Overview

This book represents the first symposium planned by ASTM Committee D-30 to cover the topic of high temperature and environmental effects on polymeric composites. The need for a symposium to address this topic arose from the realization that advanced composites are currently being investigated for use in environments which in the past were considered too harsh for polymeric based materials. For example, the aerospace and naval industries both have a need for light weight materials that can operate under extreme conditions, and yet retain their basic mechanical properties for long duration. Many of the papers presented at the symposium addressed ongoing research in these two industries. Of the 16 papers covering high temperature and environmental effects presented at the symposium, 12 are contained in this publication. The intent is that these papers will help establish the state-of-the-art in testing and analysis techniques and provide the basis for further research in this exciting area.

The symposium was organized into four technical sessions covering the topics of Damage Mechanisms and Failure, Materials Behavior Under Combined Effects-I, Constitutive Models, and Material Behavior Under Combined Effects-II. Conference sessions were chaired by John Masters of Lockheed Engineering and Sciences Company, Steve Johnson of NASA Langley Research Center, Ray Adsit of Rohr Industries and Don Morris of Virginia Polytechnic Institute and State University.

Brief introductions to each paper contained in this volume are given below. It is the hope of the editors that the reader will find the original research presented in this volume both innovative and informative.

Arslanian and Hogg measured stress corrosion crack growth in sheet molding compounds. Crack growth was measured in tapered double cantilever beam specimens tested in an environment of I M HCl. Crack growth rate was determined as a function of applied stress intensity.

Ohtani, Kitamura and Hojo investigated the delamination behavior under static and cyclic creep at elevated temperatures using unidirectional graphite/thermoplastic specimens. Under Mode I loading, they found that the crack propagated under small scale creep. The creep deformation was constrained by the fibers and confined to the vicinity of the crack tip. In addition, they found that the creep crack propagation was insensitive to the test temperature and the propagation rate correlated well with the elastic energy release rate in static and cyclic creep.

Martin performed an analytical and experimental investigation of delamination onset under cyclic thermal and mechanical loads. A fracture mechanics methodology that accounted for residual thermal stresses and cyclic thermal/mechanical stresses was used to predict edge delamination. Methodology verification was accomplished by performing isothermal static and tension-tension fatigue tests. Results indicated that the ply interface for delamination was well predicted as was the number of cycles to edge delamination.

Lo, Hwang, Chang, et al. performed characterization of a new high temperature carbon/polyimide composite. They compared the measured properties to a standard high temperature composite. The composite material property characterization included measurement of physical properties, static and cyclic mechanical tests and thermal cycling at elevated temperatures.

Aylor investigated the effect of a seawater environment on the galvanic corrosion behavior of graphite/epoxy composites coupled to metals. Galvanic couple tests and accelerated electromechanical tests in sea water were performed. For a metal coupled to the composite, measurements were taken on the rate of metallic corrosion as a function of the exposed graphite fibers in the composite. The rate of corrosion was found to increase as the exposed fiber area was increased. The magnitude of the corrosion was largely influenced by the formation of corrosion product films. Results also suggested that short term electromechanical testing was not a reliable method for assessing long term corrosion behavior, but is effective in evaluating differences in corrosion resistance with varying cathode: anode area ratios.

Wall, Taylor, and Cahen used electrochemical impedance spectroscopy to simulate and detect electrochemical damage in a graphite/bismaleimide composite. Experiments performed included cathodic and anodic potentiostatic polarizations, exposure to caustic solutions, and galvanic coupling with various metals. The technique was found to provide a rapid and sensitive assessment of changes in the composite. Observed transition from planar to porous electrode behavior was attributed to the breakdown of the fiber/matrix interface. Anodically polarized samples maintained a planar electrode response indicating uniform ablation. This may have been caused by fiber and matrix oxidation.

Chang, Swain, Lesko, et al. explored the effect of the interphase and interface region on creep and creep rupture of thermoplastic composites. Mechanical properties of the composites were altered by systematic changes in the fiber surface chemistry. Results indicated that acceptable static mechanical properties may not dictate acceptable long term performance. In addition, experimental results showed that the interphase/interface region did not affect the degradation rates of the creep rupture strength of the thermoplastic composites. However, this region did influence the creep rupture strengths.

Hastie and Morris determined the effect of physical aging on the creep response of a graphite/thermoplastic composite. They performed momentary tensile creep tests at increasing aging times following a rapid quench from above the glass transition temperature. It was found that as the aging time increased, the creep response of the material significantly decreased. Short term creep curves, obtained at various aging time, were shifted to form a momentary master compliance curve. Theoretical predictions were made for long term creep compliance using an effective time theory and compared to long term data. It was found that predictions based solely on the time-temperature superposition principle would significantly over-predict the creep response if physical aging effects were ignored.

Wang and Dillard looked at the effects of moisture sorption on the creep behavior of fibers. Using a variety of fibers, the effects of fiber processing spinning rate and fiber doping on the mechano-sorptive behavior were assessed experimentally. The suspected mechanisms that were responsible for the mechano-sorptive phenomena were discussed.

Gates explored the effects of elevated temperature on the viscoplastic modeling of graphite/polymeric composites. Using experimental data on two material systems, the material parameters required by the elastic/viscoplastic constitutive model were correlated against temperature. From this data, trends in the parameters at elevated temperatures were developed, differences between the two material systems were outlined, and the significance of the parameters in terms of ductility and rate dependent behaviors were established. Using data from matrix dominated laminates, test data and predicted behavior were compared. Periods of loading, unloading, stress relaxation and creep were accounted for. The analytical model was found to correlate well with the observed behaviors.

Milke and Vizzini explained the means to determine a load, heat, time-to-failure surface for structural polymeric composites subjected to fire. They developed a small scale test technique that was used to provide simultaneous application of load and fire. It was felt that this means of testing provided advantages, from a research standpoint, over the typical large scale testing typically performed by industry.

Maier and Friedrich measured the property improvements of polymer composites after loading these composites at high temperature. Procedures were developed for introducing internal stresses into a laminate by permanent deformation of the matrix. The introduction of these internal stresses was intended to reduce stress concentrations within the matrix of the loaded composite and thus result in an increase of strength. Under tensile loading, these tests produced a substantial increase in elongation upon damage onset. To a lesser degree, an increase in compression strength as well as an improvement of fatigue behavior was measured after introducing the internal stresses.

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