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Machine Design

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Date of Test : 17/08/2019

ANSWER KEY ➤ Machine Design

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

DETAILED EXPLANATIONS

1. (a)

$$\tau_{max} = \frac{2T}{\pi d^2 h}$$

$T = 1500$ Nm, $d = 60$ mm, $\tau_{max} = \tau_{per} = 80$ N/mm^2

$$h = \frac{2 \times 1500 \times 10^3}{\pi \times 60^2 \times 80} = 3.31 \text{ mm}$$

2. (b)

$$\begin{aligned} \text{Safe load} &= \text{no. of rivets} \times \text{projected area of rivet on one plate} \\ &\quad \times \text{bearing stress} \\ &= 2 \times 20 \times 25 \times 150 = 150000 \text{ N} = 150 \text{ kN} \end{aligned}$$

3. (b)

$$L_{10} = 10000 \times 300 \times 60 = 180 \times 10^6 \text{ rev}$$

$$C = 30 \text{ kN}$$

$$L_{10} = \left(\frac{C}{Pe}\right)^k$$

$$180 = \left(\frac{30000}{Pe}\right)^{10/3}$$

$$\Rightarrow \quad Pe = \frac{30000}{(180)^{3/10}} = 6317.41 \text{ N}$$

4. (a)

$$t = 15 \text{ mm}$$

$$l = 40 \text{ mm}$$

$$D = 50 \text{ mm}$$

$$\sigma_{ind} = 90 = \frac{F_t}{\frac{lt}{2}} = \frac{4T}{Dtl} \qquad \left[T = F_t \times \frac{D}{2}\right]$$

$$T = \frac{90 \times 50 \times 40 \times 15}{4} \text{ N-mm} = 675000 \text{ N-mm} = 675 \text{ N-m}$$

5. (b)

Taper roller bearing of heavy series having 25 mm diameter.

6. (d)

Worm gearing. For higher reduction (more than 20), worm gears are used.

Here, $\quad \text{Gear ratio} = \frac{72 \times 60}{36} = 120$

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7. (a)

$$\delta = \frac{8WD^3n}{Gd^4}, \delta \propto n$$

$$\frac{\delta_1}{\delta_2} = \frac{n_1}{n_2} = \frac{32}{16} = 2$$

9. (d)

$$\text{Bending stress} = \frac{32M}{\pi d^3}$$

$$\text{Maximum bending stress} = k_t \frac{32M}{\pi d^3}$$

$$= 1.35 \times \frac{32 \times 180 \times 10^3}{\pi \times 25^3} = 158.41 \text{ MPa}$$

10. (d)

$$P = \frac{2\pi NT}{60}$$

$$\Rightarrow \quad T = \frac{P \times 60}{2\pi N} = \frac{130 \times 1000 \times 60}{2\pi \times 3600} = 344.8 \text{N.m}$$

$$T = \frac{\pi}{16}\tau d^3$$

$$\Rightarrow \quad 344.8 = \frac{\pi}{16} \times 40 \times 10^6 \times d^3$$

$$\Rightarrow \quad d = 0.0352 \text{ m} = 35.2 \text{ mm}$$

11. (d)

For single parallel fillet weld

$$P = 0.707\, t\, l\, \tau_{per}$$

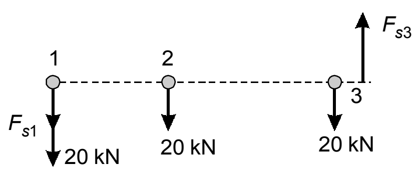
for double parallel fillet weld

$$P = 2 \times 0.707\, t\, l\, \tau_{per}$$

$$75 \times 10^3 = 2 \times 0.707 \times 12.5 \times l \times 90$$

$$l = 47.15 \text{ mm}$$

12. (c)



CG of system of rivets is at rivet 2.

Transferring the force at rivet 2.

$$\text{Primary force} = 20 \text{ kN at each rivet}$$

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$$\text{Eccentricity} = 120 \text{ mm}$$

$$F_{s1} \times 120 + F_{s2} \times 0 + F_{s3} \times 120 = 60 \times 120 \quad \text{...(i)}$$

$$F_{s1} = K \times 120 \quad \text{...(ii)}$$

$$F_{s3} = K \times 120 \quad \text{...(iii)}$$

From (i) and (ii)

$$K(120^2 + 120^2) = 60 \times 120$$

$$\Rightarrow \quad K = 0.25$$

$$F_{s1} = 120 \times 0.25 = 30 \text{ kN}$$

$$F_{s3} = 120 \times 0.25 = 30 \text{ kN}$$

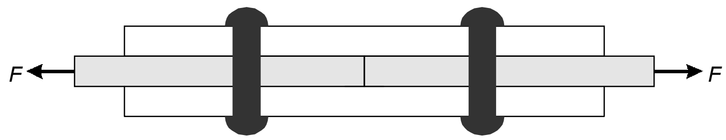
Rivet 1 has maximum amount of force

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

$$\Rightarrow \quad \frac{(20+30)\times 10^3}{\frac{\pi}{4}d^2} = 80$$

$$\Rightarrow \quad d = 28.21 \text{ mm}$$

13. (a)



Maximum shear force resisted by rivets

$$(P_{max})_{shear} = 2 \times \frac{\pi}{4}d^2 \times \tau_{per}$$

Strength of solid plate, $(P_{max})_{solid} = b\,t\,\sigma_{per}$

$$\eta = \frac{(P_{max})_{shear}}{(P_{max})_{solid}} = \frac{2 \times \frac{\pi}{4} \times 20^2 \times 90}{30 \times 100 \times 150} = 0.1256 = 12.56\%$$

