Composites کامپوزیتها

انواع کامپوزیت: الف-کامپوزیت ذره ای ب: کامپوزیت تقویت شده با الیاف   ج- کامپوزیت لایه ای

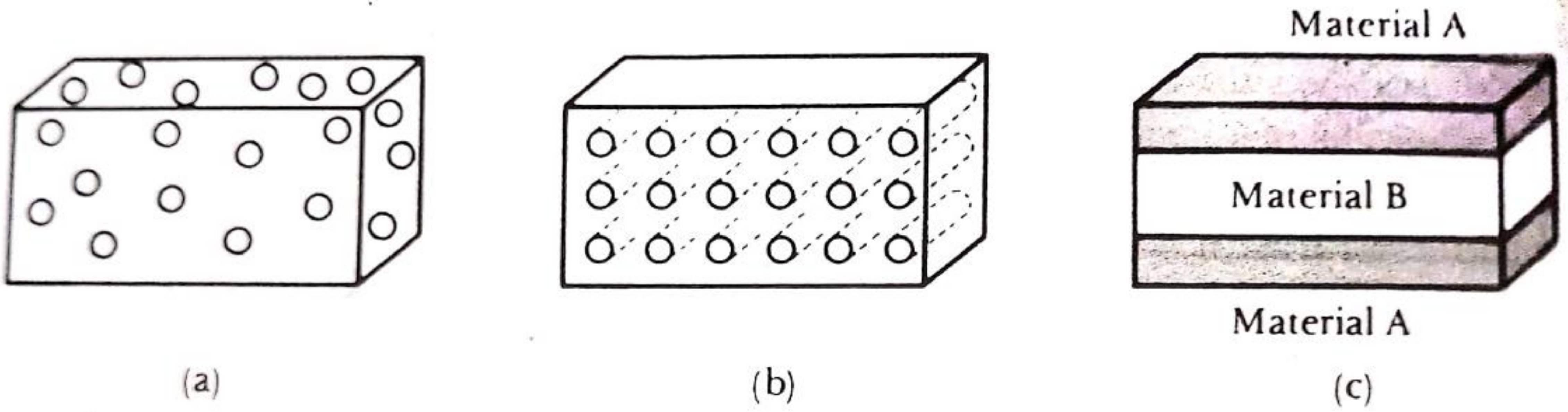
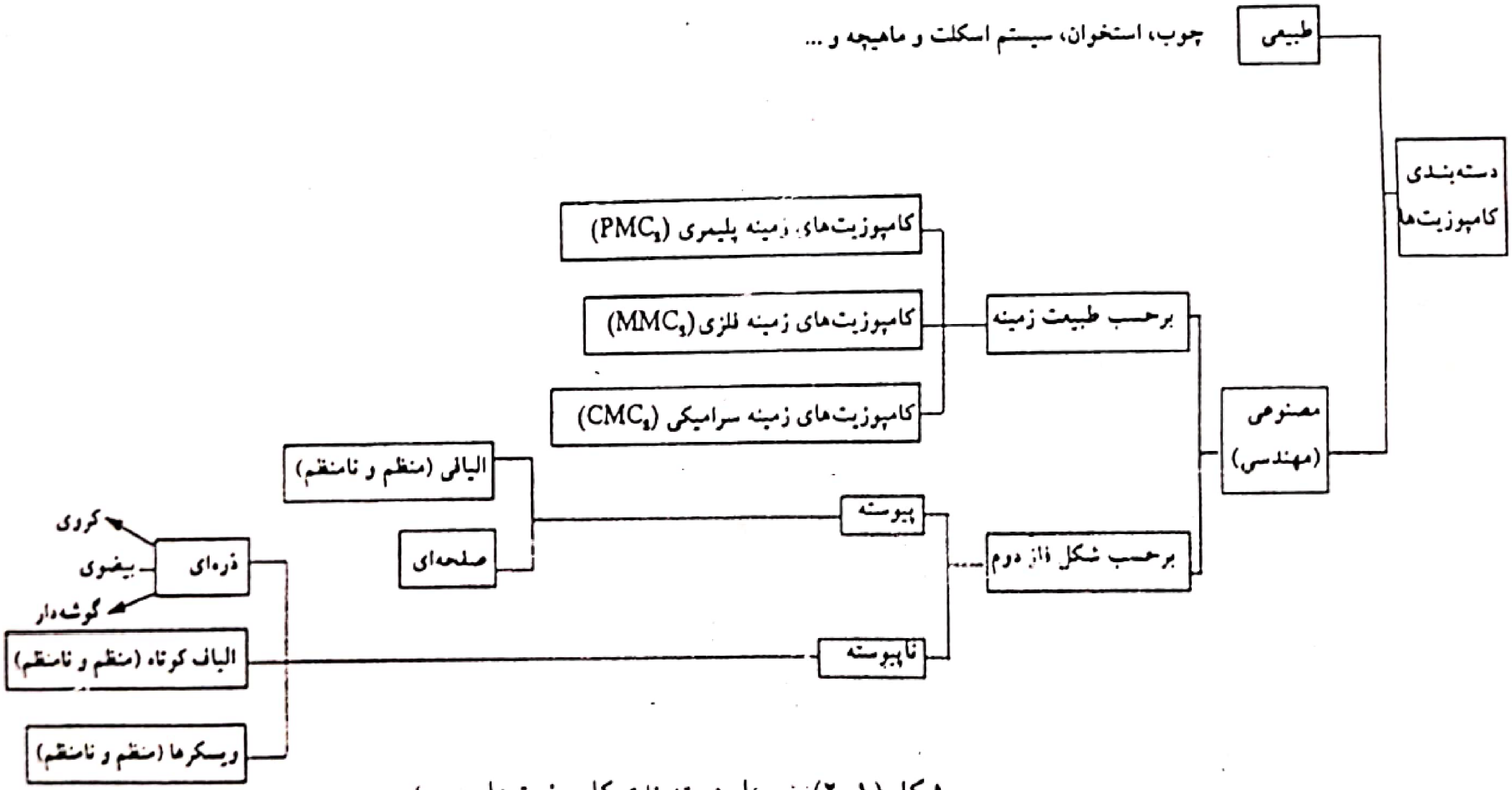


