

**MAE 20
Winter 2011
Assignment 6**

8.3 If the specific surface energy for soda-lime glass is 0.30 J/m^2 , using data contained in Table 12.5, compute the critical stress required for the propagation of a surface crack of length 0.05 mm .

Solution

We may determine the critical stress required for the propagation of an surface crack in soda-lime glass using Equation 8.3; taking the value of 69 GPa (Table 12.5) as the modulus of elasticity, we get

$$\sigma_c = \left[\frac{2E\gamma_s}{\pi a} \right]^{1/2}$$
$$= \left[\frac{(2)(69 \times 10^9 \text{ N/m}^2)(0.30 \text{ N/m})}{(\pi)(0.05 \times 10^{-3} \text{ m})} \right]^{1/2} = 16.2 \times 10^6 \text{ N/m}^2 = 16.2 \text{ MPa}$$

8.7 Suppose that a wing component on an aircraft is fabricated from an aluminum alloy that has a plane strain fracture toughness of $40 \text{ MPa}\sqrt{\text{m}}$ ($36.4 \text{ ksi}\sqrt{\text{in.}}$). It has been determined that fracture results at a stress of 365 MPa ($53,000 \text{ psi}$) when the maximum internal crack length is 2.5 mm (0.10 in.). For this same component and alloy, compute the stress level at which fracture will occur for a critical internal crack length of 4.0 mm (0.16 in.).

Solution

This problem asks us to determine the stress level at which an a wing component on an aircraft will fracture for a given fracture toughness ($40 \text{ MPa}\sqrt{\text{m}}$) and maximum internal crack length (4.0 mm), given that fracture occurs for the same component using the same alloy at one stress level (365 MPa) and another internal crack length (2.5 mm). It first becomes necessary to solve for the parameter Y for the conditions under which fracture occurred using Equation 8.5. Therefore,

$$Y = \frac{K_{Ic}}{\sigma\sqrt{\pi a}} = \frac{40 \text{ MPa}\sqrt{\text{m}}}{(365 \text{ MPa})\sqrt{(\pi)\left(\frac{2.5 \times 10^{-3} \text{ m}}{2}\right)}} = 1.75$$

Now we will solve for σ_c using Equation 8.6 as

$$\sigma_c = \frac{K_{Ic}}{Y\sqrt{\pi a}} = \frac{40 \text{ MPa}\sqrt{\text{m}}}{(1.75)\sqrt{(\pi)\left(\frac{4 \times 10^{-3} \text{ m}}{2}\right)}} = 288 \text{ MPa} \quad (41,500 \text{ psi})$$

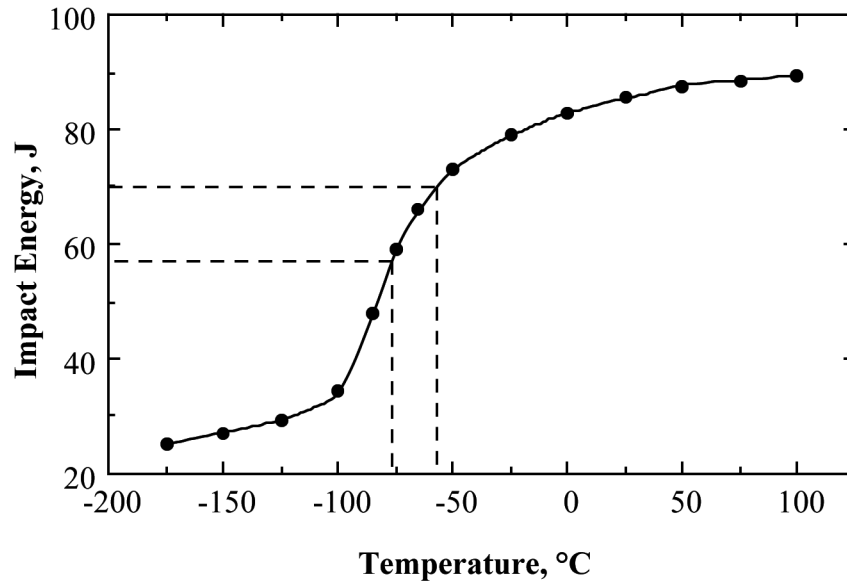
8.13 Following is tabulated data that were gathered from a series of Charpy impact tests on a tempered 4140 steel alloy.

