USN

## Internal Assessment Test 1 – Nov 2021

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|---|---|---|---|---|---|---|---|---|
| Sub: | Design of Machine Elements I | | | | | Sub Code: | 18ME52 | Branch: Mech |
| Date: | 12.11.21 | Duration: | 90 min's | Max Marks: | 50 | Sem / Sec: | V/A&B | OBE |

**Answer all the Questions**

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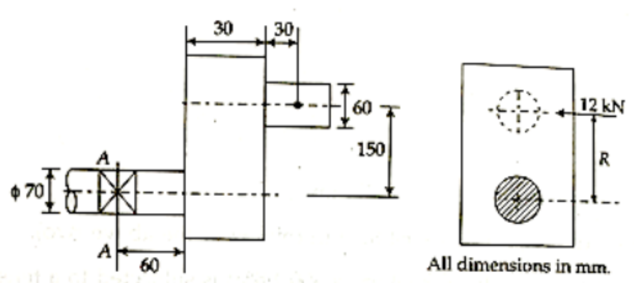
|---|---|---|---|---|
| 1 | Determine the normal stresses and shear stresses induced at section A-A when a load of 12 kN is applied at the centre of the crank pin as shown in figure.  | [15] | CO2 | L3 |



C.I C.C.I HOD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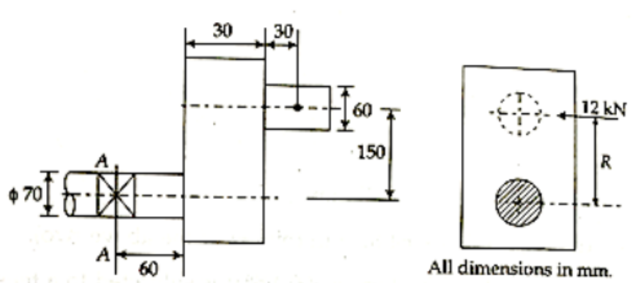
| 1 | Determine the normal stresses and shear stresses induced at section A-A when a load of 12 kN is applied at the centre of the crank pin as shown in figure.  | [15] | CO2 | L3 |



C.I C.C.I HOD

2 A mild steel shaft of 60 mm diameter is subjected to a bending moment of 25 x $10^5$ N-mm and a torque $M_t$. If the yield point of steel in tension is 230 MPa, find the maximum value of this torque without causing yielding of shaft according to
(i) Maximum principal stress theory of failure
(ii)Maximum shear stress theory of failure
(iii) Maximum distortion energy theory of failure
Adopt a factor of safety of 1.5.

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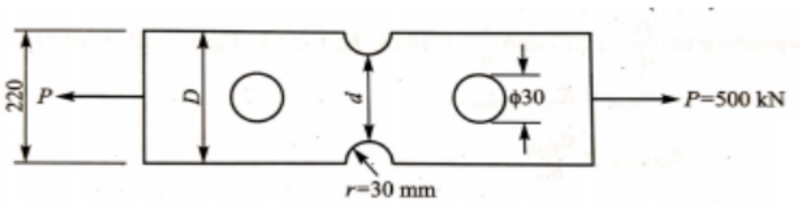


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4. What is stress concentration? Briefly explain the methods of reducing stress concentration.

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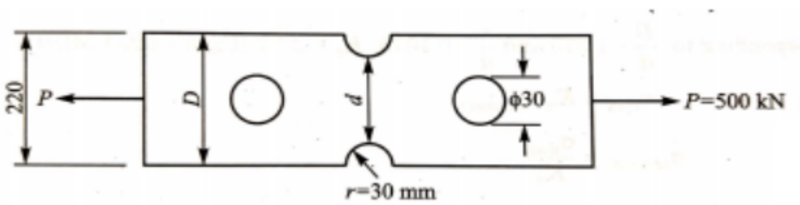


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# 18ME52 - Design of Machine Elements - I

## Scheme of Evaluation

| Q.No: | Scheme | |
|---|---|---|
| 1. | Bending Moment $M_b$ | 2 |
| | Bending stress $\sigma_b = \sigma_x$ | 3 |
| | Torque $M_t$ | 2 |
| | Shear stress $\tau = \tau_{xy}$ | 3 |
| | '$\sigma_1$' → normal stress | 2 |
| | $\tau_{max}$ → Maxm shear stress | 3 |
| 2. | (i) Maxm principal stress theory | 5 |
| | (ii) Maxm shear stress theory | 5 |
| | (iii) Maxm Distortion Energy theory | 5 |
| 3. | Notch → $K_t$, $\sigma_{nom}$, $h$ | 2+2+2 |
| | Hole → $K_t$, $\sigma_{nom}$, $h$ | 2+2+2 |
| | Recommended thickness | 3 |
| 4 | Definition | 2 |
| | Methods with sketch | 3 |

