HIGH TEMPERATURE and ENVIRONMENTAL EFFECTS on POLYMERIC COMPOSITES

2ND VOLUME

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High Temperature and Environmental Effects on Polymeric Composites: 2nd Volume

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Foreword

This publication, *High Temperature and Environmental Effects on Polymeric Composites: 2nd Volume*, contains papers presented at the symposium of the same name held in Norfolk, Virginia on 13 November 1995. The symposium was sponsored by ASTM Committee D-30 on High Modulus Fibers and Their Composites. Dr. Thomas S. Gates of NASA Langley Research Center in Hampton, Virginia and Dr. Abdul-Hamid Zureick of the Georgia Institute of Technology in Atlanta, Georgia presided as symposium chairmen and are editors of the resulting publication.

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Overview

The second symposium on High Temperature and Environmental Effects on Polymeric Composites was organized to address current research in a specialized and important area that is attracting international attention. The topics covered in the symposium represent state-of-the-art research from branches of materials science and mechanics of materials that range across the engineering disciplines from aerospace to civil. This diversity is due not only to the wide use of polymeric composites in today's world but also the tendency of manufacturers and designers to continue to expand the design envelope of these advanced materials. It is expected that this volume will provide information of use to those involved in the structural use of advanced polymeric composites for infrastructure, marine applications, and aerospace vehicles. Results are presented for research in: durability analysis procedures, moisture effects, time-dependent and fatigue behavior, long-term aging and degradation studies. Many of the papers combine analytical and experimental results while several of them rely on experimental studies to advance their research results.

Analytical models that predict long-term performance must account for the synergy and interaction between environmental factors such as load and temperature. Initially these models may be developed to provide a qualitative assessment and as they mature their predictive capabilities can be considered more quantitative and accurate. McManus and Cunningham proposed such a model to assess composite durability. Factors considered in their model included weight loss, shrinkage, and mechanical property degradation. Maier and Friedrich suggested a thermomechanical treatment procedure to improve the mechanical performance. The mechanisms causing this improvement were discussed and linked to the high permanent deformation induced in the matrix of the composite. Micromechanics, at the fiber-matrix level, were used to help describe this behavior. A methodology for the prediction of remaining strength and life in polymeric composites subjected to cyclic and thermomechanical conditions was presented by Case, Plunkett, and Reifsnider. Their model, which simulated damage accumulation and failure modes was based on micromechanical and ply-level models of strength that combined the material properties, geometry, and arrangement of the constituents to estimate global behavior.

Moisture in an elevated temperature environment can have a pronounced influence on the physical and mechanical properties of polymeric composites. VanLandingham, Eduljee, and Gillespie examined the effects of moisture at various temperatures and relative humidity on the glass transition temperature, fracture toughness, and diffusion kinetics. These properties were measured experimentally for a graphite/thermoplastic composite. Pratt and Bradley measured the effects of absorbed moisture on interfacial strength of a graphite/thermoset composite by using a single fiber fragmentation test. Changes in interfacial strength were associated with the changes in residual compressive stresses at the fiber/matrix interface. Choqueuse et al. measured the absorption kinetics and the evolution of properties for five glass fiber polymer composites immersed in distilled water for 2 years under elevated temperature and pressure conditions. They attempted correlation between the quantity of water absorbed and the loss of mechanical properties and assessed the usefulness of absorption curves for material selection. Zaffaroni used a thermodynamics formulation to determine the 2-dimensional diffusion in hybrid composites. The model was compared to the analytical Fick's law solution and experimental measurements.

Time-dependent behavior such as fatigue and viscoelasticity can have significant dependence on environmental conditions. The interaction between creep and fatigue at elevated temperatures and the effects of this interaction on Mode I delamination was investigated by Uematsu, Kitamure, and Ohtani. Crack propagation rates were measured and correlated with the stress intensity factor for two different polymeric composite materials. Shokreih, Eilers, and Lessard used a three-rail shear test to characterize the in-plane shear behavior of a graphite/epoxy tested using room-temperature fatigue and static loading. Fatigue life, residual strength, and residual stiffness were measured for both notched and unnotched specimens. Physical aging, a thermo-reversible effect, will occur in all polymers whereas chemical aging, a thermo-irreversible effect, may only occur in those polymers that have an incomplete state of cure. Elevated temperature is known to accelerate these effects. Kamvouris et al. investigated the use of time-temperature superposition to quantify the effects of physical and chemical aging on the stress relaxation behavior of high-temperature polyimide thermoset polymers. Both vertical (stiffness) and horizontal (time) shifts were measured.

Parvatareddy et al. used a fracture mechanics-based approach to evaluate the durability of a titanium/adhesive system. Testing was accomplished with wedge and double cantilever beam specimens. Aging was carried out at elevated temperatures with three different air pressures as well as a set of specimens subjected to several organic solvents. Strain energy release rates, static, and fatigue properties were measured. Bowles, Roberts, and Kamvouris measured the compressive properties of fabric reinforced composites after long-term isothermal themo-oxidative aging. Experimental properties included failure modes and compressive strength. The degradation mechanisms associated with the aging process were noted and correlated with specimen thickness and residual properties.

Many experimental and analytical techniques used to assess durability and long-term performance require data on the physical changes in the polymer matrix and fiber-matrix interface. The research by Bank and Puterman provided information on the physical changes associated with surface degradation of glass fiber pultruded rods embedded in concrete castings and subjected to standard and aqueous environments. Measurement techniques in this study included optical microscopy and scanning electron microscope. Prian et al. used thermogravimetric analysis (TGA) and weight loss to assess the degradation of a large number of polymeric composites and then correlated these results with changes in mechanical strength. The test materials were exposed to neutral, basic, and acidic media at elevated temperatures for extended periods. The results were examined for potential accelerating factors. The effects of a space environment at low earth orbit on polymeric composites was investigated by Shively et al. using laboratory test apparatus. The test environment consisted of simultaneous fluxes of hyperthermal neutral oxygen atoms, energetic electrons, vacuum ultraviolet light, and hypervelocity-particle impacts.

As evidenced by the papers presented in this volume, there is a large breadth of potential research problems in the area of high-temperature and environmental effects of polymeric composites with applications ranging from civil infrastructure to supersonic aircraft. Despite this diversity, the common threads that bind these areas together are the need for an understanding of degradation mechanisms, formulation of predictive models, and the development of accurate experimental techniques.

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