FIGURE 16-1 Comparison of the three types of composite materials. (a) Particulate composite, (b) fiber-reinforced composite, and (c) laminar composite.



شکل (۱-۲): نمودار دسته‌بندی کامپوزیت‌ها

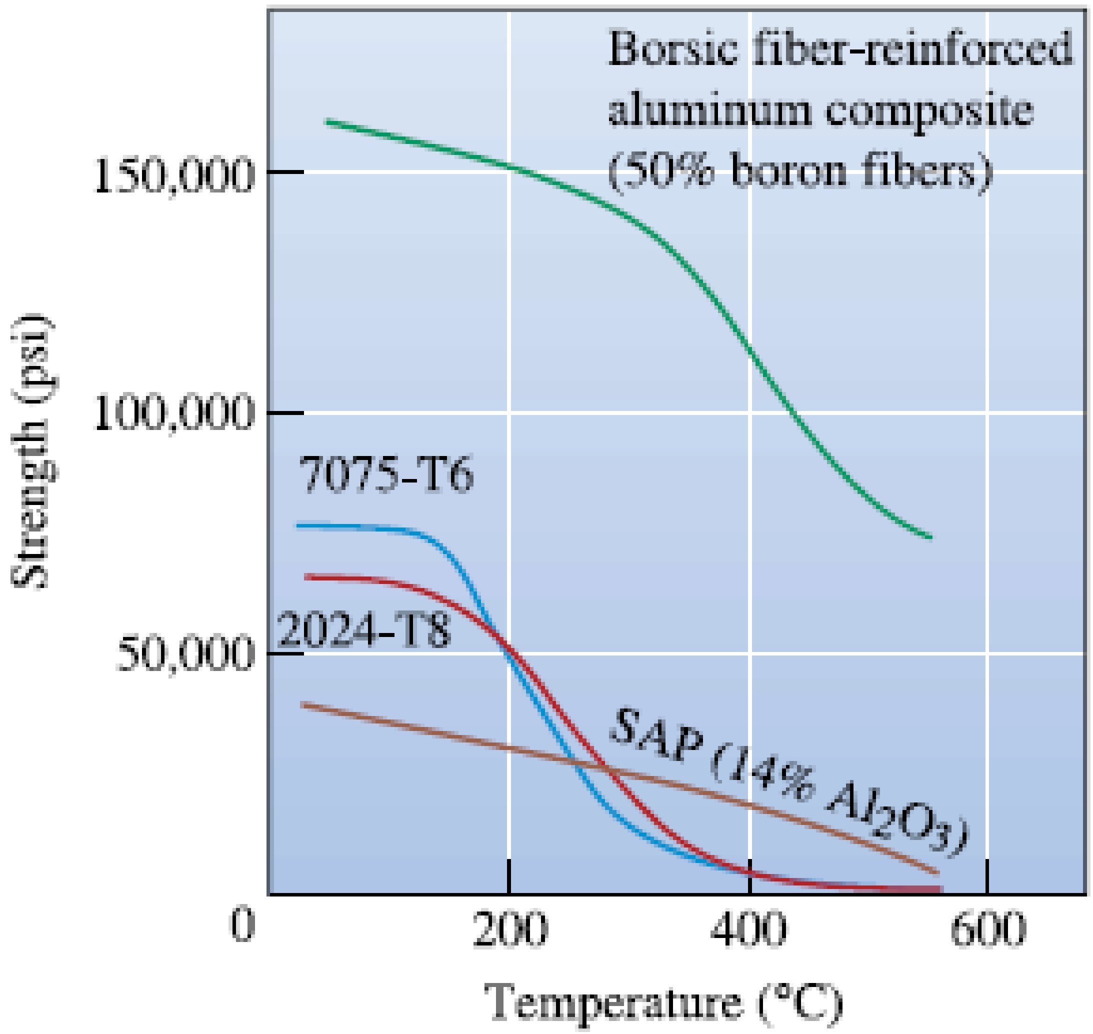


Figure 17-2
Comparison of the yield strength of dispersion-strengthened sintered aluminum powder (SAP) composite with that of two conventional two-phase high-strength aluminum alloys. The composite has benefits above about 300°C. A fiber-reinforced aluminum composite is shown for comparison.

