IAT - 2 / Question paper with Solution key

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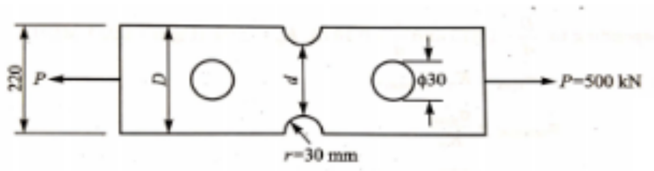
CMRIT

Internal Assessment Test 2 – Dec 2022

Sub:	Design of Machine Elements I				Sub Code:	18ME52	Branch:	Mech	
Date:	01.12.22	Duration:	90 min's	Max Marks: 50	Sem / Sec:	V		OBE	

Answer all the Questions

		MARKS	CO	RBT
1 a)	A bar of rectangular cross section is subjected to an axial pull of 500 KN. Calculate its thickness if the allowable tensile stress in the bar is 200 MPa.	[15]	CO2	L3



2a)	Derive the Soderberg's equation for fatigue loading.	[5]	CO3	L3
b)	A shaft of circular section is subjected to a turning moment that fluctuates between 800 kN-m and 600 kN-m and also bending moment that fluctuates between +500 kN-m and -300 kN-m. The material selected for the shaft has a stress value of 100 MPa at endurance limit and shear stress value of 120 MPa at the yield point. Determine the diameter of the solid circular shaft taking a value of 2.5 for the factor of safety. Surface factor, size factor and load factor can be taken as 0.9, 0.85 and 1.0 respectively. Shear stress concentration factor is 1.8 and the notch sensitivity is 0.95.	[20]		
3.	A cantilever beam of rectangular cross section has a span of 800 mm. The depth is 200 mm. The free end of the beam is subjected to a transverse load that fluctuates 80 kN upward to 50 kN downward. It is made of steel having σ_u = 550 MPa and σ_y= 400 MPa. Find the width of the section taking a factor of safety of 2.5. The size and surface factors are 0.8 and 0.85 respectively.	[10]	CO3	L3

Q.no: 1

Given:

Allowable tensile stress $\sigma_{max} = 200$ MPa

Solution:

At section A-A , there is a hole and at section B-B , there is a notch.

To find: Thickness of the plate , h

Consider Section A- A:

Axial Load: F = 500 kN = 500 x 10^3 N

Width of the plate w = 220 mm

Diameter of the hole, d or a = 30 mm

$$\therefore \frac{d}{w} = \frac{a}{w} = \frac{30}{220} = 0.1364$$

from Fig. 4.5 (DHB), for $\frac{d}{w} = 0.1364$

stress concentration factor, $K_\sigma = 2.65$

$$\sigma_{nom} = \frac{F}{(w-d)h}$$

$$\sigma_{nom} = \frac{500 \times 10^3}{(220-30)h} \text{ ————————> (1)}$$

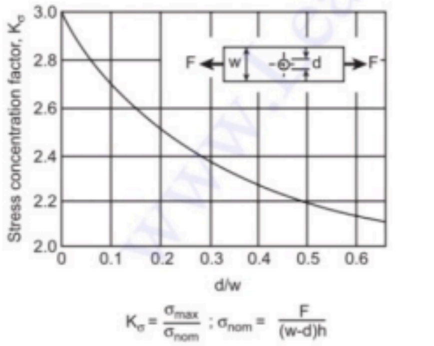


FIGURE 4-5 Reproduced with permission. Stress-concentration factor for a plate of finite width with a circular hole (cut-out) in tension. ("Design Factors for Stress Concentration," *Machine Design*, Vol. 23, Nos. 2 to 7, 1951.)

$$K_\sigma = \frac{\sigma_{max}}{\sigma_{nominal}} =>$$

$$2.65 = \frac{200}{\sigma_{nom}} =>$$

$$\sigma_{nom} = 75.472\ N/mm^2$$

From (1)

