Introduction

Fibrous composite materials composed of stiff, strong fibers in a matrix have sparked the imagination of material scientists and engineers as the structural materials of the future. Translation of the concept of fibrous composites into a primary load carrying structure has been and remains a challenging process.

Experience with ductile quasi-isotropic metals available in standard forms (plate, bar, forging, etc.) has lead to established procedures for selecting and testing materials, designing structures for stiffness and strength, fabricating and joining members, etc. Conversely, fibrous composite materials exhibit little ductility in the usual sense and a degree of anisotropy in stiffness and strength that allows design of the material as well as the structure in which it will be used. New and unorthodox fabrication methods are used in which the material and the structural component frequently are fabricated simultaneously. In addition, joining methods can involve extensive use of adhesive bonding.

The designer of fibrous composite structures is presented with numerous degrees of freedom and an opportunity to exercise ingenuity totally unavailable to him with conventional materials. However, this new freedom requires that the designer integrate into a single design step many aspects of the conventional step-by-step design process. Conceptually, it is possible to design a structural component by starting with the properties of the constituent materials, the fibers and the matrix. A parallel filament lamina is designed that provides the necessary stiffness and strength. The laminated structural component employs as many fibers in selected locations and directions as are required to provide the stiffness and strength for the prescribed service loading conditions.

While modest successes (filament wound pressure vessels) have been achieved using simplified versions of this method, complicated structures subjected to multiple loading conditions exhibit prohibitive complexity. To make the design process manageable, the concept of the "unidirectional lamina" was introduced as the "fundamental unit of material" in design. This procedure employed test data obtained from a unidirectional lamina as the basis for design of laminated components and structures. One step, the design of the material, was replaced by data obtained by testing the lamina. This procedure shifted design attention from the micromechanics level of the material, to the macromechanics (anisotropic elasticity) level of the components and structures. In retrospect, this concept of the lamina as the unit of material for use in design has restricted the freedom of the designer very little but has allowed him to get on with the job of designing and producing structural components.

Several years of experience with the concept of the lamina as the unit of material for design were reported in the First ASTM Conference on Composite

Materials: Testing and Design in 1969. The second ASTM conference considered, among other things, some of the advances that had been made in measuring the mechanical properties of the lamina and in relating these properties to the test performance of full scale components. The use of test data from a lamina plus anisotropic elasticity has enjoyed considerable success: stresses, strains, and deflections, short of failure, are predicted with reasonable engineering accuracy. At the same time, new problems in testing lamina and translating the measured properties into the behavior of laminates have arisen. Test methods useful with ductile isotropic metals lead to unexpected interactions during tests of anisotropic laminae, particularly of off-axes laminae. Further, coupling between laminae in a laminate may lead to undesirable distortions which cannot be ignored. Suitable specimens for determining static properties must be carefully designed and analyzed to ensure that unwanted influences are minimized. In addition, complex behavior, related to ultimate strength and failure by fatigue and fracture under both static and impact loading, has been observed.

The first group of papers in this symposium volume present a picture of the overall design and properties requirements and examples of current achievements with regard to structural design using composites. The next group is concerned primarily with mechanical property characterization of laminae and laminates and the development of standard test methods. As indicated earlier, the design process is predicated upon these properties. The detailed problems and proposed solutions for obtaining appropriate static mechanical property data from laboratory tests for use in design are adequately discussed. In addition, vibration behavior, discussions of toughness, and observations of behavior under repeated loads and fatigue behavior, are presented, along with behavior under impact loading and creep and rupture phenomena. A final group of papers returns to the question of design and tailoring of composite materials for specific purposes and analysis of the interaction of the constituents, the reinforcement, and the matrix.

A survey of the papers will strongly reinforce the impression that "composite materials" is a multi-disciplinary subject. This collection of papers serves to inform or remind individuals representing those disciplines, namely, the designer, the materials fabricator, the stress analyst, the test engineer, the fiber producer, the metal matrix expert, and the polymer matrix specialist, of the special problem created by the use of several quite different technical languages. In many cases, good communication of concepts at a simple level between these diverse groups of experts goes a long way toward reducing complex technical problems to manageable size. Certainly the production of efficient structural components made of fibrous composites through testing and design will require good communication.

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