مقایسه خواص خزشی فلز پلاتین با کامپوزیت زمینه پلاتین تقویت شده با ذرات توریا

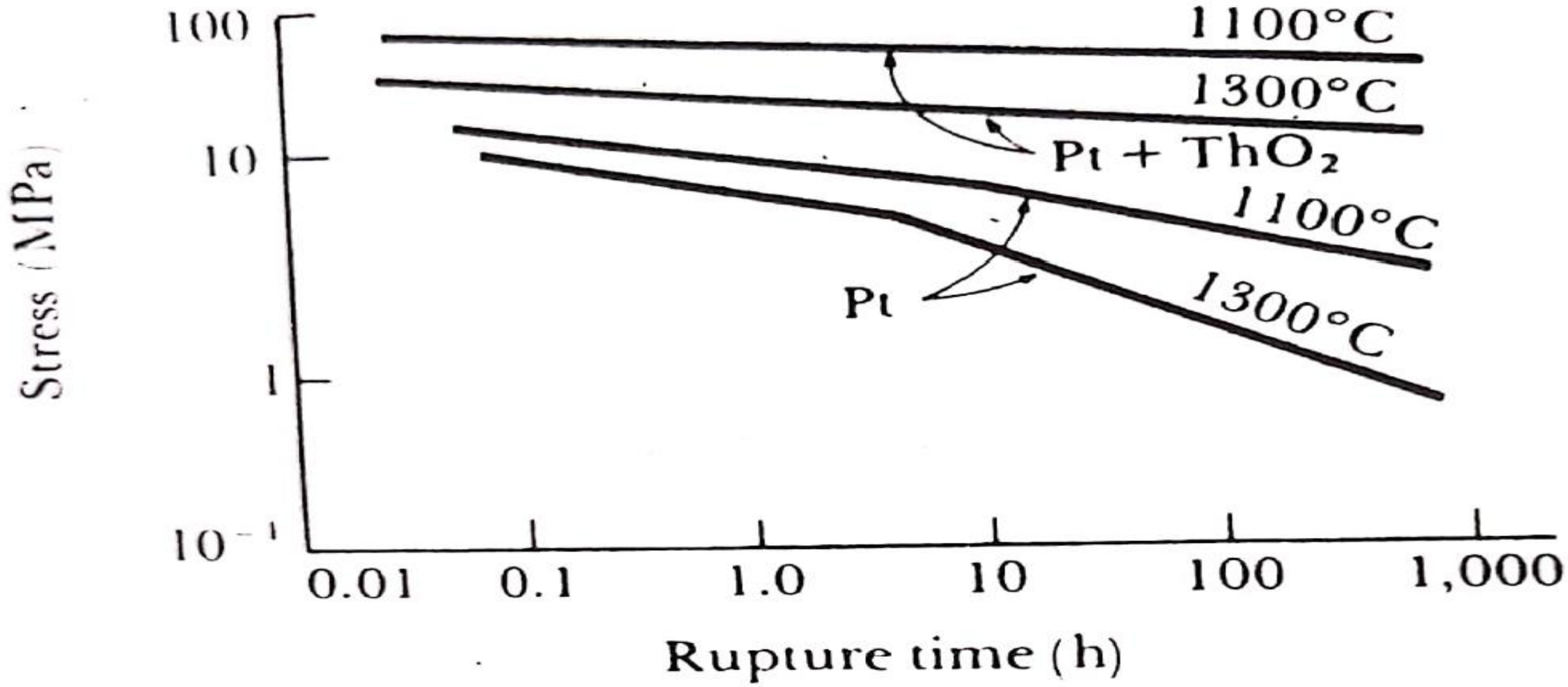


FIGURE 16-3 Dispersion-strengthened platinum, containing 12.5% ThO_2, has much higher creep resistance than pure platinum.

TABLE 17-1 ■ ***Applications of selected dispersion-strengthened composites***

System	Applications
Ag-CdO	Electrical contact materials
$Al\text{-}Al_2O_3$	Possible use in nuclear reactors
Be-BeO	Aerospace and nuclear reactors
$Co\text{-}ThO_2$, Y_2O_3	Possible creep-resistant magnetic materials
$Ni\text{-}20\%\ Cr\text{-}ThO_2$	Turbine engine components
Pb-PbO	Battery grids
$Pt\text{-}ThO_2$	Filaments, electrical components
$W\text{-}ThO_2$, ZrO_2	Filaments, heaters

