PROBLEM 6-17

Statement: **A pair of ice tongs is shown in Figure P6-7. The ice weighs 50 lb and is 10 in wide across the tongs. The distance between the handles is 4 in, and the mean radius r of the tong is 6 in. The rectangular cross-sectional dimensions are 0.75 x 0.312 in. Find the safety factor for the tongs for 5E5 cycles if their S_{ut} = 50 ksi.**

Units: $ksi := 10^3 \cdot psi$

Given: Tensile strength $S_{ut} := 50 \cdot ksi$

Cross-section

Width $w := 0.312 \cdot in$

Depth $h := 0.75 \cdot in$

Life $N_f := 5 \cdot 10^5$

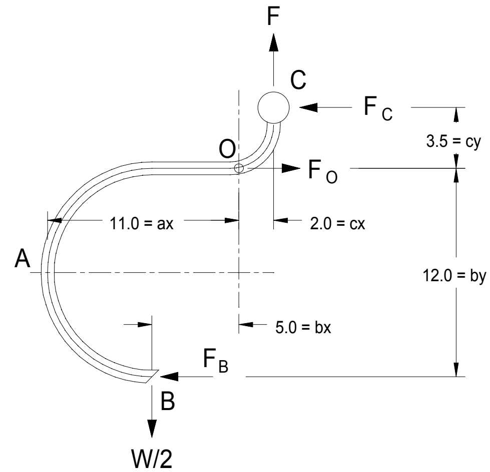

FIGURE 6-17
Free Body Diagram for Problem 6-17

Assumptions: The tongs are forged. Use 99.99% reliability. Operating temperature is between 32F and 70F.

Solution: See Problem 4-17, Figure 6-17, and Mathcad file P0617.

1. The maximum bending stress in the tong was found in Problem 4-17 at point A.

Vertical direction $\sigma_i := 8.58 \cdot ksi$

All other components are zero.

2. There are no other stress components present so

$\sigma_{1max} := \sigma_i$ $\sigma_{1max} = 8.58\,ksi$ $\sigma_{2max} := 0 \cdot ksi$ $\sigma_{3max} := 0 \cdot ksi$

3. The dynamic loading in this case is repeated, thus

$\sigma_{1min} := 0 \cdot ksi$ $\sigma_{2min} := 0 \cdot ksi$ $\sigma_{3min} := 0 \cdot ksi$

4. Even though this is a brittle material, for HCF analysis, determine the von Mises effective stresses. Since there is only one nonzero stress,

$\sigma'_{max} := \sigma_{1max}$ $\sigma'_{max} = 8.58\,ksi$

$\sigma'_{min} := \sigma_{1min}$ $\sigma'_{min} = 0\,ksi$

$\sigma'_a := \dfrac{\sigma'_{max} - \sigma'_{min}}{2}$ $\sigma'_a = 4.29\,ksi$

$\sigma'_m := \dfrac{\sigma'_{max} + \sigma'_{min}}{2}$ $\sigma'_m = 4.29\,ksi$

5. Calculate the unmodified endurance limit. $S'_e := 0.5 \cdot S_{ut}$ $S'_e = 25\,ksi$

6. Calculate the endurance limit modification factors for a nonrotating rectangular beam.

Load $C_{load} := 1$

Size $A_{95} := 0.05 \cdot w \cdot h$ $A_{95} = 7.548\,mm^2$

$d_{equiv} := \sqrt{\dfrac{A_{95}}{0.0766}}$ $d_{equiv} = 9.927\,mm$

$$C_{size} := 1.189 \cdot \left(\frac{d_{equiv}}{mm}\right)^{-0.097} \qquad C_{size} = 0.952$$

Surface $A := 39.9$ $b := -0.995$ (forged)

$$C_{surf} := A \cdot \left(\frac{S_{ut}}{ksi}\right)^{b} \qquad C_{surf} = 0.814$$

Temperature $C_{temp} := 1$

Reliability $C_{reliab} := 0.702$ (R = 99.99%)

7. Calculate the modified endurance limit.

$$S_e := C_{load} \cdot C_{size} \cdot C_{surf} \cdot C_{temp} \cdot C_{reliab} \cdot S'_e \qquad S_e = 13.59\,ksi$$

8. Using equation (6.9), calculate the fatigue strength at $N = 10^3$ cycles. $S_m := 0.9 \cdot S_{ut}$ $S_m = 45\,ksi$

9. The equation for the S-N curve in the HCF region is given by equation (6.10a): $S_f = a \cdot N^b$

10. Determine the constants a and b from equations (6.10c) and (6.10a). From Table 6-5, for $N = 10^6$, $z := -3.000$

$$b := \frac{1}{z} \cdot \log\left(\frac{S_m}{S_e}\right) \qquad b = -0.1733$$

$$a := \frac{S_m}{\left(10^3\right)^b} \qquad a = 148.991\,ksi$$

11. Using equation (6.10a), determine the fatigue strength. $S_{f5E5} := a \cdot N_f^{\,b}$ $S_{f5E5} = 15.326\,ksi$

12. Assuming a Case 3 load line, use equation (6.18e) to calculate the factor of safety.

$$N_{f5E5} := \frac{S_{f5E5} \cdot S_{ut}}{\sigma'_a \cdot S_{ut} + \sigma'_m \cdot S_{f5E5}} \qquad N_{f5E5} = 2.7$$