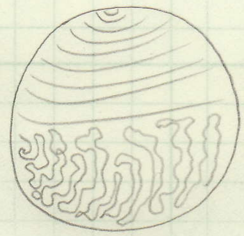
MAE 160 HW # 8 Solutions

19.1

Bicycle crank



typical fatigue fracture surface

ⓐ The fracture surface resembles the typical fatigue fracture surface due to cyclic loading
(initiation → Fatigue crack propagating → rupture)
Clam shell marks

ⓑ see figure above on the left

ⓒ rupture part

ⓓ at the bottom of the thread

ⓔ moderate

20.1

$$\dot{\epsilon} = A\sigma^5 e^{-Q/RT}$$

$$\ln\dot{\epsilon} = \ln\left(A\sigma^5 e^{-Q/RT}\right)$$

$$\ln\dot{\epsilon} = \ln(A\sigma^5) + \ln\left(e^{-Q/RT}\right)$$

$$\ln\dot{\epsilon} = \ln(A\sigma^5) - \frac{Q}{RT}\ln e$$

$$\ln\dot{\epsilon} = \underbrace{\ln(A\sigma^5)}_{\substack{\text{intercept} \\ y_0}} + \underbrace{\left(\frac{-Q}{R}\right)}_{\substack{\text{slope} \\ m}}\frac{1}{T}$$

$$\sigma = \frac{Pr}{t} = \frac{(6\,MNm^{-2})\left(\frac{40\times10^{-3}}{2}\right)}{2\times10^{-3}}$$

$$\sigma = 60\ MNm^{-2}$$

Plot: $\ln\dot{\epsilon}$ vs. $1/T$

look at data sheet & graph

$$\ln\dot{\epsilon} = \underbrace{16.991}_{y_0} - \underbrace{29597}_{\text{slope}}\left(1/T\right)$$

$$\ln(A\sigma^5) = 16.991 \Rightarrow A\sigma^5 = e^{16.991} \Rightarrow A = 7.5\times10^{-35}$$

$$Q/R = 29597$$

$$\dot{\epsilon} = A\sigma^5 e^{-Q/RT}$$

@ 510°C $\dot{\epsilon} = 7.5\times10^{-35}\,(200\times10^{6})^5\, e^{-29597\left(1/(510+273)\right)}$

$$= 2.23\times10^{-12}\ s^{-1}$$

$$\epsilon = \dot{\epsilon}\times t$$

$$t = 9\ \text{years} = 2.8\times10^{8}\ s$$

$$\epsilon = 2.23\times10^{-12}\times 2.8\times10^{8}$$

$\epsilon = 0.00057 < 0.01 \Rightarrow$ design safe.

20.2

$$\dot{\varepsilon} = A\sigma^5 e^{-Q/RT}$$

$\sigma_1 = 25 \text{ MN m}^{-2}$

$T_1 = 620 + 273 = 893 \text{ K}$

$\dot{\varepsilon}_1 = 3.1 \times 10^{-12} \text{ s}^{-1}$

$\sigma_2 = 30 \text{ MN m}^{-2}$

$T_2 = 650 + 273 = 923 \text{ K}$

$Q = 160 \times 10^3 \text{ J/mol}$

$$\dot{\varepsilon}_1 = A\sigma^5 e^{-Q/RT_1}$$

$$A = \frac{\dot{\varepsilon}_1}{\sigma^5 e^{-Q/RT_1}} = \frac{3.1 \times 10^{-12}}{(25 \times 10^6)^5 e^{-160 \times 10^3 / 8.31 \times 893}}$$

$$A = 7.34 \times 10^{-40}$$

$$\dot{\varepsilon}_2 = (7.34 \times 10^{-40})(30 \times 10^6)^5 e^{\frac{-160 \times 10^3}{8.31 \times (650 + 273)}}$$

$$\dot{\varepsilon}_2 = 1.55 \times 10^{-11} \text{ s}^{-1}$$

$$\varepsilon_{Ave} = 0.30 [1.55 \times 10^{-11}] + 0.70 [3.1 \times 10^{-12}]$$

$$= 6.8 \times 10^{-12} \text{ s}^{-1}$$

20.6

Although steel will not melt, creep might be a problem. when the temp. is too high. (above melting temp)