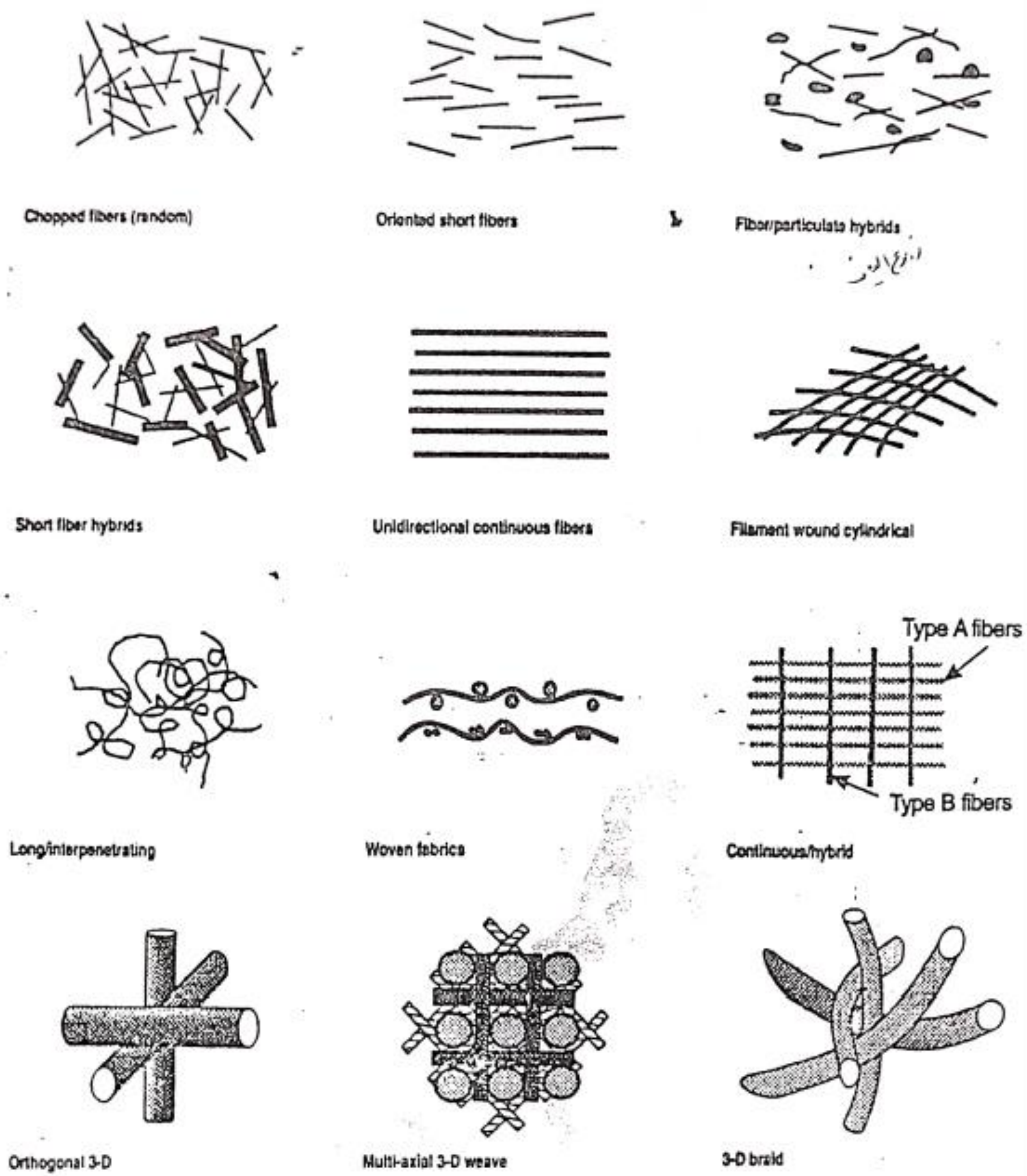


Fig. 1 Examples of reinforcement styles, combinations, orientations, and configurations (composite types)

Example 17-1 *TD-Nickel Composite*

Suppose 2 wt% ThO_2 is added to nickel. Each ThO_2 particle has a diameter of 1000 Å. How many particles are present in each cubic centimeter?

SOLUTION

The densities of ThO_2 and nickel are 9.69 and 8.9 g/cm^3, respectively. The volume fraction is

$$f_{ThO_2} = \frac{\frac{2}{9.69}}{\frac{2}{9.69} + \frac{98}{8.9}} = 0.0184$$

Therefore, there is 0.0184 cm^3 of ThO_2 per cm^3 of composite. The volume of each ThO_2 sphere is

$$V_{ThO_2} = \tfrac{4}{3}\pi r^3 = \tfrac{4}{3}\pi(0.5 \times 10^{-5} \text{ cm})^3 = 0.524 \times 10^{-15} \text{ cm}^3$$

$$\text{Concentration of ThO}_2 \text{ particles} = \frac{0.0184}{0.524 \times 10^{-15}} = 35.1 \times 10^{12} \text{ particles/cm}^3$$

an accurately predict these properties. The density of a particulate composite, for xample, is

$$\rho_c = \sum (f_i \rho_i) = f_1\rho_1 + f_2\rho_2 + \cdots + f_n\rho_n \quad (17\text{-}1)$$

