CLASS TEST

S.No.: 01SKME_ABCDEFGHI_15725

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MACHINE DESIGN

MECHANICAL ENGINEERING

Date of Test : 15/07/2025

ANSWER KEY

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

DETAILED EXPLANATIONS

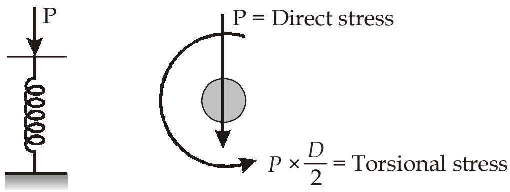
1. (d)

$$k_a = 0.79,\ k_b = 0.85,\ k_c = 0.897$$

$$k_d = \frac{1}{k_f} = \frac{1}{1.5} = 0.67\ ,\ S_e = 320\text{ MPa}$$

So,
$$S_e' = k_a k_b k_c k_d\, S_e$$
$$S_e' = 129.14\text{ MPa}$$

2. (d)



3. (b)

$$k_b = 1.5,\ k_t = 2$$
$$M_b = 500\text{ kN-m},\ M_t = 400\text{ kN–m}$$

Equivalent torsional moment, $(T_e) = \sqrt{(k_b M_b)^2 + (k_t M_t)^2}$

$$T_e = \sqrt{(1.5\times 500)^2 + (2\times 400)^2}$$
$$T_e = 1096.58\text{ kN–m}$$

4. (c)

$$P = \frac{W}{l\times d}$$

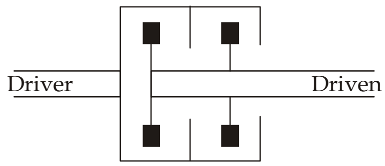
$$W = \frac{2\times 10^6 \times 0.075\times 0.12}{1000} = 18\text{ kN}$$

$$H = f\times W\times v$$

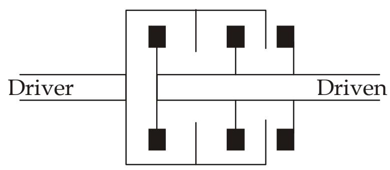
$$H = \frac{0.03\times 18\times 10^3\times(\pi\times 0.075\times 1200)}{60\times 1000} = 2.545\text{ kW}$$

5. (a)

For 3 driver and 2 driven disks we will have (3 + 2 – 1) = 4 contact surfaces.



For 3 driver and 3 driven disks we will have (3 + 3 – 1) = 5 contact surfaces.



So, torque transmission capacity would increase by $\frac{5-4}{4}\times 100$ = 25%.

6. (c)

$$\text{Bending stress, } \sigma = \frac{M}{\pi \times r^2 \times t}$$

$$140 = \frac{2486}{\pi \times t \times 25^2}$$

$$t = 9.04 \times 10^{-3} \text{ m}$$

$$t = 9.04 \text{ mm}$$

$$\text{Size of weld, } h = \frac{t}{0.707}$$

$$h = 12.786 \text{ mm}$$

$$h \simeq 13 \text{ mm}$$

7. (a)

The result came from guest's theory and hencky, both are suitable for ductile material but hencky's results are safer and more economical.

8. (b)

9. (c)

$$\sigma_1 = 360 \text{ MPa}$$

$$\sigma_2 = 140 \text{ MPa}$$

$$\sigma_{eff} = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2}$$

$$= \sqrt{(360)^2 - 140 \times 360 + 140^2}$$

$$\sigma_{eff} = 314.32 \text{ MPa}$$

10. (d)

$$\sigma_1 = -200 \text{ MPa}$$

$$\sigma_2 = -150 \text{ MPa}$$

$$\sigma_3 = 0$$

$$\tau_{max} = \frac{S_{yt}}{2 \times FOS}$$

$$\tau_{per} = \text{maximum of} \left\{ \left|\frac{\sigma_1 - \sigma_2}{2}\right|, \left|\frac{\sigma_2 - \sigma_3}{2}\right|, \left|\frac{\sigma_3 - \sigma_1}{2}\right| \right\}$$

