CLASS TEST

S.No.: 01SP_ABCDEFG_02062024

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MACHINE DESIGN

MECHANICAL ENGINEERING

Date of Test : 02/06/2024

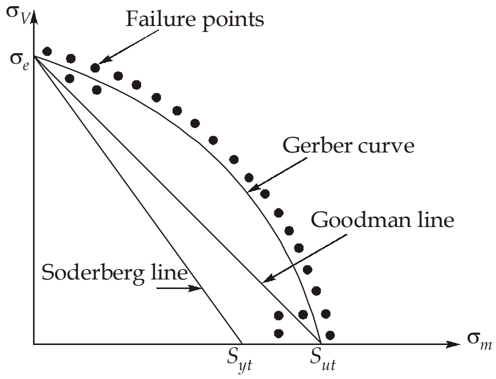
ANSWER KEY

1.	(a)	7.	(a)	13.	(c)	19.	(c)	25.	(b)
2.	(b)	8.	(c)	14.	(a)	20.	(d)	26.	(c)
3.	(d)	9.	(c)	15.	(d)	21.	(c)	27.	(b)
4.	(b)	10.	(b)	16.	(a)	22.	(c)	28.	(b)
5.	(a)	11.	(b)	17.	(a)	23.	(d)	29.	(d)
6.	(b)	12.	(b)	18.	(c)	24.	(c)	30.	(c)

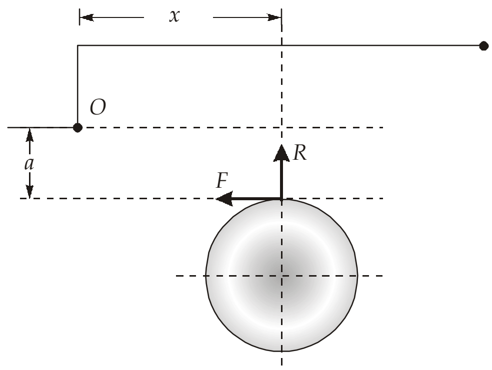
DETAILED EXPLANATIONS

1. (a)

Theories based on the Soderberg line or the Goodman line, as failure criteria are conservative theories. This results in increased dimensions of the components, thus they become uneconomical. The Gerber curve takes the mean path through failure points. It is, therefore, more accurate and economical in predicting fatigue failure.



2. (b)



$$\Sigma M_0 = 0$$

$$P \times L + F \times a = R \times x$$

or $$P = \frac{Rx - Fa}{L}$$

To prevent self locking,

$$P > 0$$

$\because$ $$F = \mu \cdot R$$

$$R \cdot x > F \cdot a$$

$$R \cdot x > \mu R \cdot a$$

$$x > \mu a$$

3. (d)

Intensity of pressure, p = 0.2 MPa

Outer diameter = 400 mm

Inner diameter = 200 mm

Axial force = $p \times$ Area

$$F = 0.2\times10^6\times\frac{\pi}{4}(0.4^2-0.2^2)$$

$$F = 6000\,\pi N$$

4. (b)

The point where the cross-section changes abruptly experiences maximum stress due to stress concentration.

7. (a)

$$\tau_{per} = \frac{2.83\,T}{\pi h d^2}$$

$$\Rightarrow \quad 140 = \frac{2.83\times5000\times10^3}{\pi\times h\times100^2}$$

$$\Rightarrow \quad h = 3.217 \text{ mm} \approx 3.22 \text{ mm}$$

8. (c)

When a material is fully sensitive to notches,

$$\Rightarrow \quad q = 1$$

So, $k_f = 1 + q(k_t - 1) = 1 + (k_t - 1)$

$$k_f = k_t$$

10. (b)

Sommerfield no. is given by,

$$S = \left(\frac{r}{c}\right)^2\left(\frac{\mu n_s}{P}\right) = (100)^2\left(\frac{28\times10^{-3}\times2400}{1.4\times10^6\times60}\right) = 8\times10^{-3}$$

