Summary

Since 1984, ASTM Committee D-30 has aggressively promoted development of test methods for metal matrix composites and transfer of research results related to these materials. In November 1985 ASTM held a symposium on Testing Technology of Metal Matrix Composites in Nashville, Tennessee. The results of that symposium are now archived in *ASTM STP 964* which was edited by DiGiovanni and Adsit. At that symposium, task forces were formed to address test methods for metal matrix composites. At subsequent meetings workshops highlighting the activities of the task forces were held. The objectives of these meetings have been to provide leadership and a focal point for addressing test method development for metal and ceramic matrix composites and to act as a forum for presenting and debating results of research directed toward these materials.

Subcommittee E24.07 has recently been given the charter to focus on advanced materials including metal matrix and ceramic matrix composites. The primary emphasis is on fracture of these materials. Since 1987, E-24 and D-30 have been combining the composites technology of D-30 with the fracture knowledge of E-24 to study and understand composite materials.

During 1988 ASTM sponsored two symposia on metal and ceramic matrix composites as well as several workshops and task force meetings. The first symposia, Metal Matrix Composites: Testing, Analysis, and Failure Modes was held in Sparks, Nevada, on 25–26 April 1988. The symposia and the resulting special technical publication, *ASTM STP 1032* (editor: Johnson) were a comprehensive review of the state of the art in testing and analyzing continuous fiber reinforced metal matrix composites. Additional papers dealt with failure of these materials. The second symposia, Thermal and Mechanical Behavior of Ceramic and Metal Matrix Composites was held in Atlanta, Georgia, on 7–8 November 1988. The presentations and the collection of papers in this special technical publication, *ASTM STP 1080* are results of recent research and development programs for ceramic and metal matrix composites.

The papers in this special technical publication are a significant contribution to the development and understanding of the behavior of ceramic and metal matrix composites. Each of the papers in the four sections is briefly summarized in the following paragraphs with some perspective on the significance of the work.

Analysis and Modeling

"Local Stresses in Metal Matrix Composites Subjected to Thermal and Mechanical Loading" by Highsmith, Shin, and Naik—This paper developed a micromechanics model and presented results for the stress state at the fiber matrix interface due to thermal and mechanical loading. The results provide a clear understanding of the strength requirements necessary to maintain integrity at the interface.

"Plasticity Analysis of Fibrous Composite Laminates Under Thermomechanical Loads" by Bahei-El-Din—An elastic-plastic thermomechanical micromechanics analysis was developed which included temperature depended mechanical properties of the fiber and matrix.

"Thermomechanical, Time-Dependent Analysis of Layered Metal Matrix Composites" by Lee and Krempl—At elevated temperatures, inelastic deformations such creep, relaxation, and rate sensitivity cannot be neglected. This paper proposes a modified laminated plate theory which includes time dependent effects.

"Computational Simulation of High-Temperature Metal Matrix Composites Cyclic Behavior" by Chamis, Murthy, and Hopkins—The authors have developed a numerical procedure to model the cyclic behavior of metal matrix composites and the associated degradation in material properties. The model accounts for the interphase. The results show that the combined thermomechanical cycling degrades the composite faster than superposition of the two individual effects. This model may be useful for predictiong the useful life of metal matrix composites in thermomechanical environments.

"Effects of Environmental and Microstructural Variables on the Plastic Deformation of Metal Matrix Composites Under Changing Temperature Conditions" by Daehn—An elastic-plastic model for the deformation of aligned, whisker reinforced metal matrix composites is developed. This model shows that these materials will degrade during thermal cycling at stresses far below the yield strength of the composite.

"Analysis of a Ceramic Matrix Composite Flexure Specimen" by Dharani—A detailed stress analysis of the three- and four-point bend tests was conducted to predict the behavior of ceramic matrix composites with multiple cracks. The analysis shows that the stresses are substantially different than those predicted by beam theory. The analysis can also predict the failure mode.

