CLASS TEST

Sl. 02_SP_ME_D+E_210922

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MACHINE DESIGN

MECHANICAL ENGINEERING

Date of Test : 21/09/2022

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)

$$\sigma_1 = 360 \text{ MPa}$$
$$\sigma_2 = 140 \text{ MPa}$$
$$\sigma_{eff} = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2}$$
$$= \sqrt{(360)^2 - 140 \times 360 + 140^2}$$
$$\sigma_{eff} = 314.32 \text{ MPa}$$

3. (d)

$$\sigma_1 = -200 \text{ MPa}$$
$$\sigma_2 = -150 \text{ MPa}$$
$$\sigma_3 = 0$$
$$\tau_{max} = \frac{S_{yt}}{2 \times FOS}$$
$$\tau_{per} = \text{maximum of} \left\{ \left|\frac{\sigma_1 - \sigma_2}{2}\right|, \left|\frac{\sigma_2 - \sigma_3}{2}\right|, \left|\frac{\sigma_3 - \sigma_1}{2}\right| \right\}$$
$$= \left|\frac{-200 - (-150)}{2}\right| = 25$$
$$= \left|\frac{-150 - 0}{2}\right| = 75$$
$$= \frac{0 - (-200)}{2} = 100$$
$$\frac{S_{yt}}{FOS} = 2 \times 100$$
$$\text{FOS} = \frac{S_{yt}}{200} = \frac{430}{200} = 2.15$$

6. (b)

$$P = (0.707t \times L_1 \times \sigma_t) + (1.414t \times L_2 \times \tau)$$

Given
$$t = 15 \text{ mm}$$
$$\sigma_t = 80 \text{ MPa}$$
$$\tau = 60 \text{ MPa}$$
$$L_2 = L$$
$$L_1 = 70 \text{ mm}$$
$$P = 80 \text{ kN}$$
$$80 \times 10^3 = (0.707 \times 15 \times 70 \times 80) + (1.414 \times 15 \times L \times 60)$$
$$L = 16.196 \text{ mm}$$

7. (a)

Maximum principal stress theory or Rankine theory is used for brittle materials, as they under go abrupt failure.

8. (d)

$$\frac{P_1}{P_2} = \frac{k_1}{k_2} = \frac{250}{150} = \frac{5}{3}$$

$$P_1 + P_2 = 1800 \text{ N}$$

$$P_2\left(\frac{P_1}{P_2}+1\right) = 1800$$

$$P_2\left(\frac{5}{3}+1\right) = 1800$$

$$P_2\left(\frac{8}{3}\right) = 1800$$

$$P_2 = \frac{1800 \times 3}{8} = 675 \text{ N}$$

$$= k_2 x$$

$$675 = 150x$$

$$x = 4.5 \text{ mm}$$

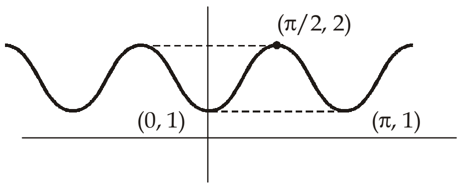
9. (b)

$$S = \left(\frac{r}{c}\right)^2\left(\frac{\mu n_s}{P}\right) = (100)^2\left(\frac{28\times10^{-3}\times2400}{1.4\times10^6\times60}\right) = 8 \times 10^{-3}$$

11. (d)

$$P = 50(1 + \sin^2 x) \text{ N}$$

The graph of $1 + \sin^2 x$



$$P_{max} = 50 \times 2 = 100 \text{ N}$$

$$P_{min} = 50 \text{ N}$$

$$P_m = \frac{1}{2}(P_{max} + P_{min}) = \frac{1}{2}(100+50)$$

$$= 75 \text{ N}$$

$$P_a = \frac{1}{2}(P_{max} - P_{min}) = \frac{1}{2}(100-50)$$

$$= 25 \text{ N}$$

$$\text{Amplitude ratio} = \frac{P_a}{P_m} = \frac{25}{75} = 0.33$$

12. (d)

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

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

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

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

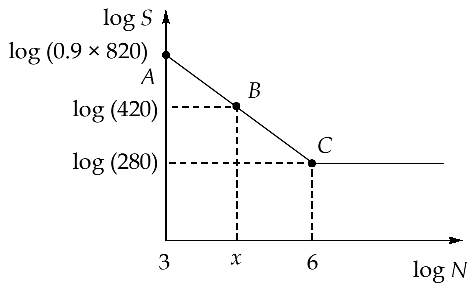
Rankine theory (maximum principal stress theory)

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

Haigh's theory (Total strain energy theory)

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

13. (c)



