CHAPTER ONE

Introduction

In this book we focus on fiber-reinforced composites composed of fibers embedded in a matrix. The fibers may be short or long, continuous or discontinuous, and may be in one or in multiple directions (Fig. 1.1). Such materials offer advantages over conventional isotropic structural materials such as steel, aluminum, and other types of metal. These advantages include high strength, low weight, and good fatigue and corrosion resistance. In addition, by changing the arrangements of the fibers, the properties of the material can be tailored to meet the requirements of a specific design.

The excellent properties of composites are achieved by the favorable characteristics of the two major constituents, namely the fiber and the matrix. In low-performance composites, the reinforcements, usually in the form of short or chopped fibers (or particles), provide some stiffening but very little strengthening; the load is mainly carried by the matrix. In high-performance composites, continuous fibers provide the desirable stiffness and strength, whereas the matrix provides protection and support for the fibers, and, importantly, helps redistribute the load from broken to adjacent intact fibers.

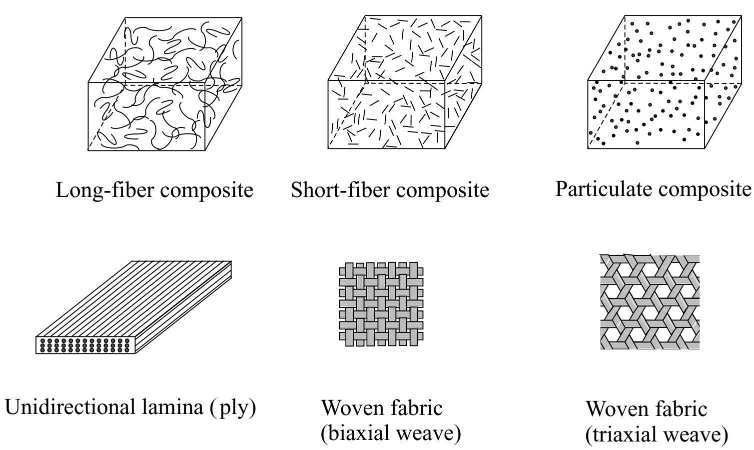

Figure 1.1: Composite material systems.

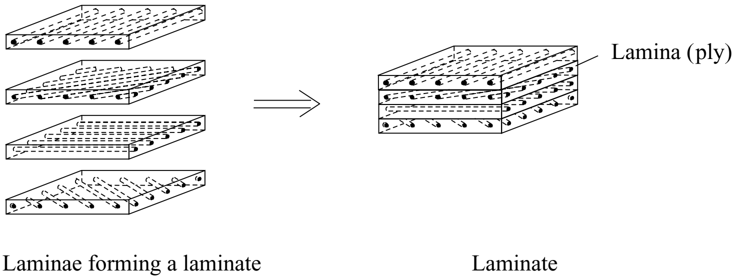

Figure 1.2: Laminated composite.

The arrangement of the fibers in a structure is governed by the structural requirements and by the process used to fabricate the part. Frequently, though not always, composite structures are made of thin layers called laminae or plies. Within each lamina, the fibers may be aligned in the same direction (unidirectional ply, Fig. 1.1) or in different directions. The latter configuration is produced, for example, by weaving the fibers in two or more directions (woven fabric). The lamina may also contain short fibers either oriented in the same direction or distributed randomly. Several laminae are then combined into a laminate to form the desired structure (Fig. 1.2).

The mechanical and thermal behaviors of a structure depend on the properties of the fibers and the matrix and on the amount and orientations of the fibers. In this book, we consider the design steps from micromechanics (which takes into account the fiber and matrix properties) through macromechanics (which treats the properties of the composite) to structural analysis. These steps are illustrated in Figure 1.3 for a structure made of laminated composite.

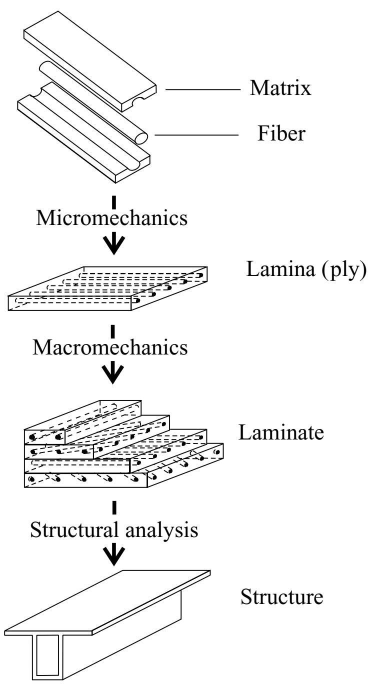

Figure 1.3: The levels of analysis for a structure made of laminated composite.