Temperature (°C)	Impact Energy (J)
100	89.3
75	88.6
50	87.6
25	85.4
0	82.9
-25	78.9
-50	73.1
-65	66.0
-75	59.3
-85	47.9
-100	34.3
-125	29.3
-150	27.1
-175	25.0

- (a) Plot the data as impact energy versus temperature.
- (b) Determine a ductile-to-brittle transition temperature as that temperature corresponding to the average of the maximum and minimum impact energies.
- (c) Determine a ductile-to-brittle transition temperature as that temperature at which the impact energy is 70 J.

Solution

The plot of impact energy versus temperature is shown below.



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

$$\text{Average} = \frac{89.3 \text{ J} + 25 \text{ J}}{2} = 57.2 \text{ J}$$

As indicated on the plot by the one set of dashed lines, the ductile-to-brittle transition temperature according to this criterion is about -75°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 70 J is about -55°C .

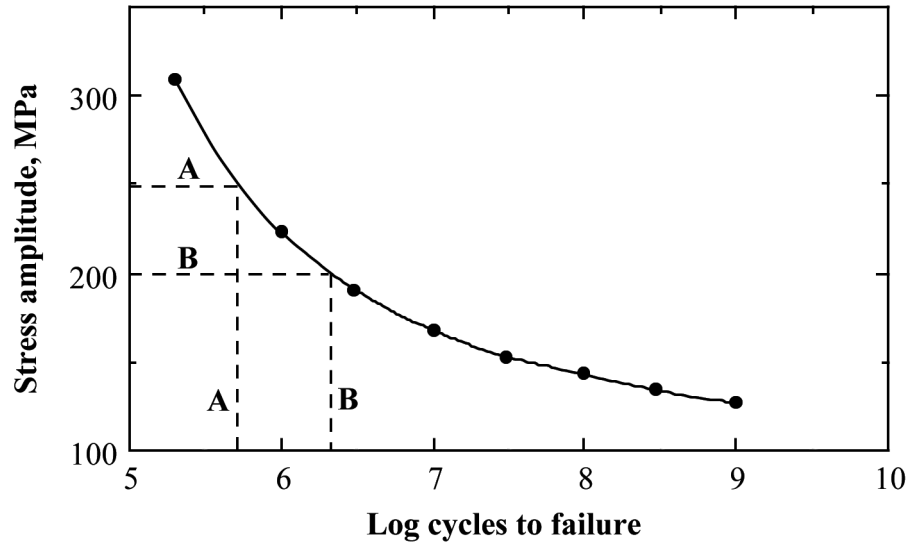
8.18 *The fatigue data for a brass alloy are given as follows:*

<i>Stress Amplitude (MPa)</i>	<i>Cycles to Failure</i>
310	2×10^5
223	1×10^6
191	3×10^6
168	1×10^7
153	3×10^7
143	1×10^8
134	3×10^8
127	1×10^9

- (a) Make an $S-N$ plot (stress amplitude versus logarithm cycles to failure) using these data.
 (b) Determine the fatigue strength at 5×10^5 cycles.
 (c) Determine the fatigue life for 200 MPa.

Solution

- (a) The fatigue data for this alloy are plotted below.



(b) As indicated by the “A” set of dashed lines on the plot, the fatigue strength at 5×10^5 cycles [$\log(5 \times 10^5) = 5.7$] is about 250 MPa.

(c) As noted by the “B” set of dashed lines, the fatigue life for 200 MPa is about 2×10^6 cycles (i.e., the log of the lifetime is about 6.3).

8.22 Three identical fatigue specimens (denoted A, B, and C) are fabricated from a nonferrous alloy. Each is subjected to one of the maximum-minimum stress cycles listed below; the frequency is the same for all three tests.

Specimen	σ_{\max} (MPa)	σ_{\min} (MPa)
A	+450	-350
B	+400	-300
C	+340	-340

- (a) Rank the fatigue lifetimes of these three specimens from the longest to the shortest.
 (b) Now justify this ranking using a schematic $S-N$ plot.