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

$$\frac{\log(0.9\times820)-\log(280)}{3-6} = \frac{\log(420)-\log(280)}{x-6}$$

$$x = 4.7448$$

$$\log N = 4.7448 \Rightarrow N = 55576.32 \text{ cycles}$$

14. (a)

$$\sigma_{04\phi} = \frac{p}{(w-d)t} = \frac{17\times1000}{(20-4)\times17} = 62.5 \text{ MPa}$$

$$\sigma_{\text{corrected}} = k_t \times 62.5 = 2.50 \times 62.5 = 156.25 \text{ MPa}$$

$$\sigma_{05\phi} = \frac{17\times1000}{(20-5)\times17} = 66.66 \text{ MPa}$$

$$\sigma_{\text{corrected}} = 2.30 \times 66.66 = 153.333 \text{ MPa}$$

$$\sigma_{09\phi} = \frac{17\times1000}{(20-9)\times17} = 90.90 \text{ MPa}$$

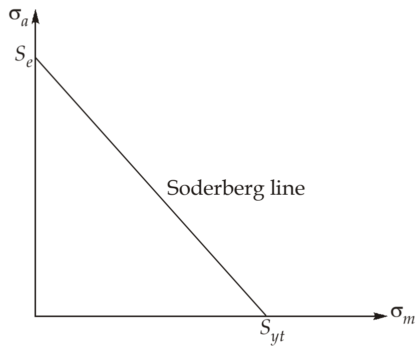
$$\sigma_{\text{corrected}} = 2.15 \times 90.90 = 195.454 \text{ MPa}$$

$$\frac{\sigma_{\max}}{\sigma_{\min}} = \frac{195.454}{153.333} = 1.2747$$

15. (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,



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

16. (a)

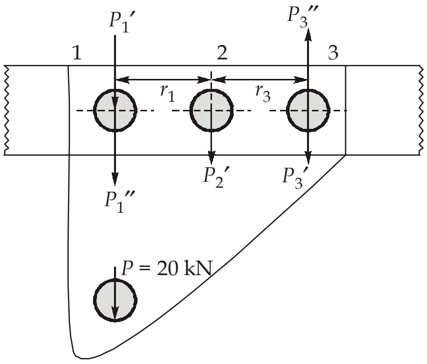
$$\tau = \frac{M_t}{2\pi t r^2}$$
$$140 = \frac{2500 \times 1000}{2\pi \times t(25)^2}$$
$$t = 4.55 \text{ mm}$$
$$\text{Size of weld, } h = \frac{t}{0.707} = 6.43 \text{ mm}$$
$$h = 7 \text{ mm}$$

17. (d)

$$C = 22 \text{ kN}$$
$$F_{\text{max radial}} = \text{Pe}$$
$$L_{90} = \left[\frac{C}{Pe}\right]^3$$
$$L_{90} = 2000 \times 60 \times 600$$
$$L_{90} = 72 \times 10^6 \text{ revolution}$$
$$72 = \left[\frac{22}{Pe}\right]^3$$
$$\text{Pe} = 5.29 \text{ kN}$$

18. (c)

$$r_1 = 80 \text{ mm}, \qquad r_2 = 0$$
$$r_3 = 80 \text{ mm}, \qquad e = 80 \text{ mm}$$



Primary direct force, $P_1' = P_2' = P_3' = \dfrac{P}{3} = \dfrac{20 \times 10^3}{3}$

$= 6666.67$ N

Secondary shear force, $c = \dfrac{P.e}{r_1^2 + r_2^2 + r_3^2} = \dfrac{20 \times 10^3 \times 80}{(80)^2 + (0)^2 + 80^2}$

$= \dfrac{20 \times 10^3 \times 80}{2 \times (80)^2} = 125 \text{ N/mm}$

For maximum load, $P_1'' = P_3'' = C.r.$

$= 125 \times 80 = 10000$ N

Resultant shear force, $P = P_1' + P_1'' = 6666.67 + 10000$

$= 16666.67$ N

$= 16.7$ kN

19. (a)

$$T_e = \sqrt{M^2 + T^2}$$

Pure torsion $\quad M = 0$

$$T_e = T = \frac{\pi d^3}{16} \tau_{max} \qquad ...(1)$$

$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

$$\frac{T}{2} = \frac{\pi d^3}{32} \sigma_{max} \qquad ...(2)$$

From equation (1) and (2)

$$\frac{\tau_{max}}{\sigma_{max}} = 1 : 1 = 1$$

20. (d)

$$F = 20 \text{ kN}, \quad R_0 = 2.5\,R_i$$
$$P = 300 \text{ kN/m}^2, \quad N = 150 \text{ rpm}$$
$$\mu = 0.04, \quad \alpha = \frac{110^\circ}{2} = 55^\circ$$
$$p = \frac{F}{\pi(R_0^2 - R_i^2)}$$
$$300 \times 10^3 = \frac{20 \times 10^3}{\pi[(2.5R_i)^2 - R_i^2]}$$
$$(2.5R_i)^2 - R_i^2 = \frac{20 \times 10^3}{\pi \times 300 \times 10^3} = 0.0212$$
$$R_i = 0.06354 \text{ m}$$
$$R_0 = 0.15886 \text{ m}$$
$$D_0 = 317.73 \text{ mm}$$