18ME52 → DME - I → Solutions for IAT - 1

Q no: 1

Bending stress due to load at section A A

$\sigma_b = \frac{M_b}{I} \times C \longrightarrow (1)$

$M_b = 12000 \times (60 + 30 + 30) = 144 \times 10^4$ N-mm

$I = \frac{\pi d^4}{64} = 1.178 \times 10^6$ mm⁴

$C = \frac{d}{2} = 35$ mm

Substituting all the above values in ①

$\sigma_b = 42.78$ N/mm²

Torque $M_t$ due to load is given by

$M_t = 12000 \times 150 = 1.8 \times 10^6$ N-mm

Now shear stress $\tau_{xy} = \frac{16 M_t}{\pi d^3} = 26.72$ N/mm²

Normal stress $\sigma_1 = \frac{1}{2}\left[\sigma_x + \sqrt{\sigma_x^2 + 4\tau_{xy}^2}\right]$

$\sigma_1 = 55.6$ N/mm²

Max shear stress $\tau_{max} = \frac{1}{2}\sqrt{\sigma_x^2 + 4\tau_{xy}^2}$

$\tau_{max} = 34.227\ N/mm^2$

Min principal stress

$\sigma_2 = \frac{1}{2}\left[\sigma_x - \sqrt{\sigma_x^2 + 4\tau_{xy}^2}\right]$

$\sigma_2 = -12.83\ N/mm^2.$

Q No: 2

**Data :**

$$d = 60 \text{ mm};\quad M_b = 25 \times 10^5 \text{ N-mm};\quad \sigma_{y_t} = 230 \text{ N/mm}^2;\quad FOS = n = 1.5$$

***Solution :***

From the general expression for bending load (Equation 2.52 Old DDHB; 2.90 New DDHB)

$$\text{Bending stress } \sigma = \frac{M_b}{I}.c$$

$$\therefore \sigma = \frac{25\times10^5}{\frac{\pi}{64}60^4} \times \frac{60}{2} = 117.893 \text{ N/mm}^2 = \sigma_x$$

From the general expression for torsional load (Equation 2.50 Old DDHB; 2.86 New DDHB)

$$\text{Torsional shear stress } \tau = \frac{M_t}{J}.r$$

$$\tau = \frac{M_t}{\frac{\pi}{32}\times60^4} \times \frac{60}{2} = 2.358 \times 10^{-5} M_t = \tau_{xy}$$

$$\sigma_y = 0$$

$$\text{Maximum principal stress } \sigma_1 = \frac{\sigma_x}{2} + \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_{xy}^2} \quad (\because \sigma_y = 0) \quad \text{---- 2.32 (Old DDHB)}$$

$$= \frac{117.893}{2} + \sqrt{\left(\frac{117.893}{2}\right)^2 + \left(2.358\times10^{-5}M_t\right)^2}$$

$$= 58.9465 + \sqrt{3474.69 + 5.56\times10^{-10}M_t^2} \quad \text{---- 2.34 (New DDHB)}$$

$$\text{Minimum principal stress } \sigma_2 = \frac{\sigma_x}{2} - \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_{xy}^2} \quad (\because \sigma_y = 0) \quad \text{---- 2.33 (Old DDHB)}$$

$$= \frac{117.893}{2} - \sqrt{\left(\frac{117.893}{2}\right)^2 + \left(2.358\times10^{-5}M_t\right)^2}$$

$$= 58.9465 - \sqrt{3474.69 + 5.56 \times 10^{-10} M_t^2}$$

**(i) Maximum principal stress theory**

Since $\sigma_1 > \sigma_2$, the design equation is $\sigma_1 = \dfrac{\sigma_{y_t}}{n}$

$$\therefore\ 58.9465 + \sqrt{3474.69 + 5.56 \times 10^{-10} M_t^2} = \frac{230}{1.5}$$

$\therefore$ Maximum torque $M_t = 3.1263 \times 10^6$ N-mm = 3.1263 kN-m

**(ii) Maximum shear stress theory**

For bi-axial stress state system $\tau_{max}$ is the largest among the three values of $\dfrac{\sigma_1 - \sigma_2}{2}$, $\dfrac{\sigma_1}{2}$ and $\dfrac{\sigma_2}{2}$.

Since $\sigma_1$ and $\sigma_2$ are of opposite sign,

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \sqrt{3474.69 + 5.56 \times 10^{-10} M_t^2}$$

The design equation is, $\tau_{max} = \dfrac{\tau_y}{FOS} = \dfrac{\sigma_{y_t}}{2 \times FOS}$

$$\therefore\ \sqrt{3474.69 + 5.56 \times 10^{-10} M_t^2} = \frac{230}{2 \times 1.5}$$

$\therefore$ Maximum torque $M_t = 2.079 \times 10^6$ N-mm = 2.079 kN-m

**(iii) Maximum distortion energy theory**

According to this theory, the design equation for bi-axial stress state system is,

$$\left(\frac{\sigma_{y_t}}{n}\right)^2 = \sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2$$