$$= \left|\frac{-200-(-150)}{2}\right| = 25 \quad = \left|\frac{-150-0}{2}\right| = 75$$

$$= \frac{0-(-200)}{2} = 100$$

$$\frac{S_{yt}}{FOS} = 2 \times 100$$

$$\text{FOS} = \frac{S_{yt}}{200} = \frac{430}{200} = 2.15$$

11. (d)

Corrected endurance limit, $S_e' = \dfrac{S_e}{K_f}$

$$K_f = 2.2$$

$$S_e' = 66.3636 \text{ MPa}$$

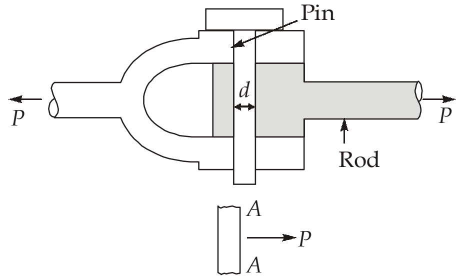
So, $$\sigma_a = \frac{S_e'}{FOS} = \frac{66.3636}{2} = 33.1818 \text{ MPa}$$ (where factor of safety is 2)

So, $$\sigma_a = \frac{P}{(50t)}$$

$$t = \frac{P}{50\sigma_a} = \frac{50\times10^3}{50\times33.1818} = 30.137 \text{ mm}$$

$$t_{min} = 31 \text{ mm}$$

12. (d)



Shear stress, $\tau = \dfrac{P}{2A}$

$$A = \frac{\pi}{4}\times d^2$$

$$\tau = \frac{4P}{2\times\pi d^2}$$

According to distortion energy theory, $\tau_{max} = 0.577\ S_{yt}$
(where S_{yt} is 380 MPa)

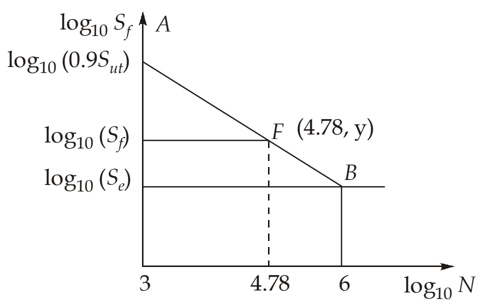
$$\tau_{max} = 219.26 \text{ N/mm}^2$$

Now, $$\tau \le \frac{\tau_{max}}{N}$$

$$\frac{4\times25\times10^3}{2\times\pi\times d^2} \le \frac{219.26}{2.5}$$

$$d \ge 13.471 \text{ mm}$$

13. (d)



$$A = [3, \log_{10}(0.9 \times 650)]$$
$$= (3, 2.7671)$$
$$B = [6, \log_{10}(300)]$$
$$= (6, 2.4771)$$
$$F = [\log_{10}(60000), y] = (4.78, y)$$

Equation of AB

$$(y - 2.7671) = \frac{(2.4771-2.7671)(4.78-3)}{6-3}$$

$$y = 2.595$$

$$S_f = 393.58 \text{ MPa}$$

14. (c)

$$\text{Mean force, } F_m = \frac{F_{max}+F_{min}}{2} = \frac{(25.2+10.8)}{2} = 18 \text{ N}$$

$$\text{Alternating force, } F_a = \frac{F_{max}-F_{min}}{2} = \frac{(25.2-10.8)}{2} = 7.2 \text{ N}$$

$$\text{Moment of inertia, } I = \frac{bh^3}{12} = \frac{1}{12}\times(1.25)\times(0.16)^3 \text{ cm}^4 = 4.27 \times 10^{-12} \text{ m}^4$$

$$\sigma_m = \frac{M_m \times y}{I} = \frac{F_m L \times y}{I} = \frac{18\times6\times0.08\times10^{-4}}{4.27\times10^{-12}\times10^6} = 202.34 \text{ MPa}$$

$$\sigma_a = \frac{M_a \times y}{I} = \frac{F_a L \times y}{I} = \frac{7.2\times6\times0.08\times10^{-4}}{4.27\times10^{-12}\times10^6} = 80.937 \text{ MPa}$$

