Overview

On 22–24 March 1994, a symposium entitled *Life Prediction Methodology for Titanium Matrix Composites* was held on Hilton Head Island, South Carolina. The symposium was sponsored by ASTM Committees D30 on High Modulus Fibers and Their Composites, E8 on Fatigue and Fracture Mechanics, and NASA Langley Research Center. Thirty-three papers were presented by researchers from government laboratories, universities, and industry. The volume represents a collection of those papers that were submitted and passed peer review by three knowledgeable referees.

The rationale for this symposium was to collect the current state of the art in life prediction methodology for Titanium Matrix Composites, TMCs. From the mid 1980's through the early 1990's several large technical programs pushed the development of TMCs and the development of the related life prediction methodology. Most visible among these programs were the National Aerospace Plane (NASP), the Integrated High Performance Turbine Engine Technology Program (IHPTET), and the Hi-Temp Program. These were large programs sponsored by various branches of the U.S. government. The NASP emphasized TMC for structural airframe applications on hypersonic vehicles, while the IHPTET (USAF) and Hi-Temp (NASA) programs developed TMCs for improved gas turbine engine performance. Of course researchers outside of the United States were also involved in TMC studies.

In order to develop accurate life prediction methodologies, a very through understanding of the mechanical damage mechanisms and environmental effects must be established. The envisioned usage conditions of these TMC materials are extreme. Temperature variations between 816°C and − 130°C may be encountered on a hypersonic vehicle structure. Cyclic loads up to 60% of ultimate strength would be encountered routinely. Under these conditions the matrix material may not only undergo time dependent deformations but may undergo metallurgical changes as well. Many of the systems discussed in this volume are metastable beta-alloys of titanium. These materials may age with time at temperature in such a way that their mechanical properties, such as ultimate strength, yield strength, and modulus may increase over time. However, at elevated temperatures these materials become sensitive to oxidation, which causes embrittlement and enhanced susceptibility to cracking. Further complications arise because these composites that have fibers and matrices with significantly different coefficients of thermal expansions. Thus as temperature changes so does the internal stress state in the fibers and matrix. Because of this strong influence of thermally induced stresses, the approaches developed for thermal mechanical fatigue of metal that deal with the determination of mechanically induced stresses and strains are no longer applicable. Mathematical analysis must be developed to predict these complex internal stresses since they cannot be measured directly. Thus, the thermo-viscoplastic behavior of the constituents must be determined. Since both the fiber and matrix are very strong, the fiber/matrix interface is usually the weak link in the progression of mechanical failure. Understanding how the strength of the interface can change with time and how the interfacial strength is effected by the thermal residual stresses presents unique challenges on the microstructural scale. The interfacial strength play a significant role in the overall strength and fatigue resistance of TMCs.

This Special Technical Publication is organized into five sections that progress from the basic understanding to the life prediction methodology. The sections are as follows:

Interfacial Properties and Microstructure—Five papers are directed toward understanding the interplay between interfacial strength, residual thermal stresses and the effects of time at temperature.

Fiber Bridging Behavior—Four papers focus on the important role of fiber bridging in the progression of damage. Some papers present modeling approaches while others make detailed experimental observations of the bridging process.

Inelastic Material Behavior and Modeling—Seven papers deal with the complex aspects of experimentally determining inelastic material responses and how to model such behavior in a composite.

Fatigue—Seven papers discuss the various aspects of fatigue damage evolution.

Life Predictions—Six papers present various approaches to tying together all the basic understanding into a methodology that will allow one to predict total life of a TMC.

The collection of work presented here represents tremendous progress toward the characterization and modeling of Titanium Matrix Composites. Nearly all the work was conducted over a relatively short period of time, beginning in 1987. This body of understanding shows that TMCs can be attractive structural materials in stiffness and strength driven designs at elevated temperatures. Like any material, TMCs have their limitations in terms of usage temperature and life. In spite of their high costs, TMCs should find applications that demand their unique blend of mechanical properties and temperature tolerance.

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