8.5 This problem asks us to determine whether or not the 4340 steel alloy specimen will fracture when exposed to a stress of 1030 MPa, given the values of K_{Ic}, Y, and the largest value of a in the material. This requires that we solve for σ_c from Equation 8.6. Thus

$$\sigma_c = \frac{K_{Ic}}{Y\sqrt{\pi a}} = \frac{54.8 \text{ MPa}\sqrt{\text{m}}}{(1.0)\sqrt{(\pi)\left(0.5 \text{ x } 10^{-3} \text{ m}\right)}} = 1380 \text{ MPa} \quad (199{,}500 \text{ psi})$$

Therefore, fracture will *not* occur because this specimen will tolerate a stress of 1380 MPa (199,500 psi) before fracture, which is greater than the applied stress of 1030 MPa (150,000 psi).

8.8 For this problem, we are given values of K_{Ic} $\left(82.4 \text{ MPa}\sqrt{\text{m}}\right)$, σ (345 MPa), and Y (1.0) for a large plate and are asked to determine the minimum length of a surface crack that will lead to fracture. All we need do is to solve for a_c using Equation 8.7; therefore

$$a_c = \frac{1}{\pi}\left(\frac{K_{Ic}}{Y\sigma}\right)^2 = \frac{1}{\pi}\left[\frac{82.4 \text{ MPa}\sqrt{\text{m}}}{(1.0)(345 \text{ MPa})}\right]^2 = 0.0182 \text{ m} = 18.2 \text{ mm} \quad (0.72 \text{ in.})$$

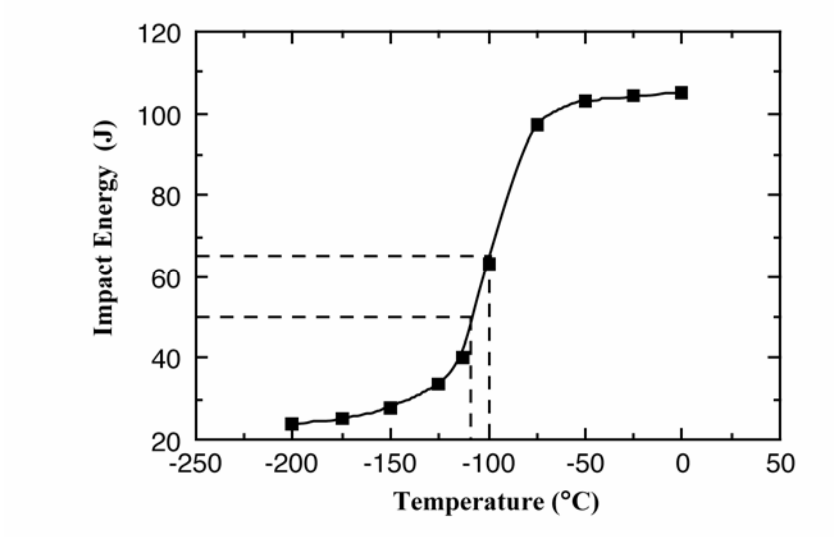
8.10 This problem asks that we determine whether or not a critical flaw in a wide plate is subject to detection given the limit of the flaw detection apparatus (3.0 mm), the value of K_{Ic} $(98.9 \text{ MPa}\sqrt{\text{m}})$, the design stress ($\sigma_y/2$ in which σ_y = 860 MPa), and Y = 1.0. We first need to compute the value of a_c using Equation 8.7; thus

$$a_c = \frac{1}{\pi}\left(\frac{K_{Ic}}{Y\sigma}\right)^2 = \frac{1}{\pi}\left[\frac{98.9 \text{ MPa}\sqrt{\text{m}}}{(1.0)\left(\frac{860 \text{ MPa}}{2}\right)}\right]^2 = 0.0168 \text{ m} = 16.8 \text{ mm} \quad (0.66 \text{ in.})$$

Therefore, the critical flaw is subject to detection since this value of a_c (16.8 mm) is greater than the 3.0 mm resolution limit.

Impact Fracture Testing

8.12 (a) The plot of impact energy versus temperature is shown below.



(b) The average of the maximum and minimum impact energies from the data is

$$\text{Average} = \frac{105 \text{ J} + 24 \text{ J}}{2} = 64.5 \text{ J}$$

As indicated on the plot by the one set of dashed lines, the ductile-to-brittle transition temperature according to this criterion is about –100°C.

