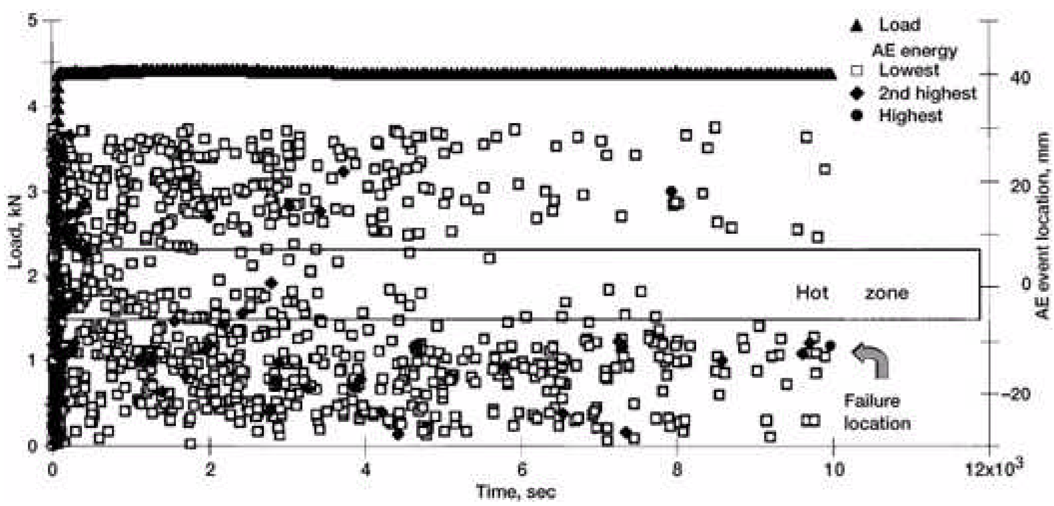
Modal Acoustic Emission Used at Elevated Temperatures to Detect Damage and Failure Location in Ceramic Matrix Composites

Ceramic matrix composites are being developed for elevated-temperature engine applications. A leading material system in this class of materials is silicon carbide (SiC) fiber-reinforced SiC matrix composites. Unfortunately, the nonoxide fibers, matrix, and interphase (boron nitride in this system) can react with oxygen or water vapor in the atmosphere, leading to strength degradation of the composite at elevated temperatures. For this study, constant-load stress-rupture tests were performed in air at temperatures ranging from 815 to 960 °C until failure. From these data, predictions can be made for the useful life of such composites under similar stressed-oxidation conditions.

During these experiments, the sounds of failure events (matrix cracking and fiber breaking) were monitored with a modal acoustic emission (AE) analyzer through transducers that were attached at the ends of the tensile bars. Such failure events, which are caused by applied stress and oxidation reactions, cause these composites to fail prematurely. Because of the nature of acoustic waveform propagation in thin tensile bars, the location of individual source events and the eventual failure event could be detected accurately.



Acoustic emission (AE) event location and load versus time for stress-rupture experiment performed in air at 960 °C.

The graph shows the load versus time and the AE event location versus time for an experiment performed at 960 °C. The AE events are plotted according to their respective energies; that is, the highest energy events are the loudest events and correspond to large matrix cracks. Also noted on this figure is the location of the hot zone, which is a 15-mm region of the furnace that is at 960 °C. Outside of this region the temperature decreases. It is evident that after a few thousand seconds very little activity occurs in the hot zone. However, just outside the hot zone, a significant amount of AE activity occurs, with eventual composite failure occurring at about 880 °C. For experiments performed at 815 °C, the failure location is always in the hot zone. Because at ~800 to 900 °C chemical reactions between the interphase and environment reduce the load-carrying ability of the reinforcing fibers, this constitutes the "pest" temperature regime for this material.

Modal AE accurately located the failure location of the composite. In addition, it detected a number of loud AE events in the same relative failure location prior to failure. Since eventual failure of these composites occurs at a specific location after a progression of smaller matrix cracks and fiber failures which weaken that area of the composite, this type of monitoring can be used to actually predict the location of composite failure.

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