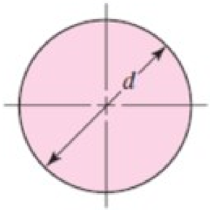
HW03 (Fall 2021)

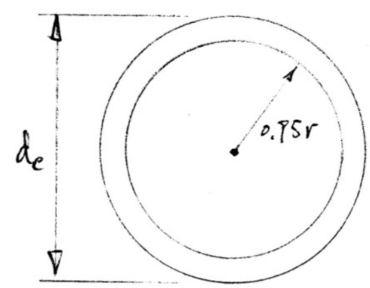
Question 01 (20 points)

Table 6-3 states that effective diameter d_e of a nonrotating bar is 0.370d. Use 95 critical stress area method to validate this effective diameter.

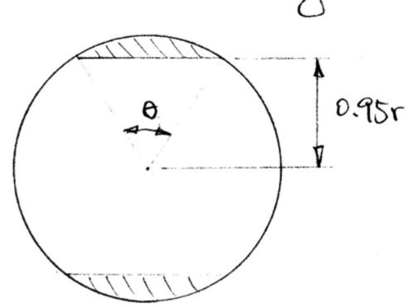


$$A_{0.95\sigma} = 0.01046d^2$$
$$d_e = 0.370d$$

Rotating



Non-Rotating



$$A_{.95\sigma} = \frac{\pi}{4}\left[d_e^2 - (0.95\,d_e)^2\right]$$
$$= 0.0766\, d_e^2$$
$$= \left(\frac{2\pi\theta}{360} - \sin\theta\right)\frac{d^2}{4}$$
$$= 0.01046\, d^2$$
$$d_e^2 = 0.1366\, d^2$$
$$d_e = 0.37\, d$$

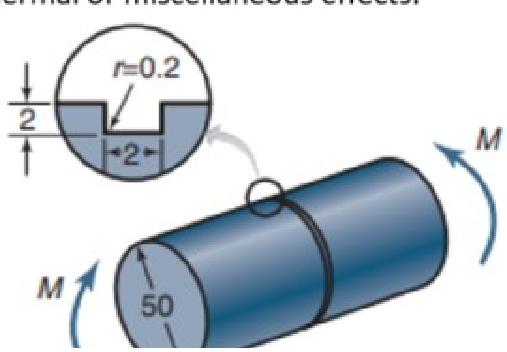
$$A_{.95\sigma} = 0.0766\, d_e^2$$

$$\theta = 2\cdot\cos^{-1}(0.95) = 0.635\,\text{rad}$$
$$\text{Shaded Area} = (\theta - \sin\theta)\, r^2$$
$$= \left(\frac{\theta\cdot 2\pi}{360} - \sin\theta\right) r^2 \qquad \theta = 36.39^\circ$$
$$= 0.0418\, r^2$$
$$= A_{0.95\sigma}$$

Question 02 (40 points)

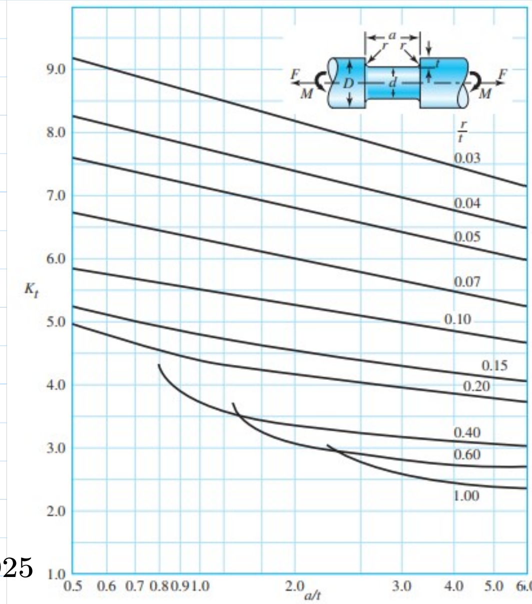
A rotating round shaft with a flat groove used to seat a retaining ring is shown in the figure below. AISI 1020 steel (quenched and tempered at 870◦C) is used for the shaft, which is machined to its final dimensions. Endurance limit of the AISI 1020 steel is 200 MPa and ultimate strength is 395 MPa.

a. Estimate the modified endurance limit for the shaft if the shaft is operating under room temperature.
b. Calculate the allowable bending moment using a safety factor of 5.0. Use a reliability of 99% and no thermal or miscellaneous effects.



Shaft Diameter $D := 50 \cdot mm$

From Table A-15-16



$r := 0.2 \cdot mm$ $\quad t := 2 \cdot mm$ $\quad a := 2 \cdot mm$

Shaft Diameter at Groove Root: $d := D - 2 \cdot t = 46\ mm$

AISI 1020 Steel $S_{ut} := 395 \cdot MPa$

$S_e := 200 \cdot MPa$

Correction Factors

Surface Condition $k_a := 4.51 \cdot \left(\dfrac{S_{ut}}{MPa}\right)^{-0.265} = 0.925$

Size Effect $d_e := d = 46\ mm$

$$k_b := \left(\frac{d_e}{7.62 \cdot mm}\right)^{-0.107} = 0.825$$

Load Effect $k_c := 1$

Temperature Effect $k_d := 1$

Reliability Effect $k_e := 0.814$

Corrected Endurance Strength $S_e := k_a \cdot k_b \cdot k_c \cdot k_d \cdot k_e \cdot S_e = 124.219\ MPa$

From Table A-15-16 $at := \dfrac{a}{t} = 1$ $\quad rt := \dfrac{r}{t} = 0.1$ $\quad K_t := 5.5$

Notch Sensitivity Factor $q := 0.45$ Table 6-20

Fatigue Stress Concentration: $K_f := 1 + q \cdot (K_t - 1) = 3.025$

Safety Factor $n_s := 5$

Nominal stress at the groove root is: $K_f \sigma_{\text{avg}} = K_f \left(\dfrac{32M}{\pi d^3}\right) = \dfrac{S_e}{n_s}.$

Allowable Bending Moment: $M := \dfrac{\pi \cdot S_e \cdot d^3}{32 \cdot K_f \cdot n_s} = 78.481\ (N \cdot m)$

Question 03 (40 points)

Calculate endurance limits and modification factors of a non-rotating rectangular cross section (width=40 mm, height=60mm. The beam is subjected to fully-reversed bending moment. As in Question 02, use AISI 1020 steel with a reliability of 99%, and no thermal or miscellaneous effects.

Cross-Section of Square Beam $b := 40 \cdot mm$ $h := 60 \cdot mm$

AISI 1020 Steel $S_{ut} := 395 \cdot MPa$ $S_e := 200 \cdot MPa$

Correction Factors

Surface Condition $k_a := 4.51 \cdot \left(\dfrac{S_{ut}}{MPa}\right)^{-0.265} = 0.925$

Size Effect $d_e := 0.808 \cdot \sqrt{b \cdot h} = 39.584\ mm$

$k_b := \left(\dfrac{d_e}{7.62 \cdot mm}\right)^{-0.107} = 0.838$

Load Effect $k_c := 1$

Temperature Effect $k_d := 1$

Reliability Effect $k_e := 0.814$

Corrected Endurance Strength $S_e := k_a \cdot k_b \cdot k_c \cdot k_d \cdot k_e \cdot S_e = 126.231\ MPa$