

INTRODUCTION TO COMPOSITE MATERIALS

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Introduction

This module introduces basic concepts of stiffness and strength underlying the mechanics of fiber-reinforced advanced composite materials. This aspect of composite materials technology is sometimes termed “micromechanics,” because it deals with the relations between macroscopic engineering properties and the microscopic distribution of the material’s constituents, namely the volume fraction of fiber. This module will deal primarily with unidirectionally-reinforced continuous-fiber composites, and with properties measured along and transverse to the fiber direction.

Materials

The term *composite* could mean almost anything if taken at face value, since all materials are composed of dissimilar subunits if examined at close enough detail. But in modern materials engineering, the term *usually* refers to a “matrix” material that is reinforced with fibers. For instance, the term “FRP” (for Fiber Reinforced Plastic) usually indicates a thermosetting polyester matrix containing glass fibers, and this particular composite has the lion’s share of today’s commercial market. Figure 1 shows a laminate fabricated by “crossplying” unidirectionally-reinforced layers in a 0° - 90° stacking sequence.

Many composites used today are at the leading edge of materials technology, with performance and costs appropriate to ultrade manding applications such as spacecraft. But heterogeneous materials combining the best aspects of dissimilar constituents have been used by nature for millions of years. Ancient society, imitating nature, used this approach as well: the Book of Exodus speaks of using straw to reinforce mud in brickmaking, without which the bricks would have almost no strength.

As seen in Table 1¹, the fibers used in modern composites have strengths and stiffnesses far above those of traditional bulk materials. The high strengths of the glass fibers are due to processing that avoids the internal or surface flaws which normally weaken glass, and the strength and stiffness of the polymeric aramid fiber is a consequence of the nearly perfect alignment of the molecular chains with the fiber axis.

¹F.P. Gerstle, “Composites,” *Encyclopedia of Polymer Science and Engineering*, Wiley, New York, 1991. Here E is Young’s modulus, σ_b is breaking stress, ϵ_b is breaking strain, and ρ is density.

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