vhere ρ_c is the density of the composite, $\rho_1, \rho_2, \ldots, \rho_n$ are the densities of each constituent n the composite, and $f_1, f_2, \ldots, f_n$ are the volume fractions of each constituent. Note that he connectivity of different phases (i.e., how the dispersed phase is arranged with respect o the continuous phase) is also very important for many properties.

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Example 17-2 *Cemented Carbides*

A cemented carbide cutting tool used for machining contains 75 wt% WC, 15 wt% TiC, 5 wt% TaC, and 5 wt% Co. Estimate the density of the composite.

SOLUTION

First, we must convert the weight percentages to volume fractions. The densities of the components of the composite are

$$\rho_{WC} = 15.77 \text{ g/cm}^3 \qquad \rho_{TiC} = 4.94 \text{ g/cm}^3$$
$$\rho_{TaC} = 14.5 \text{ g/cm}^3 \qquad \rho_{Co} = 8.83 \text{ g/cm}^3$$

$$f_{WC} = \frac{75/15.77}{75/15.77 + 15/4.94 + 5/14.5 + 5/8.83} = \frac{4.76}{8.70} = 0.546$$

$$f_{TiC} = \frac{15/4.94}{8.70} = 0.349$$

$$f_{TaC} = \frac{5/14.5}{8.70} = 0.040$$

$$f_{Co} = \frac{5/8.90}{8.70} = 0.065$$

From the rule of mixtures, the density of the composite is

$$\rho_c = \sum(f_i\rho_i) = (0.546)(15.77) + (0.349)(4.94) + (0.040)(14.5) + (0.065)(8.83) = 11.5 \text{ g/cm}^3$$