11. (b)

$$\sigma_{min} = 100 \text{ MPa}, \sigma_{max} = 150 \text{ MPa}$$

$$\text{Stress ratio } (R) = \frac{\sigma_{min}}{\sigma_{max}} = \frac{100}{150} = 0.67$$

$$\text{Amplitude ratio } (A) = \frac{\sigma_a}{\sigma_m} = \frac{\sigma_{max}-\sigma_{min}}{\sigma_{min}+\sigma_{min}}$$

$$= \frac{150-100}{150+100} = \frac{50}{250} = 0.2$$

12. (b)

Given : $(\sigma_x)_{min} = 40$, $(\sigma_x)_{max} = 100$

$$(\sigma_x)_m = \frac{40+100}{2} = 70 \text{ MPa}$$

$$(\sigma_x)_a = \frac{100-40}{2} = 30 \text{ MPa}$$

$(\sigma_y)_{min} = 10$ MPa, $(\sigma_y)_{max} = 80$ MPa

$$(\sigma_y)_m = \frac{(\sigma_y)_{max}+(\sigma_y)_{min}}{2} = 45 \text{ MPa}$$

$$(\sigma_y)_a = \frac{(\sigma_y)_{max} - (\sigma_y)_{min}}{2} = 35 \text{ MPa}$$

From distortion energy theory,

$$\sigma_m = \sqrt{(\sigma_x)_m^2 + (\sigma_y)_m^2 - (\sigma_x)_m \times (\sigma_y)_m}$$

$$= \sqrt{(70)^2 + (45)^2 - 70 \times 45} = 61.44 \text{ MPa}$$

$$\sigma_a = \sqrt{(\sigma_x)_a^2 + (\sigma_y)_a^2 - (\sigma_x)_a \times (\sigma_y)_a}$$

$$= \sqrt{(30)^2 + (35)^2 - 30 \times 35} = 32.79 \text{ MPa}$$

From Goodman diagram,

$$\frac{\sigma_m}{S_{ut}} + \frac{\sigma_a}{S_e} = \frac{1}{N}$$

$$\Rightarrow \quad \frac{61.44}{660} + \frac{32.79}{270} = \frac{1}{N}$$

$$N = 4.66$$

13. (c)

$$P = 3 \text{ kW} = 3000 \text{ W}$$

$$n = 25 \text{ rps}$$

Form factor, $Y = 0.3$

Face width, $b = 38$ mm

Module, $m = 3$ mm

Number of teeth, $Z = 18$

$$P = \frac{2\pi n T}{60} = 2\pi n T$$

$$T = \frac{3000}{2\pi \times 25} = 19.098 \text{ Nm}$$

$$F_t \times \frac{D}{2} = T$$

$$F_t \times \frac{mZ}{2} = T$$

$$F_t = \frac{2 \times 19.098 \times 10^3}{3 \times 18} = 707.333 \text{ N}$$

For safe working of gear,

$$F_D \leq F_b$$

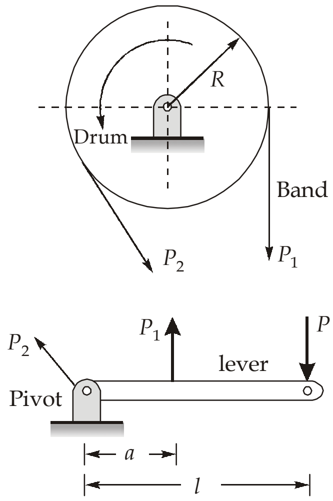
$$F_t \times C_v \leq F_b$$

$$707.333 \times C_v \leq (\sigma_b) m b Y$$

$$\Rightarrow \quad 707.333 \times 1.5 \leq (\sigma_b) \times 38 \times 3 \times 0.3$$

$$\sigma_b \geq 31.02 \text{ MPa}$$

14. (a)



Tension in tight side(P_1 is assuming as a maximum tension).

