Summary

The papers in this volume have been grouped into five major sections, each corresponding to a session title in the Seventh Conference on Composite Materials: Testing and Design. For convenience, the summary will be presented by major heading.

Structures

Toughness is a key issue in structural applications of composite materials. This is reflected in the four papers presented in this section. The effect of manufacturing and service-induced damage on the static and fatigue strength of aircraft composite structures is discussed by Garrett. Analysis of composite bolted repairs subjected to biaxial or shear loads is presented by Bohlmann, Renieri, and Riley. Process-induced defects, stress concentrations, and impact behavior are key issues in the characterization of T300/V-378A graphite/bismaleimide composites as performed by Ramkumar, Grimes, and Kong. Fracture toughness of thick-wall graphite/epoxy filament-wound composites is considered by Riddle and Beckwith. Both Mode I and Mode II energy release rates are determined for through-the-thickness cracks and delaminations.

Failure Mechanisms

Emphasis in this section is on matrix dominated failure modes. Mandell, Grande, Tsiang, and McGarry propose a single-fiber interfacial shear strength test in which the fiber is loaded in compression by a probe. Nicholls discusses a unique approach to determining the biaxial stress-strain behavior of neat resin specimens. Hahn and Williams identify transverse splitting, in addition to the usual modes of fiber failure and shear crippling, as a major failure mode for unidirectional composites subjected to compression loading. A microstructural analysis of laminates failed under uniaxial compression is performed by Kar, Herfert, and Kessler. Their investigation reveals that specimens tested at elevated temperature and high moisture content (>1%) display different characteristics than specimens tested at room temperature with a lower moisture content.

Strength

Damage tolerance issues of stress concentrations and impact behavior are presented in this section. Lagace shows a laminate stacking sequence effect on the strength of graphite/epoxy composites containing circular holes. The stacking sequence effect is attributed to interlaminar stresses and ply constraints. The effect of laminate thickness on apparent fracture toughness is the subject of the paper by Harris and Morris. They consider through-the-thickness cracks in conjunction with three different test methods. Fracture toughness is shown to be a function of laminate thickness. Avva, Vala, and Jeyaseelan report on the combined effect of low-velocity impact and tension-tension fatigue loading on the residual strength of graphite/epoxy laminates. A residual strength model based on classical fracture mechanics is also presented.

Delamination

Delamination is the primary failure mode of interest in damage tolerance characterization of advanced composites. Low-velocity impact results in delamination. Delamination is also a manufacturing defect of key concern. Thus, this section is very timely. The seven papers included in this section represent a good cross section of current work in the area of delamination. Chai uses a double-cantilever-beam test to correlate neat resin fracture toughness with composite fracture toughness. His results indicate that a thin bondline resin specimen is required to simulate composite behavior. A symmetric double cracked-lap-shear specimen design for characterizing mixed-mode delamination is presented by Armanios, Rehfield, and Reddy. Less data scatter is obtained from the double crack-lap specimen as compared to the conventional single crack-lap specimen. Softening layers utilized as a mechanism for improving delamination resistance is the subject of the paper by Browning and Schwartz and the paper by Chan, Rogers, and Aker. Both of these papers demonstrate improved delamination resistance with the use of adhesive inner layers. In the paper by Browning and Schwartz a double-cantilever-beam specimen is utilized to measure Mode I behavior, while the edge delamination specimen, supplemented by a finite-element analysis, is utilized by Chan, Rogers, and Aker to characterize mixed-mode response. A unique design of the edge delamination specimen is presented by Soni and Kim. This specimen yields Mode II response with compression interlaminar normal stress for external tension loading, while resulting in mixed-mode response for external compression loading. The global-local laminate model is used to determine the interlaminar stresses. The initiation and propagation of delaminations in step-lap joints constructed of composites is presented by Ratwani and Kan. Joints with and without bondline flaws are considered. A contiuum analysis in conjunction with NASTRAN is utilized for determining interlaminar stresses. Mall and Johnson characterize the fracture behavior of adhesive bonded joints constructed of graphite/epoxy adherends. A double-cantilever-beam specimen is utilized to measure Mode I response and a cracked-lap-shear specimen

for mixed-mode behavior. They find total strain-energy release rate to be the governing parameter in debond growth.

Analysis and Characterization

This section features papers on emerging materials such as three-dimensional woven and braided structures. A number of other topics are also included. Madhukar and Awerbuch demonstrate the use of acoustic emission for studying damage initiation and propagation in center-notched boron/aluminum laminates subjected to quasi-static tensile loading. In particular, they investigate the potential of the acoustic-emission technique as a means of tracking damage in metal-matrix composites. Dynamic stress analysis in notched and unnotched flexural specimens is the subject of the paper by Murthy and Chamis. Both a slow rate of loading and impact loading are considered. A triangular pulse (to simulate concentrated loads) is utilized in conjunction with a NASTRAN finite-element code to obtain numerical results. The last three papers involve three-dimensionally reinforced materials. Ko presents an analysis and characterization of a three-dimensional braided material. In the paper by Ma, Yang, and Chou, an extensive mathematical model applicable to three-dimensional woven composites is presented. The theoretical analysis is supplemented by experimental data on Magnaweave composites. Fabrication and characterization of multi-dimensionally braided composites is discussed in the paper by Macander, Crane, and Camponeschi. Three graphite fiber systems and three processes are investigated in this work.

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