Solution

In order to solve this problem, it is necessary to compute both the mean stress and stress amplitude for each specimen. Since from Equation 8.14, mean stresses are the specimens are determined as follows:

$$\sigma_m = \frac{\sigma_{\max} + \sigma_{\min}}{2}$$

$$\sigma_m(\text{A}) = \frac{450 \text{ MPa} + (-350 \text{ MPa})}{2} = 50 \text{ MPa}$$

$$\sigma_m(\text{B}) = \frac{400 \text{ MPa} + (-300 \text{ MPa})}{2} = 50 \text{ MPa}$$

$$\sigma_m(\text{C}) = \frac{340 \text{ MPa} + (-340 \text{ MPa})}{2} = 0 \text{ MPa}$$

Furthermore, using Equation 8.16, stress amplitudes are computed as

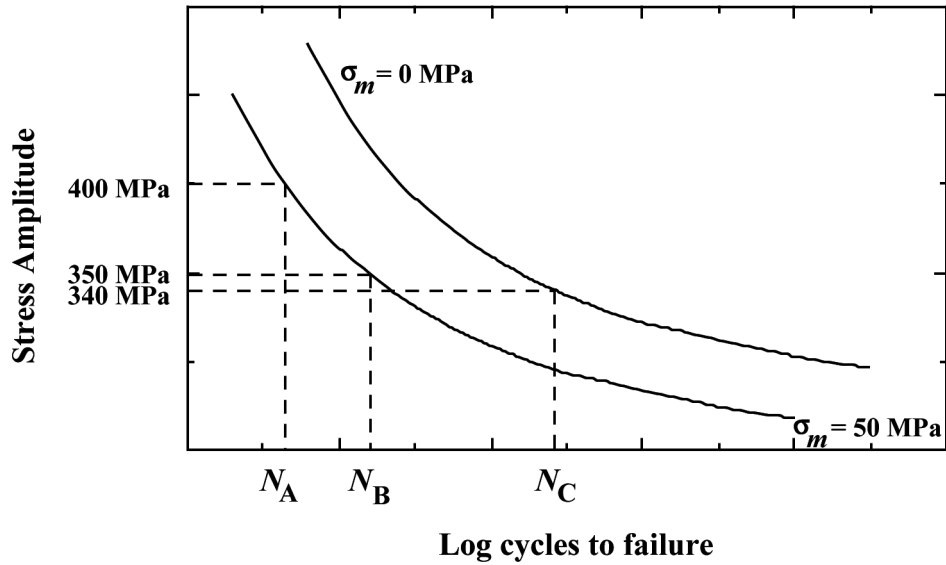
$$\sigma_a = \frac{\sigma_{\max} - \sigma_{\min}}{2}$$

$$\sigma_a(\text{A}) = \frac{450 \text{ MPa} - (-350 \text{ MPa})}{2} = 400 \text{ MPa}$$

$$\sigma_a(\text{B}) = \frac{400 \text{ MPa} - (-300 \text{ MPa})}{2} = 350 \text{ MPa}$$

$$\sigma_a(\text{C}) = \frac{340 \text{ MPa} - (-340 \text{ MPa})}{2} = 340 \text{ MPa}$$

On the basis of these results, the fatigue lifetime for specimen C will be greater than specimen B, which in turn will be greater than specimen A. This conclusion is based upon the following *S-N* plot on which curves are plotted for two σ_m values.

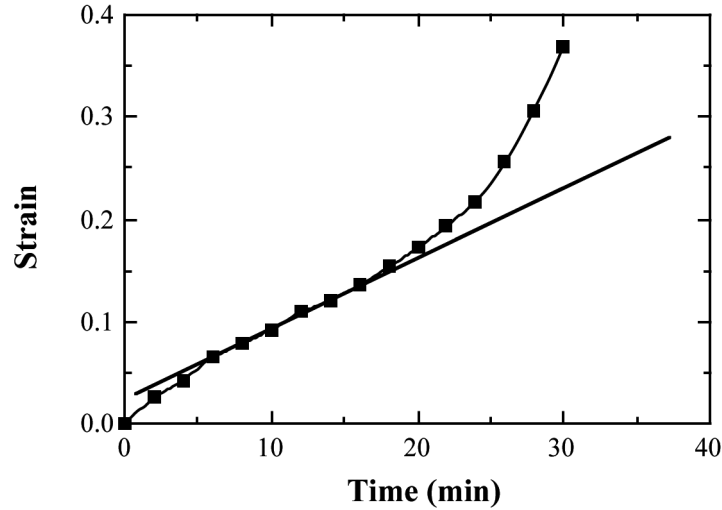


8.27 The following creep data were taken on an aluminum alloy at 400°C (750°F) and a constant stress of 25 MPa (3660 psi). Plot the data as strain versus time, then determine the steady-state or minimum creep rate. Note: The initial and instantaneous strain is not included.

