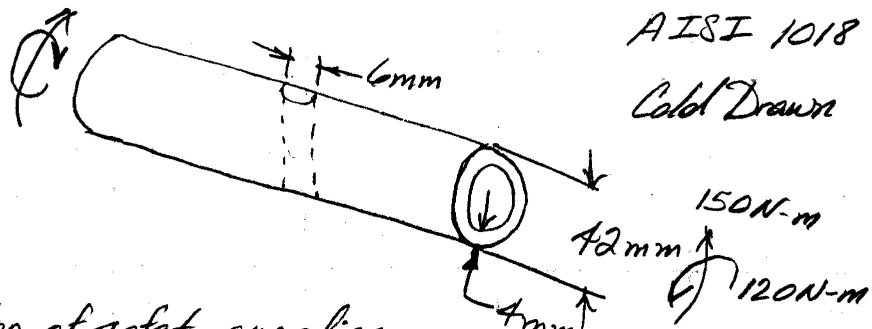
Given:



AISI 1018
Cold Drawn

Find: Factor of safety guarding against fatigue failure.

Solution:

Reference Table A-16 for bending stress concentration factor.

$$\frac{a}{D} = \frac{6}{42} = 0.142 \qquad \frac{d}{D} = \frac{34}{42} = 0.81$$

$$A \simeq 0.79 \quad K_t \simeq 2.39$$

$$Z_{net} = \frac{\pi A}{32D}(D^4 - d^4)$$

$$= \frac{\pi(0.79)}{32(0.042)}(0.042^4 - 0.034^4)$$

$$= 3.28 \times 10^{-6}\ m^3$$

$$\sigma_{ab} = \frac{M}{Z_{net}} = \frac{150\ N\text{-}m}{3.28 \times 10^{-6} m^3} = 45.8\ MPa$$

Reference TABLE A-16 for torsional stress concentration factor.

$$A = 0.89 \quad K_{ts} = 1.75$$

$$J_{net} = \frac{\pi A (D^4 - d^4)}{32} = \frac{\pi (0.89)(0.042^4 - 0.034^4)}{32}$$

$$= 1.55 \times 10^{-7}\, m^4$$

$$\tau_o = \frac{TD}{2 J_{net}} = \frac{(120\, N\text{-}m)(0.042\, m)}{2(1.55 \times 10^{-7}\, m^4)}$$

$$= 16.3\ MPa$$

From Figure 5-16, the notch sensitivity can be estimated to be $q = 0.8$.

$$\Rightarrow K_{fb} = 1 + q(K_t - 1)$$

$$= 1 + 0.8(2.39 - 1) = 2.1$$

$$K_{fs} = 1 + q(K_{ts} - 1) = 1.6$$

$$\Rightarrow \sigma_b = 45.8\, MPa(2.1) = 96.2\, MPa$$

$$\tau_s = 16.3\, MPa(1.6) = 26.1\, MPa$$

Compute principal stresses.

$$\sigma_1 = \frac{\sigma_{xx}+\sigma_{yy}}{2} + \sqrt{\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}\right)^2 + \tau_{xy}^2}$$

$$= \frac{96.2}{2} + \sqrt{\left(\frac{96.2}{2}\right)^2 + 26.1^2}$$

$$= 103.\ MPa$$

$$\sigma_2 = \frac{\sigma_{xx}+\sigma_{yy}}{2} - \sqrt{\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}\right)^2 + \tau_{xy}^2}$$

$$= \frac{96.2}{2} - \sqrt{\left(\frac{96.2}{2}\right)^2 + 26.1^2}$$

$$= -6.62\ MPa$$

Accounting for third axis and ordering in highest to lowest order yields

$$\sigma_1 = 103\ MPa,\ \sigma_2 = 0.,\ \sigma_3 = -6.62\ MPa$$

Compute von Mises stress

$$\sigma_{eff} = \sqrt{\frac{(\sigma_1-\sigma_2)^2 + (\sigma_2-\sigma_3)^2 + (\sigma_3-\sigma_1)^2}{2}}$$

$$= \sqrt{\frac{(103)^2 + (-6.62)^2 + (109.6)^2}{2}}$$

$$= \underline{\underline{106\ MPa}}$$

From TABLE A-20, $S_{ut} = 440\ MPa$

$$S_e' = 0.5\,S_{ut} = 220\ MPa$$

Compute Marin factors

$k_a = a\,S_{ut}^{\,b}$ from Table 7-4, $a = 2.70$ & $b = -0.265$

$$k_a = 2.70(440)^{-0.265} = 0.538$$

$$k_b = \left(\frac{D}{7.62}\right)^{-0.1133} = \left(\frac{42}{7.62}\right)^{-0.1133} = 0.824$$

$$k_c = k_d = 1.0$$

$$\Rightarrow S_e = (0.538)(0.824)(1.0)(1.0)\ 220\,MPa$$

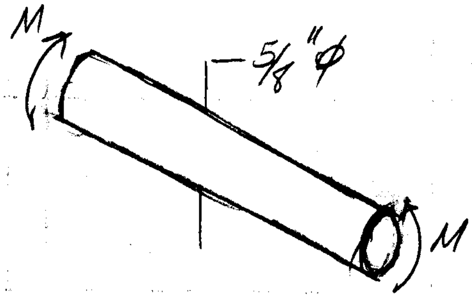
$$= 97.5\ MPa.$$

Since the endurance limit is less than the effective alternating stress, there is no safety factor for iinfinite life

$$\frac{106\ MPa}{97.5\ MPa} = \frac{1}{N_f}$$

$\Rightarrow N_f = 0.92.$ $\Rightarrow$ part will have less than infinite life, finite life estimate is required.

