Christopher King

# Mechanical Design II Homework 03

Christopher King

2018141521058

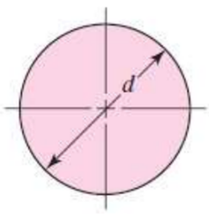
Mechanical Design 2

Class Section 01

09/15/2021

**Problem 1**

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.

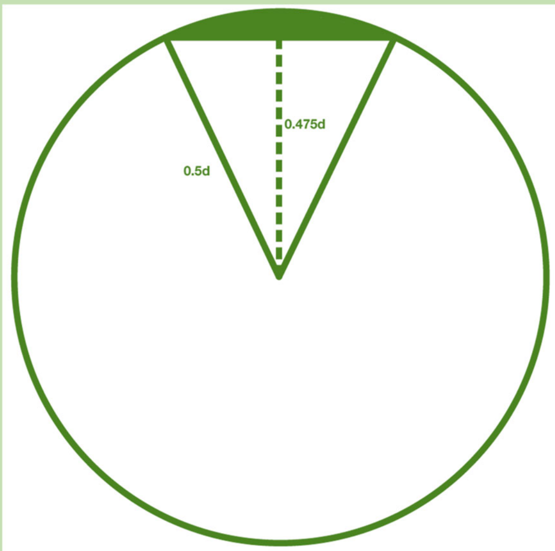



$$A_{0.95\sigma} = 0.01046d^2$$
$$d_e = 0.370d$$

**Solution:**

For this question, we are asked to use 95 critical stress area method to validate this effective diameter $d_e$ of a nonrotating bar.

The effective area is equal to the twice of the dark green area as shown in Figure below.




The area of the sector is equal to

$$A_s = \cos^{-1}\left(\frac{0.475d}{0.5d}\right) \times (0.5d)^2 = 0.07939d^2$$

The area of the triangle is equal to

$$A_t = \sqrt{(0.5d)^2 - (0.475d)^2} \times (0.475d) = 0.07416d^2$$

Therefore, the 95% effective area is equal to

$$A_{0.95\sigma} = 2A_s - 2A_t = 2 \times 0.07939d^2 - 2 \times 0.07416d^2 = 0.01046d^2$$

Hence, we can get the equation below:

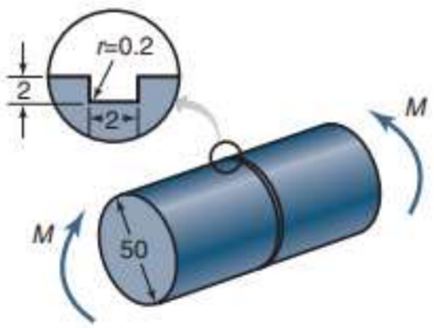
$$0.01046d^2 = \frac{\pi}{4}[d_e^2 - (0.95d_e)^2]$$

$$d_e = 0.370d$$

**Problem 2**

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.




**Solution:**

a. For this question, we are asked to estimate the modified endurance limit for the shaft if the shaft is operating under room temperature.
   Surface Condition (machined):
   $$k_a = 4.51 \times 395^{-0.265} = 0.9249$$
   Size Effect ($d = 50$ mm):
   $$k_b = \left(\frac{d}{7.62}\right)^{-0.107} = \left(\frac{50}{7.62}\right)^{-0.107} = 0.8177$$
   Loading Effect (bending):

$$k_c = 1$$

Temperature Effect (room temperature):

$$k_d = 1$$

Reliability Effect (99%):

$$k_e = 0.814$$

Therefore, the modified endurance limit is equal to

$$S_e = k_a k_b k_c k_d k_e S_e' = 0.9249 \times 0.8177 \times 1 \times 1 \times 0.814 \times 200 \text{ MPa}$$
$$= 123.12 \text{ MPa}$$

b. For this question, we are asked to calculate the allowable bending moment using a safety factor of 5.0. Use a reliability of 99% and no thermal or miscellaneous effects.

According to Figure A-15-16 ($\frac{a}{t} = 1$, $\frac{r}{t} = 0.1$), the stress concentration factors is equal to

$$K_t = 5.5$$

The original stress is equal to

$$\sigma_0 = \frac{32M}{\pi d^3}$$

$$\sqrt{a} = 0.246 - 3.08 \times 10^{-3} S_{ut} + 1.51 \times 10^{-5} S_{ut}^2 - 2.67 \times 10^{-8} S_{ut}^3$$
$$= 0.246 - 3.08 \times 10^{-3} \times 57.29 + 1.51 \times 10^{-5} \times 57.29^2$$
$$- 2.67 \times 10^{-8} \times 57.29^3 = 0.114$$
$$\Rightarrow a = 0.0130$$

The fatigue stress concentration is equal to

$$K_f = 1 + \frac{(K_t - 1)}{1 + \sqrt{\frac{a}{r}}} = 1 + \frac{(5.5 - 1)}{1 + \sqrt{\frac{0.0130}{0.2}}} = 4.585$$

Therefore,

$$FS \cdot K_f \sigma_0 \leq S_e$$

$$FS \cdot K_f \frac{32M}{\pi d^3} \leq S_e$$

$$M \leq \frac{\pi d^3 S_e}{32 FS \cdot K_f}$$

$$M \leq \frac{\pi \times (46 \text{ mm})^3 \times (123.12 \text{ MPa})}{32 \times 5.0 \times 4.585} = 51.32 \text{ N} \cdot \text{m}$$

**Problem 3**

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.

**Solution:**

For this question, we are asked to calculate endurance limits and modification factors of a non-rotating rectangular cross section (width=40 mm, height=60 mm. 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.

Surface Condition (machined):

$$k_a = 4.51 \times 395^{-0.265} = 0.9249$$

Size Effect ($b = 40$ mm, $h = 60$ mm):

$$d_e = 0.808\sqrt{hb} = 0.808\sqrt{(40 \text{ mm}) \times (60 \text{ mm})} = 39.58 \text{ mm}$$

$$k_b = \left(\frac{d_e}{7.62}\right)^{-0.107} = 0.8384$$

Loading Effect (bending):

$$k_c = 1$$

Temperature Effect (room temperature):

$$k_d = 1$$

Reliability Effect (99%):

$$k_e = 0.814$$

Therefore, the modified endurance limit is equal to

$$S_e = k_a k_b k_c k_d k_e S_e' = 0.9249 \times 0.8384 \times 1 \times 1 \times 0.814 \times 200 \text{ MPa} = 126.23 \text{ MPa}$$

Christopher King