$$\frac{500 \times 10^3}{(220-30)h} = 75.472$$

$$h = 34.868 \text{ mm}$$

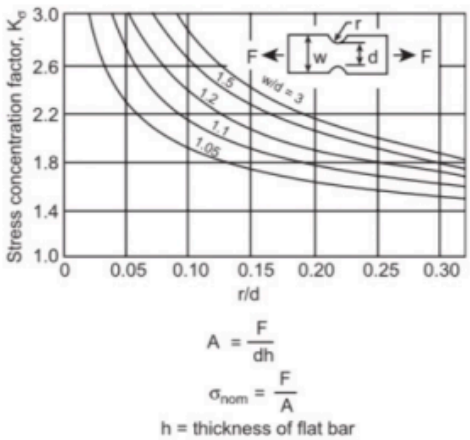


FIGURE 4-22 Reproduced with permission. Stress-concentr

Consider section B-B

r = 30 mm

d = w - 2r = 220-2(30) = 160 mm

$$\frac{r}{d} = \frac{30}{160} = 0.1875$$

$$\frac{D}{d} = \frac{220}{160} = 1.375$$

from Fig 4.22 (DDB)., corresponding to $\frac{r}{d} = 0.1875$ and $\frac{D}{d} = 1.375$,

$K_\sigma = 2.1$

Now, $K_\sigma = \frac{\sigma_{max}}{\sigma_{nom}} => 2.1 = \frac{200}{\sigma_{nom}} => \sigma_{nom} = 95.24\ N/mm^2$

Also,

$$\sigma_{nom} = \frac{F}{A} = \frac{F}{h.d}$$

$$95.24 = \frac{500 \times 10^3}{h \times 160}$$

$$h = \mathbf{32.81\ mm}$$

Thickness of the plate = 34.868 ≈ 35 mm (Choose the larger value)

Q.No: 2

$M_{tmax} = 800 \times 10^6$ N-mm

$M_{tmin} = 600 \times 10^6$ N-mm

$M_{bmax} = 500 \times 10^6$ N-mm

$M_{bmin} = -300 \times 10^6$ N-mm

$\tau_y = 120$ MPa

$\sigma_{-1} = 100$ N/mm²

$k_l = 1$

$k_{sz} = 0.85$

$k_{sr} = 0.8$

$$\tau_{max} = \frac{16 M_{tmax}}{\pi d^3}$$

$$= \frac{16 \times 800 \times 10^6}{3.14 d^3}$$

$$\tau_{max} = \frac{4076.43 \times 10^6}{d^3}\ N/mm^2$$

$$\tau_{min} = \frac{16 M_{tmin}}{\pi d^3}$$

$$= \frac{16 \times 600 \times 10^6}{3.14 d^3}$$

$$\tau_{min} = \frac{3057.32 \times 10^6}{d^3}\ N/mm^2$$

$$\sigma_{bmax} = \frac{32\, M_{bmax}}{\pi d^3}$$

$$= \frac{32 \times 500 \times 10^6}{3.14 d^3}$$

$$\sigma_{bmax} = \frac{5095.54 \times 10^6}{d^3} \quad N/mm^2$$

$$\sigma_{bmin} = \frac{32\, M_{bmin}}{\pi d^3}$$

$$= \frac{32 \times -300 \times 10^6}{3.14 d^3}$$

$$\sigma_{bmin} = \frac{-3057.32 \times 10^6}{d^3} \quad N/mm^2$$

$$\tau''_{max} = \frac{1}{2}\sqrt{\left(\frac{5095.54 \times 10^6}{d^3}\right)^2 + 4\left(\frac{4070.43 \times 10^6}{d^3}\right)^2}$$

$$= \frac{1}{2 d^3}\sqrt{(9614.24 \times 10^6)}$$

$$\tau''_{max} = \frac{4807.12 \times 10^6}{d^3}$$

$$\tau''_{min} = \frac{1}{2}\sqrt{\sigma_{min}^2 + 4\tau_{min}^2}$$

$$= \frac{1}{2}\sqrt{\left(\frac{-3057.32 \times 10^6}{d^3}\right)^2 + 4\left(\frac{3057.32 \times 10^6}{d^3}\right)^2}$$

$$\tau''_{min} = \frac{3418.18 \times 10^6}{d^3}$$

$$\tau_a'' = \frac{\tau_{max}'' - \tau_{min}''}{2}$$

$$= \frac{\left(\frac{4807.12 \times 10^6}{d^3}\right) - \left(\frac{3418.18 \times 10^6}{d^3}\right)}{2}$$