<i>Time (min)</i>	<i>Strain</i>	<i>Time (min)</i>	<i>Strain</i>
0	0.000	16	0.135
2	0.025	18	0.153
4	0.043	20	0.172
6	0.065	22	0.193
8	0.078	24	0.218
10	0.092	26	0.255
12	0.109	28	0.307
14	0.120	30	0.368

Solution

These creep data are plotted below



The steady-state creep rate ($\Delta\epsilon/\Delta t$) is the slope of the linear region (i.e., the straight line that has been superimposed on the curve) as

8.34 *Steady-state creep rate data are given below for nickel at 1000°C (1273 K):*

$\dot{\epsilon}_s$ (s^{-1})	σ [MPa (psi)]
10^{-4}	15 (2175)
10^{-6}	4.5 (650)

If it is known that the activation energy for creep is 272,000 J/mol, compute the steady-state creep rate at a temperature of 850°C (1123 K) and a stress level of 25 MPa (3625 psi).

Solution

Taking natural logarithms of both sides of Equation 8.20 yields

$$\ln \dot{\epsilon}_s = \ln K_2 + n \ln \sigma - \frac{Q_c}{RT}$$

With the given data there are two unknowns in this equation--namely K_2 and n . Using the data provided in the problem statement we can set up two independent equations as follows:

$$\ln(1 \times 10^{-4} \text{ s}^{-1}) = \ln K_2 + n \ln(15 \text{ MPa}) - \frac{272,000 \text{ J/mol}}{(8.31 \text{ J/mol-K})(1273 \text{ K})}$$

$$\ln(1 \times 10^{-6} \text{ s}^{-1}) = \ln K_2 + n \ln(4.5 \text{ MPa}) - \frac{272,000 \text{ J/mol}}{(8.31 \text{ J/mol-K})(1273 \text{ K})}$$

Now, solving simultaneously for n and K_2 leads to $n = 3.825$ and $K_2 = 466 \text{ s}^{-1}$. Thus it is now possible to solve for $\dot{\epsilon}_s$ at 25 MPa and 1123 K using Equation 8.20 as

$$\begin{aligned} \dot{\epsilon}_s &= K_2 \sigma^n \exp\left(-\frac{Q_c}{RT}\right) \\ &= (466 \text{ s}^{-1})(25 \text{ MPa})^{3.825} \exp\left[-\frac{272,000 \text{ J/mol}}{(8.31 \text{ J/mol-K})(1123 \text{ K})}\right] \\ &= 2.28 \times 10^{-5} \text{ s}^{-1} \end{aligned}$$

8.D6 Consider an 18-8 Mo stainless steel component (Figure 8.35) that is exposed to a temperature of 500°C (773 K). What is the maximum allowable stress level for a rupture lifetime of 5 years? 20 years?

Solution

We are asked in this problem to calculate the stress levels at which the rupture lifetime will be 5 years and 20 years when an 18-8 Mo stainless steel component is subjected to a temperature of 500°C (773 K). It first becomes necessary to calculate the value of the Larson-Miller parameter for each time. The values of t_r corresponding to 5 and 20 years are $4.38 \times 10^4 \text{ h}$ and $1.75 \times 10^5 \text{ h}$, respectively. Hence, for a lifetime of 5 years

$$T(20 + \log t_r) = 773[20 + \log(4.38 \times 10^4)] = 19.05 \times 10^3$$

And for $t_r = 20$ years

$$T(20 + \log t_r) = 773[20 + \log(1.75 \times 10^5)] = 19.51 \times 10^3$$

Using the curve shown in Figure 8.35, the stress values corresponding to the five- and twenty-year lifetimes are approximately 260 MPa (37,500 psi) and 225 MPa (32,600 psi), respectively.