epoxy resin binders strengthened with continuous reinforcing fibers. This is in part due to the widespread use of carbon fiber composites in military, commercial, industrial, and aerospace applications. The design community requires better understanding of these materials in order to make full use of their unique properties. Experimental testing has been performed on a unidirectional carbon fiber - epoxy composite, engineered to have high uniformity and low porosity. Planar impact testing was performed at the Shock Thermodynamics Applied Research (STAR) facility at Sandia National Labs resulting in pressures up to 15 GPa in the composite material. Results illustrate the anisotropic nature of the response under shock loading. Along the fiber direction, a two-wave structure similar to typical elastic-plastic response is observed, however, when shocked transverse to the fibers, only a single bulk shock wave is detected. The two-wave structure persists when impact occurs at angles up to 45 degrees off the fiber direction. At higher pressures, the epoxy matrix dissociates resulting in a loss of anisotropy. Details of the experimental configurations and results will be presented and discussed. Greater understanding of the mechanisms responsible for the observed response has been achieved through the use of numerical modeling of the system at the micromechanical level using the CTH hydrocode. From the simulation results it is evident that the observed two-wave structure in the longitudinal fiber direction is the result of a fast moving elastic precursor wave traveling in the carbon fibers ahead of the bulk response in the epoxy resin. Similarly, in the transverse direction, results show a collapse of the resin component consistent with the experimental observation of a single shock wave traveling at speeds associated with bulk carbon. These results will be discussed within the context of the experiments and will be used to show where additional mechanisms, not fully described by the currently used models, are present.

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