Question 1

An uncold-worked brass specimen of average grain size 0.01 mm has a yield strength of 150 MPa. Estimate the yield strength of this alloy after it has been heated to 500˚C for 1000 s, if it is known that the value of σ_o is 25 MPa .

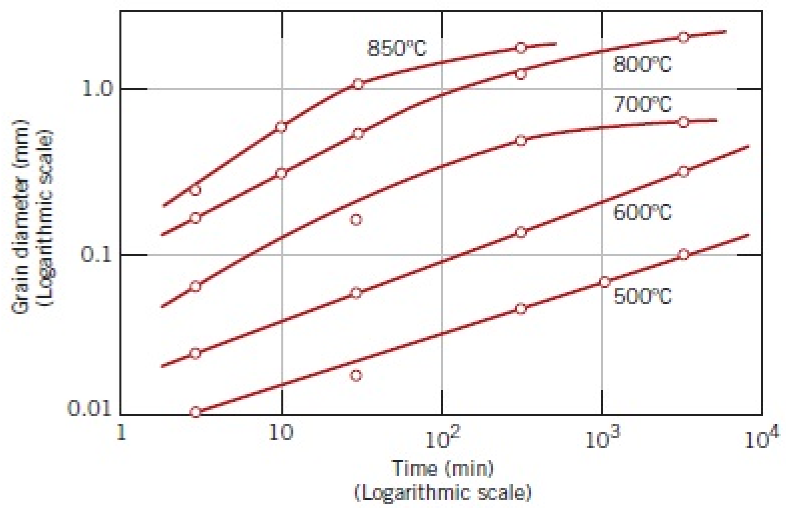
Solutions

It is first necessary to calculate the constant σ0 :

$$\frac{\sigma_y - \sigma_0}{d^{-1/2}} = k$$

$$K = (150\ MPa - 25\text{MPa}) \times (0.01)^{\frac{1}{2}} = 12.5\ MPa - mm^{1/2}$$

Next, we must determine the average grain size after the heat treatment. From the blow figure at 500°C after 1000 s the average grain size of a brass material is about 0.08 mm. Therefore, calculating σy at this new grain size using Equation 7.7 we get

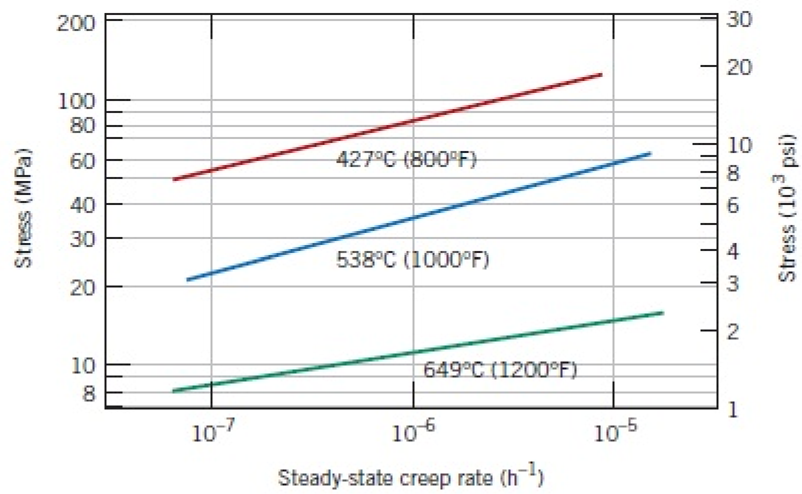


$$\sigma_y = \sigma_0 + kd^{-1/2}$$

$$\sigma_y = 25\ MPa + 12.5 \times (0.08)^{-\frac{1}{2}} = 69.1\ MPa$$

Question 2:

For a cylindrical low carbon–nickel alloy specimen (below figure) originally 19 mm in diameter and 635mm long, what tensile load is necessary to produce a total elongation of 6.44 mm after 5000 h, at 538˚C? Assume that the sum of instantaneous and primary creep elongations is 1.8 mm.



Solution

The steady state elongation, Δls, is just the difference between the total elongation and the sum of the instantaneous and primary creep elongations; that is,

$$\Delta l_s = 6.44 - 1.8 = 4.64\ mm$$

The steady state creep rate, $\dot{\varepsilon}$ is :

$$\dot{\varepsilon} = \frac{\Delta \varepsilon}{\Delta t} = \frac{\frac{\Delta l_s}{l_0}}{\Delta t} = \frac{\frac{4.64mm}{635mm}}{5000\ h} = 1.46 \times 10^{-6}$$

Employing the 538°C line in given figure, a steady state creep rate of 1.46 × 10-6 h-1 corresponds to a stress σ of about 38 MPa. Therefore the tensile load is:

$$F = \sigma A_0 = \frac{\sigma \pi d^2}{4} = \frac{(38 \times 10^6 N/m) \times 3.14 \times (19 \times 10^{-3}\ m)^2}{4} \approx 10000\ N$$

Question 3:

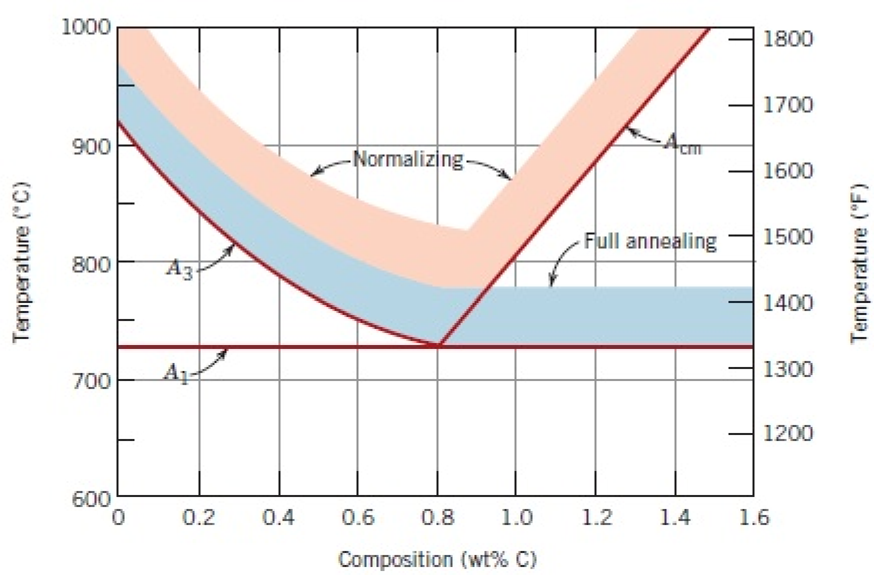
In your own words describe the following heat treatment procedures for steels and, for each, the intended final microstructure: full annealing, normalizing, quenching, and tempering.

Solution

Full annealing--Heat to about 50°C above the A_3 line, Figure 11.10 (if the concentration of carbon is less than the eutectoid) or above the A1 line (if the concentration of carbon is greater than the eutectoid) until the alloy comes to equilibrium; then furnace cool to room temperature. The final microstructure is coarse pearlite.

Normalizing--Heat to at least 55°C above the A_3 line Figure 11.10 (below figure) (if the concentration of carbon is less than the eutectoid) or above the A_{cm} line (if the concentration of carbon is greater than the eutectoid) until the alloy completely transforms to austenite, then cool in air. The final microstructure is fine pearlite.

Quenching--Heat to a temperature within the austenite phase region and allow the specimen to fully austenitize, then quench to room temperature in oil or water. The final microstructure is martensite. **Tempering**--Heat a quenched (martensitic) specimen, to a temperature between 450 and 650°C, for the time necessary to achieve the desired hardness. The final microstructure is tempered martensite.



Question 4:

For the following pairs of alloys that are coupled in seawater, predict the possibility of corrosion; if corrosion is probable, note which metal/alloy will corrode.

(a) Aluminum and magnesium

(b) Zinc and a low-carbon steel

(c) Brass (60Cu–40Zn) and Monel (70Ni–30Cu)

(d) Titanium and 304 stainless steel

(e) Cast iron and 316 stainless steel

Solution

This problem asks, for several pairs of alloys that are immersed in seawater, to predict whether or not corrosion is possible, and if it is possible, to note which alloy will corrode. In order to make these predictions it is necessary to use the galvanic series, Table 17.2 (given table). If both of the alloys in the pair reside within the same set of brackets in this table, then galvanic corrosion is unlikely. However, if the two alloys do not lie within the same set of brackets, then that alloy appearing lower in the table will experience corrosion.

(a) For the aluminum-magnesium couple, corrosion is possible, and magnesium will corrode.

(b) For the zinc-low carbon steel couple, corrosion is possible, and zinc will corrode.

(c) For the brass-monel couple, corrosion is unlikely inasmuch as both alloys appear within the same set of brackets.

(d) For the titanium-304 stainless steel pair, the stainless steel will corrode, inasmuch as it is below titanium in both its active and passive states.

(e) For the cast iron-316 stainless steel couple, the cast iron will corrode since it is below stainless steel in both active and passive states.

Table 17.2 The Galvanic Series

	Platinum
	Gold
	Graphite
	Titanium
	Silver
	[316 Stainless steel (passive)
	304 Stainless steel (passive)]
↑	[Inconel (80Ni–13Cr–7Fe) (passive)
	Nickel (passive)]
	[Monel (70Ni–30Cu)
Increasingly inert (cathodic)	Copper–nickel alloys
	Bronzes (Cu–Sn alloys)
	Copper
	Brasses (Cu–Zn alloys)]
	[Inconel (active)
	Nickel (active)]
	Tin
	Lead
Increasingly active (anodic)	[316 Stainless steel (active)
	304 Stainless steel (active)]
↓	[Cast iron
	Iron and steel]
	Aluminum alloys
	Cadmium
	Commercially pure aluminum
	Zinc
	Magnesium and magnesium alloys

Question 5:

A large-particle composite consisting of tungsten particles within a copper matrix is to be prepared. If the volume fractions of tungsten and copper are 0.70 and 0.30, respectively, estimate the upper limit for the specific stiffness of this composite given the data that follow.

	Specific Gravity	Modulus of Elasticity (GPa)
Copper	8.9	110
Tungsten	19.3	407

Solution

Using Expression of the form of Eq. 16.1 for both given Specific gravity and Modulus of Elasticity. Thus for upper specific stiffness, we have:

$$E_c(u) = E_m V_m + E_p V_p = 110\ GPa \times 0.3 + 407\ GPa \times 0.7 = 317.9\ GPa$$

And for specific gravity:

$$\rho_c = \rho_{Cu} V_{Cu} + \rho_W V_W = 8.9 \times 0.4 + 19.3 \times 0.7 = 17.07$$

Therefore

$$Specific\ Stiffness = \frac{E_c}{\rho_c} = \frac{317.9}{17.07} = 18.62\ GPa$$