$$\tau_a'' = \frac{694.47 \times 10^6}{d^3}$$

$$\tau_m'' = \frac{\tau_{max}'' + \tau_{min}''}{2}$$

$$\tau_m'' = \frac{4112.65 \times 10^6}{d^3}$$

$$k_\tau = 1.8$$

$$q = 0.95$$

$$K_{-\tau a} = 1 + q(k_\tau - 1)$$

$$= 1 + 0.95(1.8 - 1)$$

$$K_{-\tau a} = 1.76$$

$$\tau_{-1d} = \frac{K_d K_{s2} K_{sr} \sigma_{-1}}{FOS}$$

$$= \frac{1 \times 0.85 \times 0.9 \times 100}{2.5}$$

$$\tau_{-1d} = 30.6\ N/mm^2$$

$$\tau_{yd} = \frac{\tau_y}{fos} = \frac{120}{2.5}$$

$$\tau_{yd} = 48 \text{ N/mm}^2$$

From soderbergs eqn,

$$k_{\tau a} \frac{\tau''_a}{\tau_{yd}} + \frac{\tau''_m}{\tau_{yd}} = 1$$

$$1.76 \times \left(\frac{694.47 \times 10^6}{30.6\, d^3 \times 48}\right) + \left(\frac{4112.63 \times 10^6}{d^3 \times 48}\right) = 1$$

d = 500 mm

3.

iven data: Cantilever of rectangular as cross section

$$l = 800 \text{ mm}$$

$$F_{max} = 80 \text{ kN} = 80 \times 10^3 \text{ N}$$

$$F_{min} = -50 \text{ kN} = -50 \times 10^3 \text{ N}$$

(–ve because of opposite direction)

$$\sigma_u = 550 \text{ MPa}, \quad \sigma_y = 400 \text{ MPa}$$

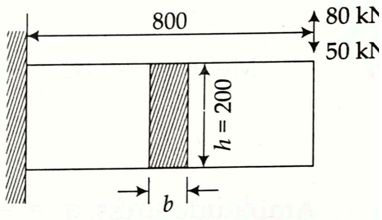


Fig. 4.7

Assume endurance stress, $\sigma_{-1} = \frac{1}{2}\sigma_u = \frac{1}{2} \times 550 = 275$ MPa

Factor of safety, FOS = 2.5

Size factor, $k_z = 0.8$

Surface factor, $k_s = 0.85$

For bending loads, load factor, $k_l = 1$

$$\therefore \quad \sigma_{ud} = \frac{\sigma_u}{FOS} = \frac{550}{2.5} = 220 \text{ MPa}$$

$$\sigma_{yd} = \frac{\sigma_y}{FOS} = \frac{400}{2.5} = 160 \text{ MPa}$$

For bending loads stress, $\sigma = \dfrac{M_b.C}{I}$

For rectangular c/s, $= C = \dfrac{d}{2} = \dfrac{200}{2} = 100$

$$I = \frac{bd^3}{12} = \frac{b(200)^3}{12} = 666666.\ 67(b)$$

$$\therefore \quad \sigma_{max} = \frac{M_{b\,max}\,C}{I} = \frac{64 \times 10^6 \times 100}{666666.67(b)} = \frac{9600}{b}$$

$$\sigma_{min} = \frac{M_{b\,min}\,C}{I} = \frac{-40 \times 10^6 \times 100}{666666.67(b)} = \frac{-6000}{b}$$

$$\therefore \quad \text{Mean stress, } \sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = \frac{\frac{9600}{b} + \left(\frac{-6000}{b}\right)}{2} = \frac{1800}{b}$$

$$\text{Amplitude stress, } \sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{\frac{9600}{b} - \left(\frac{-6000}{b}\right)}{2} = \frac{7800}{b}$$

From Goodman's relation

$$\frac{k_{\sigma a}\sigma_a}{\sigma_{-1d}} + \frac{\sigma_m}{\sigma_{ud}} = 1$$

$(k_{\sigma a} = k_\sigma = 1$ since not given)

$$\frac{1 \times 7800}{b \times 74.8} + \frac{1800}{b \times 220} = 1$$

$$b = 112.46 \simeq 113 \text{ mm}$$

From Soderberg's relation $\dfrac{k_\sigma \sigma_a}{\sigma_{-1d}} + \dfrac{\sigma_m}{\sigma_{yd}} = 1$

$$\frac{1 \times 7800}{b \times 74.8} + \frac{1800}{b \times 160} = 1$$

$$b = 115.53 \simeq 116 \text{ mm.}$$