Electrical Contacts Materials used for electrical contacts in switches and relays must have a good combination of wear resistance and electrical conductivity. Otherwise, the contacts erode, causing poor contact and arcing. Tungsten-reinforced silver provides this combination of characteristics. A tungsten powder compact is made using conventional powder metallurgy processes (Figure 17-5) to produce high interconnected

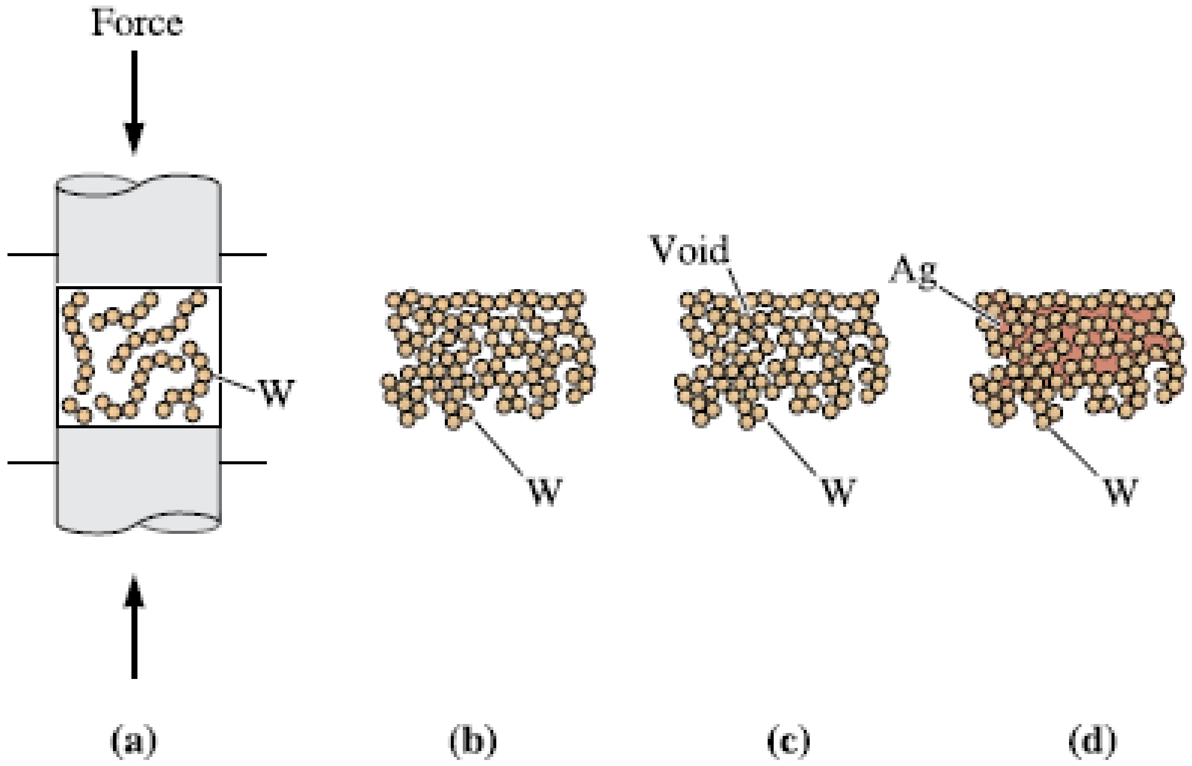

Figure 17-5 The steps in producing a silver-tungsten electrical composite: (a) Tungsten powders are pressed, (b) a low-density compact is produced, (c) sintering joins the tungsten powders, and (d) liquid silver is infiltrated into the pores between the particles.