From maximum permissible condition, $P_1 = Rw\,p_{max}$

$$= 250 \times 60 \times 0.30$$

$$P_1 = 4500 \text{ N}$$

As given: $\dfrac{P_1}{P_2} = 2.5$

$$P_2 = \frac{4500}{2.5}$$

$$P_2 = 1800$$

Torque capacity $M_t = (P_1 - P_2) \times R$

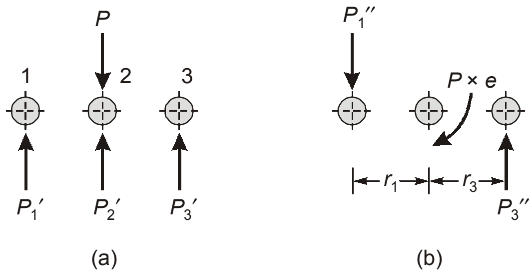
$$= (4500 - 1800) \times 250$$

$$= 675000 \text{ Nm} = 675 \text{ Nm}$$

15. (d)

Permissible shear stress, $\tau = \dfrac{\tau_y}{N} = \dfrac{0.5\sigma_y}{N} = \dfrac{0.5 \times 380}{3} = 63.33\,\text{MPa}$

The primary and secondary shear forces are shown in figure (a) and (b). The centre of gravity of three bolts will be at the centre of the bolt (2).



Primary shear force,

$$P_1' = P_2' = P_3' = \frac{P}{3} = \frac{10000}{3} = 3333.33\,\text{N}$$

$$P_1'' = P_3'' = \frac{Per_1}{r_1^2 + r_3^2} = \frac{10000 \times (200 + 30 + 75) \times 75}{75^2 + 75^2} = 20333.33\,\text{N}$$

Resultant shear force on bolt (3) is maximum.

$$P_3 = P_3' + P_3''$$

$$= 3333.33 + 20333.33$$

$$= 23666.67 \text{ N}$$

Size of bolt, $\tau = \dfrac{P_3}{A} = \dfrac{23666.67}{\frac{\pi}{4} d_c^2} = 63.33$ [Given $\tau_{yt} = 0.5\sigma_{yt}$]

$\Rightarrow$ $d_c = 21.8$ mm

16. (a)

The shearing failure,

$$\text{Load, } P_s = \tau_{max} \times \frac{\pi}{4} d^2$$

$$= 95 \times \frac{\pi}{4} \times 15^2 = 16787.88 \text{ N}$$

$$= 16.787 \text{ kN} \simeq 16.8 \text{ kN}$$

For crushing failure,

$$\text{Load, } P_c = \sigma_c \times (d \times t)$$

Take plate of minimum thickness,

$$P_c = 260 \times (15 \times 8)$$

$$= 31200 \text{ N}$$

$$= 31.2 \text{ kN}$$

$$\text{The strength of joint} = \text{Minimum of } (P_s \text{ and } P_c)$$

$$= 16.8 \text{ kN}$$

17. (a)

Given: M_t = 200 Nm, FOS = 2, μ = 0.3, P_a = 350 kPa

$$M_t \times \text{FOS} = \frac{\pi}{8} \times \mu \times P_a \times d\left(D^2 - d^2\right)$$

$$\Rightarrow \quad 200 \times 2 = \frac{\pi}{8} \times 0.3 \times 350 \times 1000\, d\left(4d^2 - d^2\right)$$

$$\Rightarrow \quad 400 = \frac{\pi}{8} \times 0.3 \times 350000 \times 3d^3$$

$$\Rightarrow \quad d = 0.148 \text{ m} = 148 \text{ mm}$$

18. (c)

Pressure variation for uniform wear is given by

$$P = \frac{W}{2\pi(r_0 - r_i)r}$$

Maximum pressure occurs at smallest radius, i.e. r_i

$$\therefore \quad P_{max} = \frac{W}{2\pi(r_0 - r_i)r_i}$$

$$= \frac{8000}{2\pi(0.2 - 0.1)0.1} = 127323.9 \text{ N/m}^2$$

$$= 127.3 \text{ kN/m}^2$$

Minimum pressure occurs at largest radius, i.e. r_0

$$P_{min} = \frac{W}{2\pi(r_0 - r_i)r_0} = \frac{8000}{2\pi(0.2 - 0.1)0.2} = 63.66 \text{ kN/m}^2$$

19. (c)

Lewis proposed the equation to design gear which was based on **Static Strength** of tooth in bending by considering it as **Cantilever beam**. Stress concentration at the tooth root was not considered since **Stress Concentration Factor** was not considered at that time.