Given:



$M_1 = 1200 \text{ in-lb}, n_1 = 2{,}000$

$M_2 = 1000 \text{ in-lb}, n_2 = 100{,}000$

$M_3 = 900 \text{ in-lb}, n_3 = 10{,}000$

Find: Determine whether bar will fail due to fatigue.

Solution:

$$I = \frac{\pi}{64} D^4 = \frac{\pi}{64}(0.625)^4 = 7.49 \times 10^{-3} \text{ in}^4$$

$$c = \frac{0.625 \text{ in}}{2} = 0.3125 \text{ in}$$

$$\sigma_1 = \frac{M_1 c}{I} = \frac{(1200 \text{ in-lb})(0.3125)}{7.49 \times 10^{-3}} = \underline{\underline{50. \text{ ksi}}}$$

$$\sigma_2 = \frac{M_2 c}{I} = \left(\frac{1{,}000 \text{ in-lb}}{1{,}200 \text{ in-lb}}\right)(50 \text{ ksi}) = \underline{\underline{41.7 \text{ ksi}}}$$

$$\sigma_3 = \frac{M_3 c}{I} = \left(\frac{900 \text{ in-lb}}{1{,}200 \text{ in-lb}}\right)(50 \text{ ksi}) = \underline{\underline{37.5 \text{ ksi}}}$$

From Fig. 7-6, at σ_1, $N_1 = 57{,}000$ cycles

$S_{ult} = 116$ ksi

Use Eq. 7-7 $\Rightarrow$ at σ_2, $N_2 = 160{,}000$ cycles

to estimate cycles. at σ_3, $N_3 = 280{,}000$ cycles

Using Minor's rule,

$$\frac{2{,}000}{57{,}000} + \frac{100{,}000}{160{,}000} + \frac{10{,}000}{280{,}000} = \underline{\underline{0.70}}$$

$\Rightarrow$ Part will not fail.

Given: Same as problem #2 except an axial force of 5,000 lb is also acting on the bar.

Find: Determine whether bar will fail due to fatigue.

Solution:

$$\sigma_m = \frac{P}{A} \qquad Area = \frac{\pi}{4}D^2 = \frac{\pi}{4}(0.625\,in)^2$$

$$= 0.307\,in^2$$

$$\Rightarrow \sigma_m = \frac{5{,}000\,lb}{0.307\,in^2} = 16.3\,ksi$$

Find equivalent alternating stress for $\sigma_a = 50\,ksi$ & $\sigma_m = 16.3\,ksi$.

$$\frac{\sigma_a}{\sigma_{eqv,}} + \frac{\sigma_m}{S_{ult}} = 1$$

$$\Rightarrow \frac{\sigma_a}{\sigma_{eqv,}} = 1 - \frac{\sigma_m}{S_{ult}}$$

$$\Rightarrow \sigma_{eqv,} = \frac{\sigma_a}{1 - \frac{\sigma_m}{S_{ult}}}$$

$$\Rightarrow \sigma_{eqv,} = \frac{50\,ksi}{\left(1 - \frac{16.3\,ksi}{116\,ksi}\right)} = \underline{\underline{58.2\,ksi}}$$

10,000

Find equivalent alternating stress for

$\sigma_a = 41.7$ ksi, $\sigma_m = 16.3$ ksi

$$\sigma_{eq_2} = \frac{41.7}{\left(1 - \frac{16.3}{116}\right)} = 48.5 \text{ ksi}$$

Find equivalent alternating stress for

$\sigma_a = 37.5$ ksi, $\sigma_m = 16.3$ ksi

$$\sigma_{eq_3} = \frac{37.5 \text{ ksi}}{\left(1 - \frac{16.3}{116}\right)} = 43.6 \text{ ksi}$$

From Fig. 7-6, Sult = 116 ksi, Use eq. 7-7 to find cycles

at $\sigma_{eqv_1} = 58.2$ ksi, $N_1 = 3{,}000$ cycles

at $\sigma_{eqv_2} = 48.5$ ksi, $N_2 = 20{,}000$ cylces

at $\sigma_{eqv_3} = 43.6$ ksi, $N_3 = 90{,}000$ cycles

Using Minor's

$$\frac{2{,}000}{25{,}000} + \frac{100{,}000}{70{,}000} + \frac{10{,}000}{120{,}000} = 1.59$$

$\Rightarrow$ Part will fail due to fatigue