Q1

Given Data

$T = 200°C$

$N = 500{,}000$ cycles

$R = 90\%$

$f = 0.9$

$r = 0.06''$

$d = 0.6''$

$D = 0.72''$

Material Properties

From table A-20:

$S_{ut} = 64$ Kpsi
$S_{yt} = 54$ Kpsi
} for AISI 1018 CD Steel

Solution

(a) $\frac{r}{d} = 0.1$, $\frac{D}{d} = \frac{0.72}{0.6} = 1.2$, $q = 0.73$ ↳ From Fig. 6-20

$K_t = 1.87$ from table A-15-14

$\Rightarrow K_f = 1 + q(K_t - 1) = 1 + 0.73(1.87 - 1)$ 1 mark

$\therefore K_f = 1.635$

Marin's factors → critical point is at groove

$\Rightarrow K_a = a S_{ut}^{b} = 2.7 \times (64)^{-0.265}$ from table 6-2

$K_a = 0.897$ (for CD steel)

$d_e = 0.37d = 0.37 \times 0.6 = 0.222$ → For non-rotating completely reversed bending

$\Rightarrow K_b = 0.879 d_e^{-0.107} = 0.879(0.222)^{-0.107}$

$\therefore K_b = 1.033$ for $0.11 < d_e < 2$ in.

$\Rightarrow K_c = 1.0$ for pure bending

2 marks

$\Rightarrow K_d = \frac{S_T}{S_{RT}} = 1.020$ from table 6-4.

$\Rightarrow K_e = 0.897$ from table 6-5

$\Rightarrow K_f = 1.0$, no any miscellaneous factor considered

$\Rightarrow S_e = K_a K_b K_c K_d K_e K_f S_e' \rightarrow$ Marin's equation

$$S_e = 0.897 \times 1.033 \times 1.0 \times 1.02 \times 0.897 \times 1.0 \times 0.5 \times 64$$

$$S_e = 27.13 \text{ kpsi}$$

2 marks

Hence, Constant a and b are given as:

$$a = \frac{(f S_{ut})^2}{S_e} = \frac{(0.9 \times 64)^2}{27.13} = 122.29 \text{ kpsi}$$

2 marks

$$b = -\frac{1}{3} \log\left(\frac{f S_{ut}}{S_e}\right) = -\frac{1}{3} \log\left(\frac{0.9 \times 64}{27.13}\right) = -0.109$$

$\Rightarrow \sigma_{rev} = S_f = a N^b \longrightarrow n = 1$

$$\sigma_{rev} = 122.29 (500{,}000)^{-0.109}$$

$$\sigma_{rev} = 29.26 \text{ kpsi}$$

2 marks

But $\sigma_{rev.} = K_f \dfrac{32M}{\pi d^3}$, $M = \pm F_y \cdot l = \pm 2.5 F_y$

$$\Rightarrow 29.26 = 1.635 \times \frac{32 \times 2.5 F_y}{\pi (0.6)^3}$$

2 marks

$\therefore F_y = 151.8 \text{ lbf} \rightarrow$ Maximum Completely reversed force

(b) $F_y = \pm 100\ lbf$, $M = \pm 100 \times 2.5 = 250\ lbf \cdot in$

2 marks

$$\sigma_{rev.} = K_f \times \frac{32M}{\pi d^3} = 1.635 \times \frac{32 \times 250}{\pi (0.6)^3}$$

$$\sigma_{rev.} = 19.275\ Kpsi$$

From (a), $S_e = 27.13\ Kpsi$

$$\Rightarrow n = \frac{S_e}{\sigma_{rev}} = \frac{27.13}{19.28} = 1.41$$

Factor of Safety for infinite life if $F_y = \pm 100\ lbf$

2 marks

Q2 Given Data

$W = 2.5''$
$t = 3/8''$
$r = 0.25''$
$n = 2$
$d = W - 2r = 2.0''$

Material properties

$S_{ut} = 68$ kpsi
$S_{yt} = 57$ kpsi
↓
- From table A-20
- For AISI 1020 CD Steel

Solution

$$\frac{W}{d} = \frac{2.5}{1.25} = 1.25$$

$$\frac{r}{d} = \frac{0.25}{1.25} = 0.125$$

2 marks

$\rightarrow K_t = 2.25$ from Figure A-15-3
$\rightarrow$ Critical point is at groove.

The notch sensitivity, q, is to be determined either from Fig. 6-20 or Eqs. (6-34) and (6-35). However, the $r = 0.25''$ is not covered by the graph. Therefore, we will use Eq. (6-35a):

$$\sqrt{a} = 0.246 - 3.08 \times 10^{-3} S_{ut} + 1.51 \times 10^{-5} S_{ut}^2 - 2.67 \times 10^{-8} S_{ut}^3$$

↳ For axial load

$$\Rightarrow a = 9.601 \times 10^{-3}$$

$$\Rightarrow q = \frac{1}{1 + \frac{\sqrt{a}}{\sqrt{r}}} = 0.836$$

2 marks

$$\Rightarrow K_f = 1 + q(K_t - 1) = 1 + 0.836(2.25-1) = 2.045$$

$$\Rightarrow \sigma_{rev.} = K_f \cdot \frac{F_a}{A} \quad \text{and} \quad n = \frac{S_e}{\sigma_{rev.}}$$ → For infinite life

$\Rightarrow$ Marin's factors

$\Rightarrow K_a = 2.70(68)^{-0.265} = 0.88$

$\Rightarrow K_b = 1$ (axial loading) 2 marks

$\Rightarrow K_c = 0.85$ (axial loading)

$K_d = 1$, assuming room temperature

$K_e = K_f = 1$, not specified

$\Rightarrow S_e = K_a \cdot K_b \cdot K_c \cdot K_d \cdot K_e \cdot K_f \cdot S_e' \Rightarrow S_e' = 0.5 S_{ut}$

$\Rightarrow S_e = 0.88 \times 0.85 \times 0.5 \times 68 = 25.4$ kpsi

2 marks

$\Rightarrow \sigma_{rev.} = \dfrac{S_e}{n} = \dfrac{25.4}{2} = 12.7$ kpsi

$\Rightarrow 12.7 = 2.045 \times \dfrac{F_a}{3/8 \times (2.0)}$

$\therefore F_a = 4.6567$ kips 2 marks