

## Overview

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Session IV is comprised of four papers concerning the performance of fiber-reinforced metal, intermetallic, or ceramic matrices subjected to mechanical loading. Two of the papers address the material's performance when it is subjected to fatigue loading at an elevated temperature. The other two papers detail the material's performance when it is subjected to statically applied loads. All four papers spend considerable time detailing the different aspects of loading or failure history or both.

Pollock and Johnson present the paper, "Characterization of Unnotched SCS-6/Ti-15-3 Metal Matrix Composites at 650°C," and in it predict the laminate static stress-strain response and fatigue cyclic stress-strain behavior from the constituent material behavior at elevated temperature. A number of different fiber layups are considered. It is found that the SCS-6 silicon-carbide fibers reinforcing the Ti-15-3 alloy metal matrix in the loading direction are the most influential component contributing to elastic modulus, tensile strength, and elongation to failure. Furthermore, they find a direct correlation between fatigue endurance and the percentage of fibers in the loading direction. Furthermore, they conclude that the fibers contribute more to the fatigue life performance at elevated temperatures rather than at room temperature conditions because of the greater load carrying of the fibers relative to the lower modulus matrix. However, inhibiting this added role of the fibers to fatigue at elevated temperature, is an observation that the in-situ fiber strength decreases by 20 to 30% at elevated temperatures, which is not the case for single fibers tested at elevated temperatures. Looking at fatigue-induced damage, the authors conclude that high fatigue loads that result in short-lived specimens show only multiple fiber breaks and no matrix failure, whereas at low fatigue loads and, hence, long life, the specimens showed extensive matrix cracking and no fiber fractures outside of the immediate vicinity of the matrix cracks. The authors also observe that during the fatigue-loading process the initial unloading modulus is higher than the loading modulus, and they attribute this to a matrix creep behavior during the unloading process.

Bartollota and Brindley also investigate the fatigue behavior of an advanced composite system in the paper, "High Temperature Fatigue Behavior of a SiC/Ti-24Al-11Nb Composite." Here, the matrix Ti-24 Al-11 Nb was an intermetallic and reinforced with SiC fiber in which the fiber volume loading is  $\sim 27\%$ , and the fiber alignment is unidirectional. Fatigue testing is performed at 425 and 815°C. Fatigue testing is performed in tension using either load- or strain-controlled conditions. All the data are analyzed by plotting the maximum fatigue strain versus the number of cycles to failure. These plots show three regimes of performance. Interestingly, the high load, low life, Region I and the low load, high life, Region III are not influenced by test temperature, but the intermediate Region II shows definite temperature-dependent performance. Region I shows a catastrophic failure performance which is mainly defined by the failure of the fiber. Region II shows a progressive failure behavior, in which in the strain-controlled tests, the load at first gradually decreases then abruptly decreases to final failure. The Region III conditions produce runout and define an endurance limit. The authors further discuss the merits and disadvantages of load- and strain-controlled testing in fatigue and conclude that the use of both is complementary and help define the failure process.

Lee and Daniel use a modified shear lag analysis to describe the tensile static stress-strain behavior of a unidirectional ceramic matrix composite in their paper, "Deformation and Fail-

ure of Longitudinally Loaded Brittle-Matrix Composites” The analysis uses a single fiber embedded in a cylindrical matrix model The matrix is assumed to have lower strain to failure than the fiber, therefore, the matrix is assumed to fail by transverse cracking before any fiber failure The shear stress in the fiber is assumed to be a linear function of the radial coordinate variable, and the shear stress in the matrix is assumed to be an inverse function of the radial coordinate variable to the second power The authors consider three cases (1) an embedded fiber of finite length in an infinite matrix medium, (2) an embedded fiber of infinite length in a semi-infinite matrix medium, and (3) a fiber in a cylindrical matrix with two transverse matrix cracks. By using various combinations of Cases 2 and 3, the authors are able to predict the stress-strain behavior and stress-versus-matrix crack density of a silicon-carbide unidirectional reinforced glass-ceramic matrix composite subject to longitudinal tensile loading The predictions are found to be in reasonably good agreement with the experimental results. In addition, the prediction accurately determines the knee of the stress-strain curve for the material considered, although the subsequent secondary loading is predicted at a somewhat lower value of strain than the experimental results show.

The last paper in this session, “A Macro-Micromechanics Analysis of a Notched Metal Matrix Composite” by Bigelow and Naik, is a numerical analysis of a unidirectional composite with central notch subject to tensile loading To demonstrate the utility of the approach, a boron-reinforced aluminum matrix monolayer having a fiber volume loading of 30% is considered The overall composite is analyzed by a three-dimensional finite element program called PAFAC The element in the vicinity of the central notch is further analyzed on a micro level by a discrete fiber-matrix (DFM) model which uses as its boundary condition the results from the three-dimensional finite element analysis of the macro scale This combined analysis shows some aspects of the stress distribution in the vicinity of the notch For instance, a unit value of applied stress to the sample results in a distribution of axial stress with maximum value of 32 MPa in the fiber closest to the notch Furthermore, the combined analysis predicts that yielding in the matrix near the notch will occur when the remote stress is as low as 5.75 MPa. This is considerably lower than the 8-MPa value that will be predicted by a macro level analysis by itself

In closing, these four session papers illustrate that much has been done in understanding the new composite systems using metal, intermetallic, and ceramic matrices, but much research remains to be done to understand further these materials