Buckingham has incorporated the effect of inaccuracies of tooth profile.

Lewis has assumed that full load is acting at up of single teeth. (So option 1 is true) effect of radial force neglected and load is uniformly distributed across full width and frictional forces due to teeth sliding are neglected.

20. (d)

$$\sigma_{nominal} = \frac{P}{(w-d)t} = \frac{12\times10^3}{40\times10} = 30 \text{ N/mm}^2$$

Now, stress concentration factor $(k_t) = \dfrac{\sigma_{maximum}}{\sigma_{nominal}}$

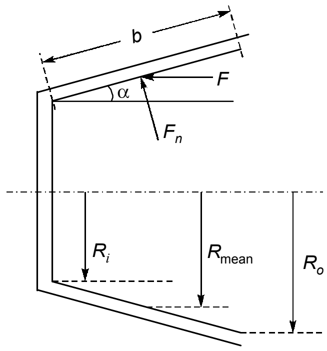
For $\dfrac{d}{w} = \dfrac{10}{50} = 0.2$,

$\Rightarrow$ $k_t = 2.5$ (from table)

$\therefore$ $\sigma_{maximum} = 2.5 \times 30 = 75 \text{ N/mm}^2$

21. (c)

Torque, $T = \mu F_n R_{mean}$



$$350 = 0.3\times F_n\times\frac{300}{2}\times10^{-3}$$

$\Rightarrow$ $F_n = 7777.778$ N

Also, normal force, $F_n = \dfrac{F}{\sin\alpha} = \dfrac{2\pi P R_{mean}(R_o - R_i)}{\sin\alpha}$ ($\because$ uniform wear theory)

$$= \frac{2\pi P R_{mean}(R_o - R_i)}{\dfrac{(R_o - R_i)}{b}} = 2\pi prb$$ [as pressure is given at mean radius]

$$7777.778 = 2\times\pi\times150\times10^3\times\frac{300}{2}\times10^{-3}\times b$$

$\Rightarrow$ $b = 0.055$ m $= 55$ mm

22. (c)

$$\frac{N_p}{N_g} = 2 = \frac{T_g}{T_p} = G \qquad \text{(Gear ratio)}$$

Wear strength, S_w (or) $P_w = kQwd_p$

$k = 1.5 \text{ N/mm}^2$

Ratio factor, $Q = \frac{2G}{G+1} = \frac{2\times 2}{2+1} = \frac{4}{3}$

$w = 100$ mm

$d_p = 400$ mm

Now, $P_w = kQwd_p$

$= 1.5\times\frac{4}{3}\times 100\times 400 = 80000 \text{ N} = 80 \text{ kN}$

23. (d)

As per St. Venant's theory (maximum principal strain theory)

$$(\sigma_1 - \mu\sigma_2) \le \left(\frac{\sigma_{yt}}{\text{F.O.S.}}\right)$$

Von-mises and hencky's theory (maximum distortion energy theory)

$$\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 \le \left(\frac{\sigma_{yt}}{\text{F.O.S.}}\right)^2$$

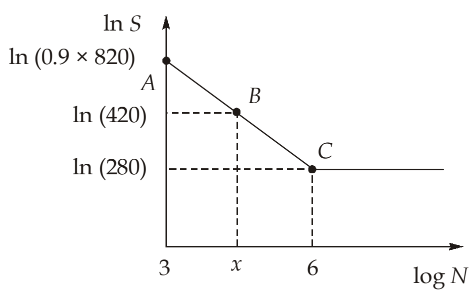
Rankine theory (maximum principal stress theory)

$$\sigma_1 \le \left(\frac{\sigma_{yt}}{\text{F.O.S.}}\right)$$

Haigh's theory (Total strain energy theory)

$$\sigma_1^2 + \sigma_2^2 - 2\mu\sigma_1\sigma_2 \le \left(\frac{\sigma_{yt}}{\text{F.O.S.}}\right)^2$$

24. (c)