Goodman eq.

$$\frac{1}{N} = \frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{80.937}{229} + \frac{202.34}{595}$$

$$N = 1.44$$

15. (c)

$$\sigma_t = \frac{S_{ut}}{f_s} = \frac{300}{2.5} = 120 \text{ N/mm}^2$$

Tensile stress due to axial load of 15 kN will be

$$\sigma_a = \frac{P}{A} = \frac{15000}{t\times5t} = \frac{3000}{t^2} \text{ N/mm}^2$$

Tensile stress due to moment of (15 kN × 7.5t) will be

$$\sigma_b = \frac{P \cdot e \cdot y}{I} = \frac{15000\times7.5t\times2.5t}{\frac{1}{12}(t)(5t)^3} = \frac{27000}{t^2} \text{ N/mm}^2$$

So, total tensile stress at the crosssection is

$$\sigma = \sigma_a + \sigma_b = \frac{30000}{t^2}$$

$$120 = \frac{30000}{t^2}$$

$$t = 15.81 \text{ mm}$$

16. (a)

$$P_1 = 55 \text{ MPa, Principal stress}$$

$$\sigma_{ut} = 150 \text{ MPa}, \sigma_{uc} = -500 \text{ MPa}$$

Mohr's theory used for materials which have different compressive and tensile strength like cast iron.

Governing equation, by Mohr's theory,

$$\frac{P_1}{\sigma_{ut}} + \frac{P_2}{\sigma_{uc}} = 1$$

$$\frac{55}{150} + \frac{P_2}{-500} = 1$$

$$P_2 = -316.67 \text{ MPa}$$

17. (b)

$$d = 6\sqrt{t} = 6\sqrt{30} = 32.863 \text{ mm}$$

Shear strength of one rivet

$$P_S = 1.875\left(\frac{\pi}{4} \times d^2 \tau\right)$$

$$P_S = 95423.824 \text{ N}$$

Crushing strength of one rivet = $(dt) \cdot \sigma_C$

$$(P_C) = 32.863 \times 30 \times 120 = 118306.8 \text{ N}$$

Tensile strength of the plate in outer row

$$P_t = (w - d) \times t \times \sigma_t = (250 - 32.863) \times 30 \times 80 = 521128.8 \text{ N}$$

$\therefore \quad P_S < P_C$

$\therefore \quad 521128.8 = n \times 95423.824$

$$n = 5.46$$

$$n \approx 6$$

18. (c)

$D = 0.2$ m, $\quad d = 0.15$ m

$\mu = 0.2$, $\quad 2\alpha = 30$

$\alpha = 15°$

$$P = P_{max} = 0.1 \text{ N/mm}^2$$

$$= 0.1 \text{ MPa}$$

We know that,
$$M_t = \frac{\mu \times \pi \times P}{\sin\alpha \times 12}\left(D^3 - d^3\right) = \frac{0.2 \times \pi \times 0.1\left(200^3 - 150^3\right)}{\sin 15 \times 12 \times 1000}$$

$$= 93.565 \text{ N-m} = 93.565 \times 1000 \text{ N-mm} = \frac{93.565 \times 1000}{1000} \text{ kN-mm}$$

$$M_t = 93.565 \text{ kN-mm}$$

19. (c)

