Mechanical, Thermal and Environmental Testing and Performance of Ceramic Composites and Components

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Foreword

This publication, *Mechanical, Thermal and Environmental Testing and Performance of Ceramic Composites and Components*, contains papers presented at the Symposium on Environmental, Mechanical, and Thermal Properties and Performance of Continuous Fiber Ceramic Composite (CFCC) Materials and Components held in Seattle, Washington on 18 May 1999. ASTM Committee C28 on Advanced Ceramics sponsored the symposium in cooperation with Committees E08 on Fatigue and Fracture and D30 on Advanced Composites. Michael G. Jenkins, University of Washington, Edgar Lara-Curzio, Oak Ridge National Laboratory, and Stephen T. Gonczy, Gateway Materials Technology, presided as co-chairmen and are co-editors of the resulting publication.

Contents

Overview

In the nearly decade and a half since its establishment in 1986, ASTM Committee C28 has provided a major forum for promoting standardized terminology, guides, classifications, practices, and test methods for advanced (a.k.a. structural, fine, and technical) ceramics. In particular, since 1991 ASTM Subcommittee C28.07 on Ceramic Matrix ASTM Composites has actively and vigorously introduced and promoted standards and activities nationally (for example, through other ASTM committees, Military Handbook 17, ASME Boiler and Pressure Vessel Code, etc.) and internationally (for example, through ISO) for advanced ceramic matrix composites, specifically continuous fiber ceramic composites.

Continuing these efforts, this publication and the Symposium on Environmental, Mechanical, and Thermal Properties and Performance of Continuous Fiber Ceramic Composite (CFCC) Materials and Components which was held in Seattle, Washington, 18 May 1999 were sponsored by ASTM Committee C28. Twenty-two papers were presented at the symposium and this publication contains twenty-one peer-reviewed manuscripts on continuous fiber-reinforced advanced ceramic composites, related test methods (standards), materials characterization, and design applications.

The advancement of technology has often been limited by the availability of materials and understanding of their behavior. Reflecting this emphasis on materials, in the technology of today, the US government has supported programs such as the Continuous Fiber Ceramic Composites (CFCCs), High Speed Research, and Enabling Propulsion Materials Programs which target specific new materials such as CFCCs for a broad range of applications, from chemical processing, to stationary heat engines, to power generation, to aerospace vehicles. Such applications require that still-emerging materials such as CFCCs be refined, processed, characterized, and manufactured in sufficient volume for successful widespread use in aggressive thermal/mechanical/environmental operating conditions. Concurrently, as the materials are refined, designers must have access to material properties and performance databases in order to integrate the material systems into their advanced engineering concepts. Without extensive materials characterization, producers of materials cannot evaluate relative process improvements nor can designers have confidence in the performance of the material for a particular application.

Developing and verifying appropriate test methods as well as generating design data and design experience for advanced materials is expensive and time consuming. High-temperature ceramic composites are more expensive to process than monolithic ceramics, not just because of the extra cost of constituent materials but also because of labor-intensive fabrication steps. Equipment for testing at elevated temperatures is highly specialized and expensive. Unique and novel test methods must be developed to take into account thermal stresses, stress gradients, measurement capabilities, gripping methods, environmental effects, statistical considerations, and limited material quantities. It is therefore imperative that test methods be carefully developed, standardized, verified, and utilized so that accurate and statistically significant data are generated and duplication of efforts can be minimized in test programs. Similarly, design codes must be written to establish which information on material properties and performance are required for particular applications as well as which standard test methods are recommended to quantify this information.

The papers in this publication provide current results of research and development programs on continuous fiber ceramic composites. The papers are divided into four major categories:

1. Room-Temperature Test Results/Methods
2. Test Results/Methods Related to Design Implications
3. Environmental Effects and Characterization
4. Damage Accumulation and Material Development

The sections addressing these categories contain papers on various types of continuous fiber ceramic composites, including those with matrices synthesized by chemical vapor infiltration (CVI), polymer impregnation and pyrolysis (PIP), melt infiltration (MI), or viscous glass infiltration. The Room-Temperature Test Results/Methods section includes papers on results of a round-robin program that used several full-consensus standards, influence of various test parameters on the tensile, shear and flexural behavior, novel transthickness tensile strength method, and delamination "toughness" and its effects. The section on Test Results/Methods Related to Design Implications includes papers on stress rupture, stress-relaxation and overstressing effects on testing and design, unload/reload tensile tests, fiber testing, fiber waviness, surface finish notch effects and notch sensitivity. The papers in the Environmental Effects and Characterization section address the thermal diffusivity changes due to microstructural damage, oxidation behavior in aggressive environments, time dependent deformation, and the effects of interphase oxidation. In the section on Damage Accumulation and Material Development, papers address damage accumulation during mechanical loading, effect of loading mode, temperature and environmental degradation of a novel pre-commercial material, degradation under constant load, and process development of a novel material system.

With this symposium and the resulting special technical publication, ASTM has made another stride forward in standardization activities by providing a wealth of information on continuous fiber ceramic composites. This information will assist the research, processing, and design community in better understanding the behavior, characterization and design nuances of these materials. This information is also invaluable for standards and code development background as test methods continue to be introduced and verified for continuous fiber ceramic matrix composites.

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