06 Properties of materials: 4. Composite materials

Composite material

is a material system composed of two or more physically distinct phases whose combination produces aggregate properties that are different from those of its constituents.

The technological and commercial interest in composite materials derives from the fact that their properties are not just different from their components but are often far superior. Some of the possibilities include:

1. Composites can be designed that are very strong and stiff, yet very light in weight, giving them strength- to-weight and stiffness-to-weight ratios several times greater than steel or aluminum. These properties are highly desirable in applications ranging from commercial aircraft to sports equipment.

2. Fatigue and toughness properties are generally better than for the common engineering metals.

3. Composites can be designed that do not corrode like steel; this is important in automotive and other applications.

4. With composite materials, it is possible to achieve combinations of properties not attainable with metals, ceramics, or polymers alone.

5. Better appearance and control of surface smoothness are possible with certain composite materials.

Composite materials can be classified in various ways. One possible classification distinguishes between:

1. Traditional composites: are those that occur in nature or have been produced by civilizations for many years. Concrete (Portland cement plus sand or gravel) and asphalt mixed with gravel are traditional composites used in construction.

2. Synthetic composites: are modern material systems normally associated with the manufacturing industries, in which the components are first produced separately and then combined in a controlled way to achieve the desired structure, properties, and part geometry.

The classification system for composite materials based on the matrix phase is:

1. Metal Matrix Composites (MMCs): include mixtures of ceramics and metals, such as cemented carbides, as well as aluminum or magnesium reinforced by strong, high stiffness fibers.

2. Ceramic Matrix Composites (CMCs): are the least common category. Aluminum oxide and silicon carbide are materials that can be imbedded with fibers for improved properties, especially in high temperature applications.

3. Polymer Matrix Composites (PMCs): Thermosetting resins are the most widely used polymers in PMCs. Epoxy and polyester are commonly mixed with fiber reinforcement.

The classification can be applied to traditional composites as well as synthetics. Concrete is a ceramic matrix composite, while asphalt and wood are polymer matrix composites.

The reinforcing phase:

It is important to understand that the role played by the secondary phase is to reinforce the primary phase. The imbedded phase is most commonly one of the shapes illustrated in Figure 6.1: fibers, particles, or flakes. In addition, the secondary phase can take the form of an infiltrated phase in a skeletal or porous matrix.

Fibers: are filaments of reinforcing material, generally circular in cross-section, although alternative shapes are sometimes used (e.g., tubular, rectangular, hexagonal). Diameters range from less than 0.0025 mm to about 0.13 mm, depending on material.

Figure 6.1 Possible physical shapes of imbedded phases in composite materials: (a) fiber, (b) particle, and (c) flake.

The effect of fiber diameter on tensile strength can be seen in Figure 6.2.

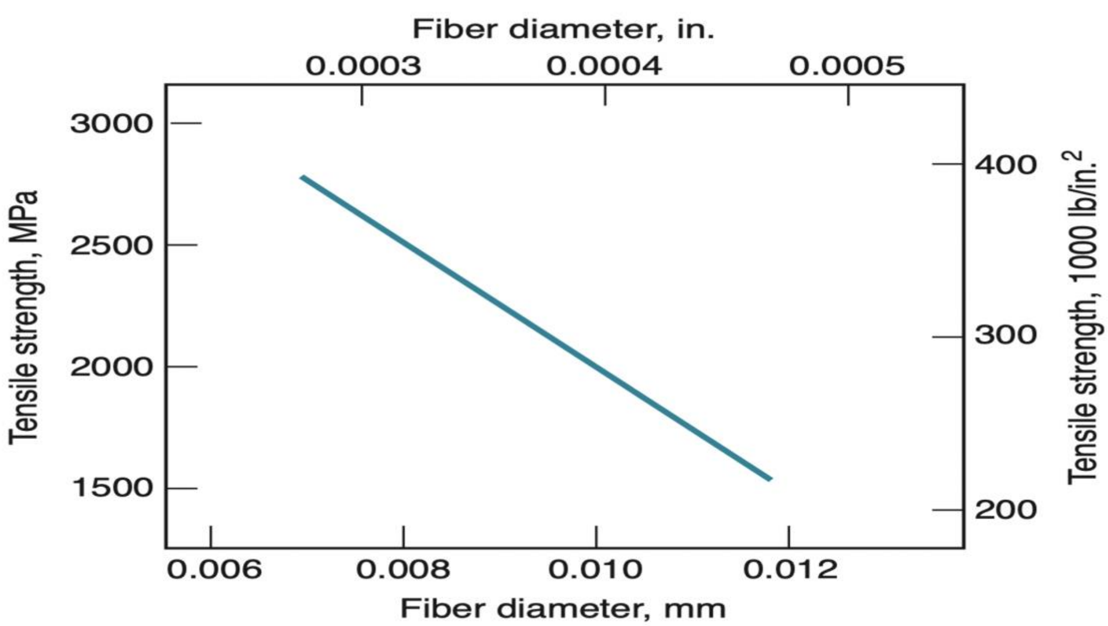


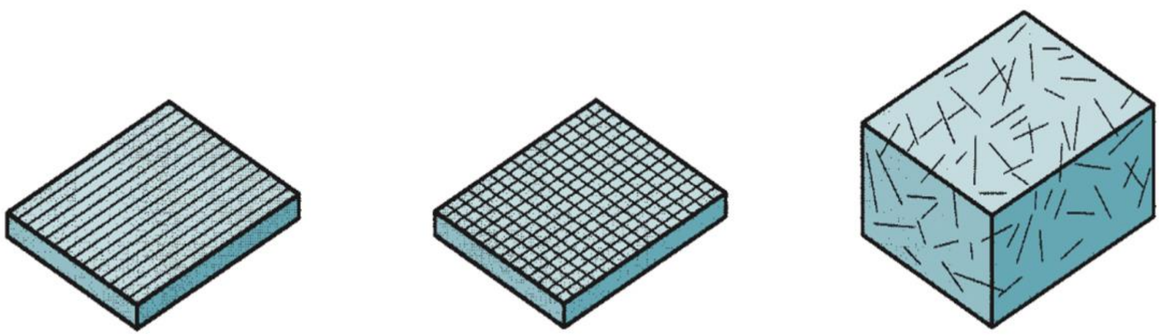
Figure 6.2 Relationship between tensile strength and diameter for a carbon fiber. Other filament materials show similar relationships.

Fiber orientation is another factor in composite parts. We can distinguish three cases, illustrated in Figure 6.3:

(a) one-dimensional reinforcement, in which maximum strength and stiffness are obtained in the direction of the fiber;

(b) planar reinforcement, in some cases in the form of a two-dimensional woven fabric;

(c) random or three- dimensional in which the composite material tends to possess isotropic properties.



(a) (b) (c)

Figure 6.3 Fiber orientation in composite materials: (a) one dimensional, continuous fibers, (b) planar, continuous fibers in the form of a woven fabric, and (c) random, discontinuous fibers.

Various materials are used as fibers in fiber-reinforced composites:

1. Metals
2. Ceramics
3. Polymers
4. Carbon
5. Boron