Given, $(L_{80})_1 = 380$ MR

$(P_e)_1 = 12$ kN

We know that,

$$\because \frac{L_{80}}{L_{90}} = \left[\frac{\ln\left(1/0.8\right)}{\ln\left(1/0.9\right)}\right]^{1/1.17}$$

$$L_{80} = 1.90\, L_{90}$$

$$(L_{90})_1 = \frac{(L_{80})_1}{1.90} = \frac{380}{1.90} = 200 \text{ MR}$$

Rated life of bearing is bearing life with 90% reliability

$$L_{90} \;\alpha\; \left(\frac{1}{P_e}\right)^3$$

$$\frac{(L_{90})_1}{(L_{90})_2} = \left[\frac{(P_e)_2}{(P_e)_1}\right]^3 \qquad \because (P_e)_2 = 2(P_e)_1$$

$$\frac{(L_{90})_1}{(L_{90})_2} = (2)^3$$

$$(L_{90})_2 = \frac{200}{8} = 25 \text{ MR}$$

20. (a)

$$\text{Sommerfeld number, } S = \left(\frac{D}{C}\right)^2 \frac{Zn}{P}$$

$$\text{Pressure, } P = \frac{W}{LD} = \frac{5\times10^3}{0.05\times0.05} = 2\times10^6 \text{ Pa}$$

$$Z = \frac{11.62}{100}\times\frac{1}{10} = 0.01162 \text{ Ns/m}^2$$

So,
$$S = \left(\frac{0.05}{50\times10^{-6}}\right)^2 \times \frac{0.01162\times1000}{60\times2\times10^6}$$

$$S = 0.096833$$

21. (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)

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

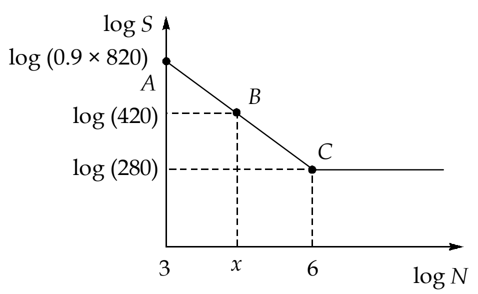
Rankine theory (maximum principal stress theory)

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

Haigh's theory (Total strain energy theory)

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

22. (c)



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

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

$$x = 4.7448$$

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

23. (c)

24. **(c)**

Shaft is under pure torsion, so

$$\sigma_1 = -\sigma_2 = \frac{16T}{\pi d^3}$$

$$\sigma_1 = \frac{16 \times 95 \times 10^3}{\pi d^3} = \frac{483.831 \times 10^3}{d^3}$$

So,
$$\sigma_2 = \frac{-483.831 \times 10^3}{d^3}$$

As per M.D.E.T.

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

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

$$3\sigma_1^2 \le \left(\frac{\sigma_{yt}}{\text{F.O.S.}}\right)^2$$

$$3\left(\frac{483.831 \times 10^3}{d^3}\right)^2 \le \left(\frac{240}{2}\right)^2$$

$$d \ge 19.11 \text{ mm} \simeq 20 \text{ mm}$$

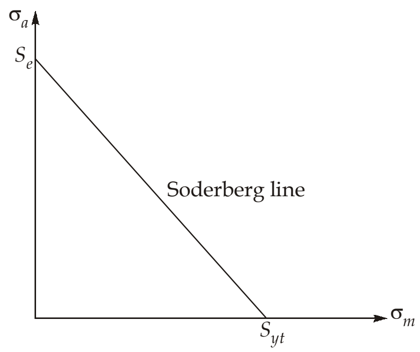
25. **(c)**

$$(M_b)_{max} = 150 \times 100 = 15000 \text{ Nmm}$$
$$(M_b)_{min} = -50 \times 100 = -5000 \text{ Nmm}$$

$$(M_b)_m = \frac{1}{2}[(M_b)_{max} + (M_b)_{min}] = \frac{1}{2}[15000 + (-5000)]$$
$$= 5000 \text{ Nmm}$$

$$(M_b)_a = \frac{1}{2}[(M_b)_{max} - (M_b)_{min}] = \frac{1}{2}[15000 - (-5000)]$$
$$= 10000 \text{ Nmm}$$

