AGGREGATE COMPOSITES

There are a variety of examples of **aggregate composites** in which particles reinforce a matrix. A large number of composite systems are based on particle reinforcement. Examples are listed in Table 12.4. As with Table 12.3, these systems include some of our most sophisticated engineering materials. Two groups of modern composites are identified in Table 12.4. **Particulate composites** refer

TABLE 12.4

Aggregate Composite Systems
Particulate composites
Thermoplastic elastomer (elastomer in thermoplastic polymer)
SiC in Al
W in Cu
Mo in Cu
WC in Co
W in NiFe
Dispersion-strengthened metals
Al_2O_3 in Al
Al_2O_3 in Cu
Al_2O_3 in Fe
ThO_2 in Ni

Source: Data from L. J. Broutman and R. H. Krock, Eds., *Modern Composite Materials,* Addison-Wesley Publishing Co., Inc., Reading, MA, 1967, Chapters 16 and 17; and K. K. Chawla, University of Alabama, Birmingham.

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specifically to systems in which the dispersed particles are relatively large (at least several micrometers in diameter) and are present in relatively high concentrations (greater than 25 vol % and frequently between 60 and 90 vol %). Earlier, we encountered a material system that can be included in this category—the polymers containing fillers discussed in Section 12.1. Remember that automobile tires are a rubber with roughly one-third carbon black particles.

A good example of a particulate composite is WC/Co, an excellent cutting-tool material. A high-hardness carbide in a ductile metal matrix is an important example of a **cermet**, a ceramic–metal composite. The carbide is capable of cutting hardened steel but needs the toughness provided by the ductile matrix, which also prevents crack propagation that would be caused by particle-to-particle contact of the brittle carbide phase. As both the ceramic and metal phases are relatively refractory, they can both withstand the high temperatures generated by the machining process. The **dispersion-strengthened metals** contain fairly small concentrations (less than 15 vol %) of small-diameter oxide particles (0.01 to 0.1 μm in diameter). The oxide particles strengthen the metal by serving as obstacles to dislocation motion. This concept can be appreciated from the discussion in Section 6.3 and Figure 6.26. Later in this section, we will find that a 10 vol % dispersion of Al_2O_3 in aluminum can increase tensile strength by as much as a factor of 4.

As wood is a common structural material and an example of a fiber-reinforced composite, concrete is an excellent example of an aggregate composite. Common concrete is rock and sand in a calcium aluminosilicate (cement) matrix. As with wood, this common construction material is used in staggering quantities. The weight of concrete used annually exceeds that of all metals combined.

EXAMPLE 12.7

A dispersion-strengthened aluminum contains 10 vol % Al_2O_3. Assuming that the metal phase is essentially pure aluminum, calculate the density of the composite. (The density of Al_2O_3 is 3.97 Mg/m^3.)

SOLUTION

From Appendix 1, we see that

$$\rho_{Al} = 2.70 \text{ Mg/m}^3.$$

For 1 m^3 of composite, we shall have 0.1 m^3 of Al_2O_3 and $1.0 - 0.1 =$ 0.9 m^3 of Al. The mass of each component will be

$$m_{Al_2O_3} = 3.97 \frac{\text{Mg}}{\text{m}^3} \times 0.1 \text{ m}^3 = 0.40 \text{ Mg}$$

and

$$m_{Al} = 2.70 \frac{\text{Mg}}{\text{m}^3} \times 0.9 \text{ m}^3 = 2.43 \text{ Mg},$$

giving

$$\rho_{\text{composite}} = \frac{m}{V} = \frac{(0.40 + 2.43) \text{ Mg}}{1 \text{ m}^3}$$
$$= 2.83 \text{ Mg/m}^3.$$

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