21. (b)

From shear consideration

$$4\left[\frac{\pi}{4}d^2\tau\right] = P$$
$$4\left[\frac{\pi}{4}d^2 \times 60\right] = 10 \times 10^3$$
$$d = 7.28 = 8 \text{ mm}$$

from crushing consideration,

$$4dt\sigma_c = P$$
$$4d(3)(120) = 10 \times 10^3$$
$$d = 6.94 = 7 \text{ mm}$$

Shearing becomes the criterion of design

$$d = 8 \text{ mm}$$

22. (b)

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

23. (c)

$$\tau = \frac{S_{ys}}{fos} = \frac{0.5S_{yt}}{fos} = \frac{0.5 \times 400}{3} = 66.66 \text{ MPa}$$
$$\text{Shear area of 4 bolts} = 4\left(\frac{\pi}{4}d^2\right)$$
$$\tau = \frac{P}{4\left(\frac{\pi}{4}d^2\right)}$$
$$66.66 = \frac{6 \times 1000}{\pi \times d^2}$$
$$d = 5.35 \text{ mm}$$

24. (a)

Equivalent dryness load (N)$P = XVF_r + YF_a$

$$\text{radial factor } X = 0.56$$
$$\text{thrust factor } Y = 1.79$$
$$\text{Since inner race rotates } V = 1$$
$$P = 0.56 \times 1 \times 10 + 1.79 \times 4 \text{ kN} = 12.76 \text{ kN}$$
$$L_{10} = \frac{60 \times N \times L_{10h}}{10^6} = \frac{60 \times 1200 \times 20000}{10^6}$$
$$L_{10} = 1440 \text{ million revolution}$$
$$c = P(L_{10})^{1/3} = 12.76(1440)^{1/3}$$
$$c = 144.09 \text{ kN}$$

25. (a)

$$P = \frac{2\pi NT}{60}$$
$$T = \frac{500 \times 10^3 \times 60}{2 \times \pi \times 1800} = 2652.58 \text{ N.m}$$
$$F_T = \frac{T}{D_P/2} = \frac{2652.58}{0.06} = 44206.70 \text{ N}$$
$$\text{Normal load on tooth } F_N = \frac{F_T}{\cos\phi} = \frac{44209.70}{\cos 22.5}$$
$$= 47852.23 \text{ N}$$
$$= 47.85 \text{ kN}$$

26. (c)

$$\tau = \frac{S_{yt}}{\sqrt{3} \times \text{fos}} = \frac{350}{\sqrt{3} \times \text{fos}}$$
$$P = 0.707 \times t \times l \times \tau$$
$$50 \times 10^3 = 0.707 \times 3 \times 240 \times \frac{350}{\sqrt{3} \times \text{fos}}$$
$$\text{fos} = \frac{0.707 \times 3 \times 240 \times 350}{\sqrt{3} \times 50 \times 10^3} = 2.057$$
$$\text{Margin of safety} = \text{fos} - 1 = 2.057 - 1 = 1.0572$$

27. (c)

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

28. (c)

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

Let F = Tensile force per bolt per mm

$$P \times a = F(l_1^2 + l_2^2 + l_3^2 + l_4^2)$$

$$P \times a = F(l_1^2 + 2l_2^2 + l_4^2)$$

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

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

Maximum tensile load $= F_2$ or $F_3 = F \times l_2$ or $F \times l_3$

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

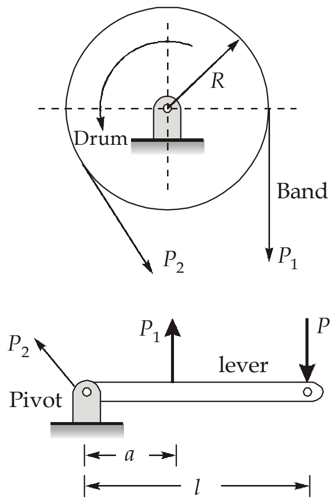
29. (a)

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: $\frac{P_1}{P_2} = 2.5$

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

$$P_2 = 1800$$

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

$= (4500 - 1800) \times 250$

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

30. (c)

$$\frac{k_b}{k_c} = 1.5, \quad P_l = 10000 \text{ N}$$

$$\frac{k_b}{k_b + k_c} = \frac{1.5k_c}{1.5k_c + k_c} = \frac{1.5}{2.5} = 0.6$$

$$(P_i)_{\text{per bolt}} = \frac{\pi}{4}(310)^2 \times 1.1 \times \left(\frac{1}{10}\right) = 8302.4439 \text{ N}$$

Resultant load on belt

$$P = P_l + P_i\left(\frac{k_b}{k_b + k_c}\right) = 10000 + 8302.4439 \times 0.6 = 14.981 \text{ kN}$$

$$\sigma_{bolt} = \frac{14.981 \times 10^3}{\frac{\pi}{4} \times (23)^2} = 36.06 \text{ MPa}$$

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