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. (a)

$$\tau = 0.75\ (S_{ut})$$
$$= 0.75 \times 1350$$
$$\tau = 1012.5 \text{ MPa}$$

Shear stress correction factor,

$$k_s = \left(1 + \frac{0.5}{C}\right) \qquad \left[C = \frac{D}{d}\right]$$

$$k_s = 1 + \frac{0.5}{5} \qquad [C = 5]$$
$$= 1.1$$

$$\tau = k_s \frac{8PC}{\pi d^2}$$

$$1012.5 = 1.1 \times \frac{8 \times (498) \times (5)}{\pi d^2}$$

$$d = 2.62 \approx 3 \text{ mm}$$
$$D = 3 \times 5 = 15 \text{ mm}$$

Actual spring rate

$$k_{\text{actual}} = \frac{Gd^4}{8D^3N} = \frac{75750 \times 3^4}{8 \times 15^3 \times 38} = 5.98 \text{ N/mm}$$

27. (a)

$$\tau = \frac{M_t}{2\pi t r^2}$$

$$140 = \frac{2500 \times 1000}{2\pi \times t(25)^2}$$

$$t = 4.55 \text{ mm}$$

$$\text{Size of weld, } h = \frac{t}{0.707} = 6.43 \text{ mm}$$

$$h = 7 \text{ mm}$$

28. (d)

$$C = 22 \text{ kN}$$
$$F_{\text{max radial}} = \text{Pe}$$

$$L_{90} = \left[\frac{C}{Pe}\right]^3$$

$$L_{90} = 2000 \times 60 \times 600$$
$$L_{90} = 72 \times 10^6 \text{ revolution}$$

$$72 = \left[\frac{22}{Pe}\right]^3$$

$$\text{Pe} = 5.29 \text{ kN}$$

29. (b)

$$\text{Beam strength } S_b = \sigma_b b\, mY$$
$$= \sigma_b \times 36 \times 3 \times 0.3$$
$$d_g = m \times t_g = 3 \times 16 = 48 \text{ mm}$$
$$M_t = \frac{3 \times 1000}{2\pi \times 20} \text{ N-m}$$
$$M_t = \frac{3 \times 10^3}{2\pi \times 20} \times 10^3 \text{ N-mm}$$
$$= 23873.241 \text{ N-mm}$$

Tangential force due to torque,

$$P_t = \frac{2 \times 23873.241}{48} = 994.718 \text{ N}$$
$$P_{\text{eff}} = P_t \times C_V = 994.718 \times 1.5$$
$$= 1492.0775 \text{ N}$$
$$1492.0775 = \sigma_b \times 36 \times 3 \times 0.3$$
$$\sigma_b = 46 \text{ MPa}$$

30. (d)

$$E = \frac{1}{2} mk^2(\omega_1^2 - \omega_2^2)$$
$$\omega_1 = \frac{2\pi N_1}{60} = \frac{2\pi \times 350}{60} = 36.65 \text{ rad/ sec}$$
$$\omega_2 = 0$$
$$m = \frac{\pi}{4} d^2 \times t \times \rho = \frac{\pi}{4} \times (1^2) \times 0.2 \times 7200 = 1130.97 \text{ kg}$$

Radius of gyration (k) of a solid disk about its axis of rotation is $\left(\frac{d}{\sqrt{8}}\right)$

$$k = \frac{d}{\sqrt{8}}$$
$$k = \frac{1}{\sqrt{8}}$$
$$\Rightarrow \quad k^2 = \frac{1}{8}$$
$$E = \frac{1}{2} \times (1130.97) \times \frac{1}{8} \times (36.65)^2$$
$$E = 94.946 \text{ kJ}$$

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