Behavior of Ceramic Matrix Composites

"Toughness Models of Whisker Reinforced Ceramic Matrix Composites" by Chiang and Chou—Unlike homogeneous metals, whisker reinforced ceramic and metal matrix composites have anisotropic fracture properties. A model is presented to predict the critical strain energy release rate for ceramic matrix composites.

"Comparison of High-Temperature Tension Testing Results of Ceramic Fibers" by Rigdon and Hong—The authors have collected tensile strength and elastic property data for three different ceramic matrix composites and compared the results. Substantial differences in the test results were obtained for the different test methods utilized. The differences in results highlights the need for standard test methods for these materials to avoid variation in the test results due to differences in the test method.

"Comparison of Methods for Determining Fiber/Matrix Interface Frictional Stresses in Ceramic Matrix Composites" by Cranmer, Deshmukh, and Coyle—Fiber indentation tests and single fiber pull-out tests were conducted on two ceramic matrix composite material system. The authors recommend the fiber indentation push-out test for characterizing the bonding between the fiber and the matrix.

"Monotonic and Cyclic Behavior of Silicon Carbide/Calcium-Aluminosilicate Ceramic Composite" by Rousseau—An experimental investigation at elevated and room temperature identified the basic elements of laminate response and damage due to monotonic and cyclic loading. Degradation in material properties was due to damage in off-axis plies and embrittlement of the fiber/matrix interface.

Behavior of Metal Matrix Composites

"Mechanical and Thermal Properties of Silicon-Carbide Particle-Reinforced Aluminum" by Schmidt, Zweben, and Arsenault—Particle reinforced aluminum is being considered as a replacement material for homogeneous metals in electronics packaging. An experimental program to determine key material properties showed that these materials are viable electronics packaging materials because of their low thermal coefficient of expansion, high thermal conductivity, and low density. However, the fracture toughness is low and limits the applications in fracture critical application.

"Temperature-Dependent Tensile and Shear Response of P100/6061 Graphite-Aluminum" by Fujita, Pindera, and Herakovich—Experiments were conducted to the elastic and strength properties in tension and shear. Elastic properties did not change appreciably over the temperature range at which test were conducted. Strength properties changed substantially over the same range. However, the changes in strength properties did not follow that of the bulk aluminum. Evaluation of the thermal residual stresses explained the variation in the strength properties, in particular the yield strength.

"The Bonding Strength at the Fiber/Matrix Interface of Metal Matrix Composites" by Kim, Lee, and Jun—The fiber indentation test method was used to obtain the optimal manufacturing process paramenters for continuous fiber reinforced metal matrix composites produced by squeeze casting. It was assumed that the fiber matrix interface is the critical element in producing a mechanically attractive composite. Using the fiber indentation test enabled the authors to determine an optimal manufacturing process map which can substantially reduce the time to determine the optimal manufacturing process.

"Mechanical Characterization of Unnotched SCS_6/Ti-15-3 Metal Matrix Composites at Room Temperature" by Johnson, Lubowinski, and Highsmith—Five laminates of silicon carbide reinforced titanium were tested in tension to characterize the elastic properties and the failure modes. Analytical models predicted the elastic properties and strengths accurately. Fatigue tests showed that most of the damage occurs in the first few cycles due to the low strength of the fiber/matrix interface.

"Fatigue Crack Growth in an $A1_2O_3$ Short Fiber Reinforced A1-2Mg Alloy" by Preston, Melander, Groth, and Blom—Fatigue crack growth experiments were conducted to determine the fundamental crack growth mechanisms. The initial damage was traced back to the manufacturing process. The small initial flaws linked up to form a dominant crack. Damage growth could be correlated using measurements of crack closure.

Test Methods

"Ceramics Tensile Grip" by Larsen—Alignment is critical when testing ceramic materials including ceramic composites. A new gripping technique for tensile testing ceramic is discussed. The grip is designed to differentiate bending due to alignment and bending due to test specimen eccentricities. The grip is capable of producing accurate results for brittle materials.

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