Modulus of Elasticity The rule of mixtures is used to predict the modulus of elasticity when the fibers are continuous and unidirectional. Parallel to the fibers, the modulus of elasticity may be as high as

$$E_{c,\parallel} = f_m E_m + f_f E_f \quad (17\text{-}5)$$

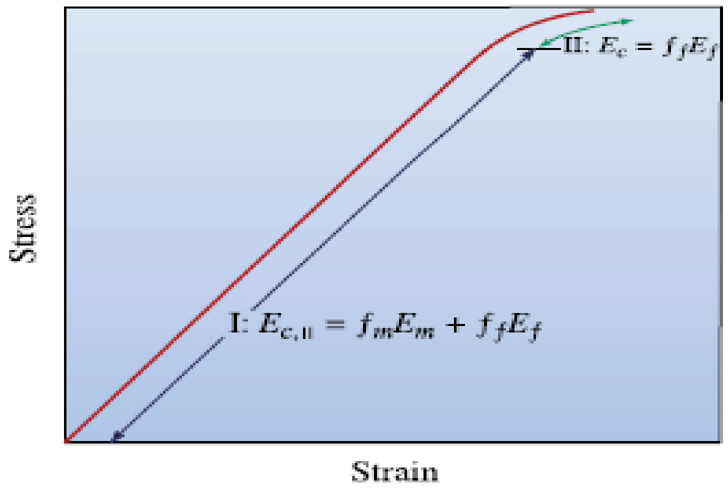

Figure 17-8 The stress-strain curve for a fiber-reinforced composite. At low stresses (region I), the modulus of elasticity is given by the rule of mixtures. At higher stresses (region II), the matrix deforms and the rule of mixtures is no longer obeyed.

When the applied stress is very large, the matrix begins to deform and the stress-strain curve is no longer linear (Figure 17-8). Since the matrix now contributes little to the stiffness of the composite, the modulus can be approximated by

$$E_{c,\|} = f_f E_f \tag{17-6}$$

When the load is applied perpendicular to the fibers, each component of the composite acts independently of the other. The modulus of the composite is now

$$\frac{1}{E_{c,\perp}} = \frac{f_m}{E_m} + \frac{f_f}{E_f} \tag{17-7}$$

Again, if the fibers are not continuous and unidirectional, the rule of mixtures does not apply.

The following examples further illustrate these concepts.

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Example 17-5 ***Rule of Mixtures for Composites: Stress Parallel to Fibers***

Derive the rule of mixtures (Equation 17-5) for the modulus of elasticity of a fiber-reinforced composite when a stress (σ) is applied along the axis of the fibers.

SOLUTION

The total force acting on the composite is the sum of the forces carried by each constituent:

$$F_c = F_m + F_f$$

Since $F = \sigma A$

$$\sigma_c A_c = \sigma_m A_m + \sigma_f A_f$$

$$\sigma_c = \sigma_m\left(\frac{A_m}{A_c}\right) + \sigma_f\left(\frac{A_f}{A_c}\right)$$

If the fibers have a uniform cross-section, the area fraction equals the volume fraction f:

$$\sigma_c = \sigma_m f_m + \sigma_f f_f$$

From Hooke's law, $\sigma = \varepsilon E$. Therefore,

$$E_{c,\|}\varepsilon_c = E_m\varepsilon_m f_m + E_f\varepsilon_f f_f$$

If the fibers are rigidly bonded to the matrix, both the fibers and the matrix must stretch equal amounts (iso-strain conditions):

$$\varepsilon_c = \varepsilon_m = \varepsilon_f$$

$$E_{c,\|} = f_m E_m + f_f E_f$$

Example 17-6 *Modulus of Elasticity for Composites: Stress Perpendicular to Fibers*

Derive the equation for the modulus of elasticity of a fiber-reinforced composite when a stress is applied perpendicular to the axis of the fiber (Equation 17-7).

SOLUTION

In this example, the strains are no longer equal; instead, the weighted sum of the strains in each component equals the total strain in the composite, whereas the stresses in each component are equal (iso-stress conditions):

$$\varepsilon_c = f_m \varepsilon_m + f_f \varepsilon_f$$

$$\frac{\sigma_c}{E_c} = f_m\left(\frac{\sigma_m}{E_m}\right) + f_f\left(\frac{\sigma_f}{E_f}\right)$$

Since $\sigma_c = \sigma_m = \sigma_f$,

$$\frac{1}{E_{c,\perp}} = \frac{f_m}{E_m} + \frac{f_f}{E_f}$$

Whiskers are single crystals with aspect ratios of 20 to 1000. Because the whiskers contain no mobile dislocations, slip cannot occur, and they have exceptionally high strengths. Because of the complex processing required to produce whiskers, their cost may be quite high.