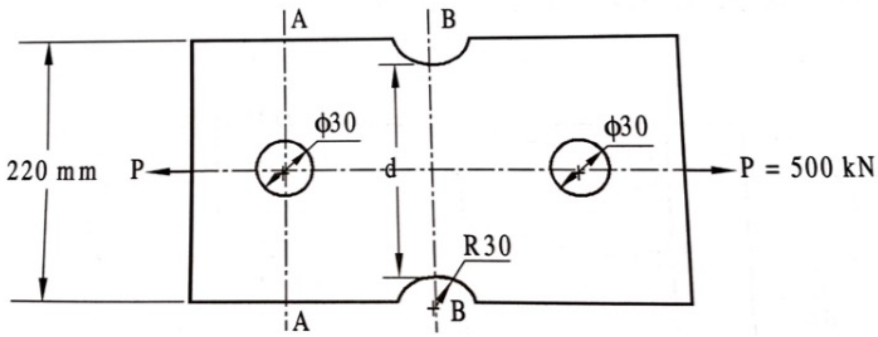
i.e., $$\left(\frac{230}{1.5}\right)^2 = \left\{58.9465 + \sqrt{3474.69 + 5.56 \times 10^{-10} M_t^2}\right\}^2 + \left\{58.9465 - \sqrt{3474.69 + 5.56 \times 10^{-10} M_t^2}\right\}^2$$
$$- \left\{58.9465 + \sqrt{3474.69 + 5.56 \times 10^{-10} M_t^2}\right\}\left\{58.9465 - \sqrt{3474.69 + 5.56 \times 10^{-10} M_t^2}\right\}$$

i.e., $$\left(\frac{230}{1.5}\right)^2 = 2\left(58.9465^2 + 3474.69 + 5.56 \times 10^{-10} M_t^2\right) - \left\{58.9465^2 - \left(3474.69 + 5.56 \times 10^{-10} M_t^2\right)\right\}$$

$$= 58.9465^2 + 3 \times 3474.69 + 3 \times 5.56 \times 10^{-10} M_t^2$$

$\therefore$ Maximum torque $M_t = 2.4 \times 10^6$ N-mm = 2.4 kN-m

3)




**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, $K_\sigma = 2.65$

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

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

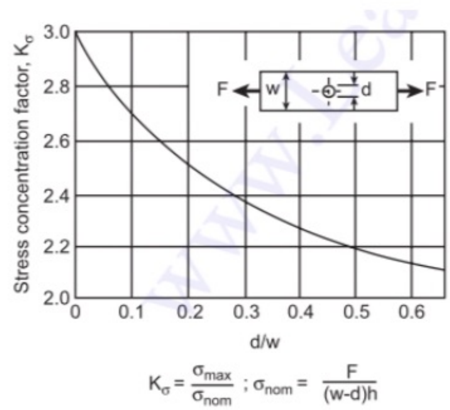



**FIGURE 4-5** Reproduced with permission. Stress-concentration factor for a plate of finite width with a circular hole (cut-out) in tension. ("Design Factors for Stress Concentration," *Machine Design*, Vol. 23, Nos. 2 to 7, 1951.)

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

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

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

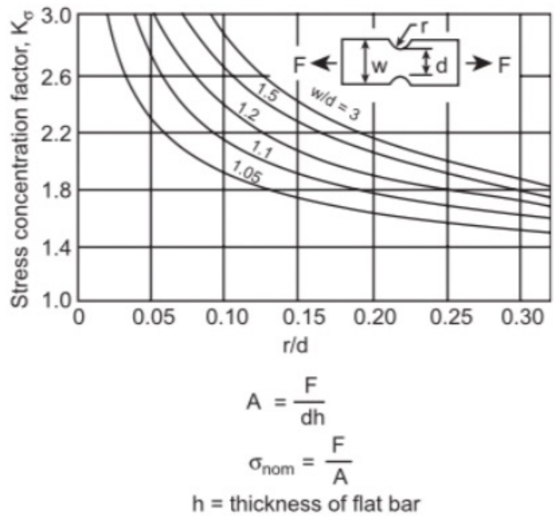



**FIGURE 4-22** Reproduced with permission. Stress-concent

From (1)

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

$h = 34.868$ mm

***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,

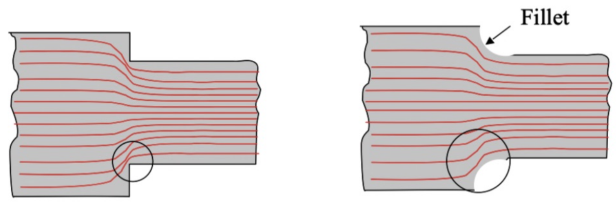
$$\sigma_{nom} = \frac{F}{A} = \frac{F}{h\,.\,d}$$

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

$h$ = **32.81 mm**

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

4) Stress concentration is defined as any localization of maximum stress due to irregularities in cross section or any abrupt change in cross section. Any such discontinuity will affect the stress distribution in the neighbourhood and the discontinuity will act as a stress raiser.




Abrupt change
Stress "flow lines" crowd
High stress concentration

Smoother change
"Flow lines" less crowded
Lower stress concentration

Causes of stress concentration

- Geometric discontinuities such as holes, notches, fillets, grooves, keyways, threads etc.
- Internal defects such as cracks, voids, non-metallic inclusions etc
- Load Discontinuities
- Material discontinuities