Since ABC is a straight line, so slope of AC = slope of BC

$$\frac{\ln(0.9\times 820)-\ln(280)}{3-6} = \frac{\ln(420)-\ln(280)}{x-6} \Rightarrow \frac{\ln(420)-\ln(280)}{\ln(0.9\times 820)-\ln(280)} = \frac{x-6}{-3}$$

$x = 4.7448$

$\log N = 4.7448 \Rightarrow N = 55576.32$ cycles

25. (b)

$$(M_b)_{max} = 150 \times 100 = 15000 \text{ Nmm}$$
$$(M_b)_{min} = -50 \times 100 = -5000 \text{ Nmm}$$
$$(M_b)_m = \frac{1}{2}[(M_b)_{max} + (M_b)_{min}] = \frac{1}{2}[15000 + (-5000)]$$
$$= 5000 \text{ Nmm}$$
$$(M_b)_a = \frac{1}{2}[(M_b)_{max} - (M_b)_{min}] = \frac{1}{2}[15000 - (-5000)]$$
$$= 10000 \text{ Nmm}$$

Based on soderberg criterion,

$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{yt}} = 1$$
$$\sigma = \frac{32M_b}{\pi d^3}$$
$$\frac{32(M_b)_a}{\pi d^3 \times 125} + \frac{32(M_b)_m}{\pi d^3 \times 380} = 1$$
$$\frac{32 \times 10000}{\pi d^3 \times 125} + \frac{32 \times 5000}{\pi d^3 \times 380} = 1$$
$$814.8733 + 134.0252 = d^3$$
$$d = 9.82 \text{ mm}$$

26. (c)

In the given direction try to rotate gear A and keeping gear B fixed and also same for gear B fixed gear C.

27. (b)

Tearing efficiency of rivet is given by,

$$\eta = \frac{P-d}{P} = 1 - \frac{d}{P} = 1 - 0.25 = 0.75$$

28. (b)

$$\text{Torque} = \text{Force} \times \text{Radius}$$
$$1000 = (T_1 - T_2) \times \left(\frac{0.24}{2}\right)$$
$$(T_1 - T_2) = 8333.33 \text{ N}$$
$$\frac{T_1}{T_2} = e^{\mu\theta} = e^{0.3 \times 240 \times \frac{\pi}{180}} = 3.514$$
$$\frac{T_1}{T_2} = 3.514$$
$$T_1 = 3.514\, T_2$$
$$T_1 - T_2 = 8333.33 \text{ N}$$
$$3.514\, T_2 - T_2 = 8333.33 \text{ N}$$

$$T_2 = 3314.77 \text{ N}$$
$$T_1 = 11648 \text{ N} = 11.65 \text{ kN}$$

29. (d)

$$T = 79.6 \times 10^3 \text{ Nmm}$$
$$M = (W + T_1 + T_2)\, 300 = (507 + 1303 + 200) \times 300$$
$$= 603 \times 10^3 \text{ Nmm}$$
$$T_e = \sqrt{M^2 + T^2} = 608.23 \times 10^3 \text{ Nmm}$$
$$\therefore \quad \frac{\pi d^3 \times 35}{16} = 608.23 \times 10^3$$
$$\Rightarrow \quad d = 44.57 \text{ mm}$$

30. (c)

$$P \times a = 15000 \times 400 = 6 \times 10^6 \text{ N-mm}$$

Let F = Tensile force per bolt per mm

$$\text{P} \times \text{a} = \text{F}(l_1^2 + l_2^2 + l_3^2 + l_4^2)$$
$$\text{P} \times \text{a} = \text{F}(l_1^2 + 2l_2^2 + l_4^2)$$
$$\Rightarrow \quad \text{F} = \frac{P \times a}{l_1^2 + 2l_1^2 + l_4^2} = \frac{6 \times 10^6}{30^2 + 2 \times 350^2 + 200^2} = 20.9863 \text{ N/mm}$$

As bolts 2 and 3 are located at maximum distance from the lower edge,

Maximum tensile load $= \text{F}_2$ or $\text{F}_3 = \text{F} \times l_2$ or $\text{F} \times l_3$

$= 20.9863 \times 350 = 7345.225 \text{ N} = 7.345 \text{ kN}$

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