(c) Also, as noted on the plot by the other set of dashed lines, the ductile-to-brittle transition temperature for an impact energy of 50 J is about –110°C.

8.15 This problem asks that we determine the minimum allowable bar diameter to ensure that fatigue failure will not occur for a 1045 steel that is subjected to cyclic loading for a load amplitude of 66,700 N (15,000 lb_f). From Figure 8.34, the fatigue limit stress amplitude for this alloy is 310 MPa (45,000 psi). Stress is defined in Equation 6.1 as $\sigma = \frac{F}{A_0}$. For a cylindrical bar

$$A_0 = \pi \left(\frac{d_0}{2}\right)^2$$

Substitution for A_0 into the Equation 6.1 leads to

$$\sigma = \frac{F}{A_0} = \frac{F}{\pi \left(\frac{d_0}{2}\right)^2} = \frac{4F}{\pi d_0^2}$$

We now solve for d_0, taking stress as the fatigue limit divided by the factor of safety. Thus

$$d_0 = \sqrt{\frac{4F}{\pi \left(\frac{\sigma}{N}\right)}}$$

$$= \sqrt{\frac{(4)(66{,}700 \text{ N})}{(\pi)\left(\frac{310 \times 10^6 \text{ N/m}^2}{2}\right)}} = 23.4 \times 10^{-3} \text{ m} = 23.4 \text{ mm} \quad (0.92 \text{ in.})$$

8.17 This problem asks that we compute the maximum and minimum loads to which a 15.2 mm (0.60 in.) diameter 2014-T6 aluminum alloy specimen may be subjected in order to yield a fatigue life of 1.0 x 10^8 cycles; Figure 8.34 is to be used assuming that data were taken for a mean stress of 35 MPa (5,000 psi). Upon consultation of Figure 8.34, a fatigue life of 1.0 x 10^8 cycles corresponds to a stress amplitude of 140 MPa (20,000 psi). Or, from Equation 8.16

$$\sigma_{max} - \sigma_{min} = 2\sigma_a = (2)(140 \text{ MPa}) = 280 \text{ MPa} \quad (40{,}000 \text{ psi})$$

Since σ_m = 35 MPa, then from Equation 8.14

$$\sigma_{max} + \sigma_{min} = 2\sigma_m = (2)(35 \text{ MPa}) = 70 \text{ MPa} \quad (10{,}000 \text{ psi})$$

Simultaneous solution of these two expressions for σ_{max} and σ_{min} yields

$$\sigma_{max} = +175 \text{ MPa} \quad (+25{,}000 \text{ psi})$$
$$\sigma_{min} = -105 \text{ MPa} \quad (-15{,}000 \text{ psi})$$

Now, inasmuch as $\sigma = \frac{F}{A_0}$ (Equation 6.1), and $A_0 = \pi\left(\frac{d_0}{2}\right)^2$ then

$$F_{max} = \frac{\sigma_{max}\pi d_0^2}{4} = \frac{(175 \text{ x } 10^6 \text{ N/m}^2)(\pi)(15.2 \text{ x } 10^{-3} \text{ m})^2}{4} = 31{,}750 \text{ N} \quad (7070 \text{ lb}_f)$$

$$F_{min} = \frac{\sigma_{min}\pi d_0^2}{4} = \frac{(-105 \text{ x } 10^6 \text{ N/m}^2)(\pi)(15.2 \text{ x } 10^{-3} \text{ m})^2}{4} = -19{,}000 \text{ N} \quad (-4240 \text{ lb}_f)$$

Generalized Creep Behavior

8.26 Creep becomes important at about $0.4T_m$, T_m being the absolute melting temperature of the metal. (The melting temperatures in degrees Celsius are found inside the front cover of the book.)

For Sn, $0.4T_m$ = (0.4)(232 + 273) = 202 K or -71°C (-96°F)
For Mo, $0.4T_m$ = (0.4)(2617 + 273) = 1156 K or 883°C (1621°F)
For Fe, $0.4T_m$ = (0.4)(1538 + 273) = 724 K or 451°C (845°F)
For Au, $0.4T_m$ = (0.4)(1064 + 273) = 535 K or 262°C (504°F)
For Zn, $0.4T_m$ = (0.4)(420 + 273) = 277 K or 4°C (39°F)
For Cr, $0.4T_m$ = (0.4)(1875 + 273) = 859 K or 586°C (1087°F)