14. (b)

$$\text{Effective length of bolt} = 3 \times 20 = 60 \text{ mm}$$

$$\text{Core area of the bolt} = \frac{\pi}{4} \times d_c^2 = \frac{\pi}{4} \times 25^2 = 490.874 \text{ mm}^2$$

$$\text{Stiffness of the bolt} = \frac{EA}{L} = \frac{180 \times 10^3 \times 490.874}{60} = 1.4726 \times 10^6 \text{ N/mm}$$

15. (d)

$$P_e = s(XVFr + YFa)$$

$$= 1(0.56 \times 1 \times 10 + 1 \times 5) = 10.6 \text{ kN}$$

$$L_{50} = 15000 \times 60 \times 1000 = 900 \text{ mR}$$

$$L_{50} = 5\,L_{10}$$

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$$L_{10} = \frac{900}{5} = 180 \text{ mR}$$

$$L_{10} = \left(\frac{C}{P_e}\right)^k$$

$$\Rightarrow \quad C = 180^{1/3} \times 10.6 \times 10^3 = 59.894 \text{ kN}$$

16. (a)

$$\tau = \frac{\mu V}{C}$$

$$= \frac{22 \times 10^{-3} \times 30 \times 22.5 \times 10^{-3}}{0.0225 \times 10^{-3}} = 660 \text{ N/m}^2$$

Force, $F = \tau A = 660 \times \pi \times 0.045 \times 0.045$ $(\because A = \pi d l)$

$$= 4.1987 \text{ N}$$

$$\text{Torque} = F \times r$$

$$= 4.1987 \times 22.5 \times 10^{-3}$$

$$= 0.09447 \text{ N-m} = 94.47 \text{ N-mm}$$

17. (b)

$$z = 16 \times 10^{-3} \text{ Pa-s}$$

$$n = \frac{1500}{60} \text{ rps} = 25 \text{ rps}$$

$$p = \frac{W}{ld} = \frac{60 \times 10^3}{0.1 \times 0.1} = 60 \times 10^5 \text{ N/m}^2$$

$$\mu = 2\pi^2 \left(\frac{zn}{p}\right)\left(\frac{r}{c}\right)$$

$$= 2\pi^2 \times \frac{16 \times 10^{-3} \times 25}{60 \times 10^5} \times \left(\frac{50}{0.12}\right)$$

$$= 5.4831 \times 10^{-4}$$

$$\text{Power loss} = \mu W v$$

$$= 5.4831 \times 10^{-4} \times 60 \times 10^3 \times \frac{\pi \times 0.1 \times 1500}{60}$$

$$= 258.38 \text{ W}$$

18. (c)

$$\text{Sum of pitch circle radius} = r_P + r_G = \frac{mz_P + mz_G}{2} = 480$$

$$z_P + z_G = 160 \qquad \text{...(i)}$$

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$$\text{Speed reduction} = \frac{4}{1} = \frac{z_G}{z_P}$$

$$\Rightarrow \quad z_G = 4\,z_P \qquad \text{...(ii)}$$

From (i) and (ii)

$$5\,z_P = 160$$

$$z_P = 32$$

19. (b)

$$P = 3500\text{ W}$$

$$N = 800\text{ rpm}$$

$$y = \text{form factor} = 0.25$$

$$b = \text{face width} = 44\text{ mm}$$

$$C_v = \text{velocity factor} = 1.4$$

$$m = 4\text{ mm}$$

$$z = 20$$

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

$$D = mz = 4 \times 20 = 80\text{ mm}$$

$$P = 2\pi NT = 2\pi \times \frac{800}{60} \times T = 3500$$

$$T = 41.778\text{ N-m} = 41.778 \times 10^3\text{ N-mm}$$

$$F_{\text{dynamic}} = F_t \,.\, C_v \,.\, s$$

$$= \frac{2T}{D} \times 1.4 \times 1 \qquad (\text{Assuming, } s = 1)$$

$$= \frac{2 \times 41.778 \times 10^3}{80} \times 1.4 = 1462.236\text{ N}$$

$$F_{\text{dynamic}} \le (F_t)_{\max}$$

$$1462.236 \le bmy(\sigma_b)_{\text{permissible}}$$

$$(\sigma_b)_{\text{permissible}} = \frac{1462.236}{44 \times 4 \times 0.25} = 33.23\text{ MPa}$$

20. (b)

Stiffness of spring, $$k = \frac{Gd^4}{8D^3N}$$

Deflection of spring, $$\delta = \frac{P}{k} = \frac{8PD^3N}{Gd^4} \qquad \text{...(i)}$$

Here in question, $$d_2 = d_1 + 0.08\,d_1 = 1.08\,d_1$$

Since from (i), $$\delta \propto \frac{1}{d^4}$$

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$$\frac{\delta_2}{\delta_1} = \left(\frac{d_1}{d_2}\right)^4 = \left(\frac{1}{1.08}\right)^4 = 0.735$$

$$\text{Change in deflection} = \frac{\delta_2 - \delta_1}{\delta_1} = \frac{0.735 - 1}{1} = -0.265$$

$$\% \text{ change} = -26.5\%$$

21. (b)

$$(\tau_{max})_1 = \frac{8W_1D_1}{\pi d_1^3} K_w$$

$$(\tau_{max})_2 = \frac{8W_2D_2}{\pi d_2^3} K_w$$

$$K_w = \frac{4c-1}{4c-4} + \frac{0.615}{c}$$

$$c = \frac{D}{d}$$

Since c remains unchanged, K_w will be same in both cases.

$$(\tau_{max})_2 = \frac{8(2W_1)(2D_1)}{\pi(2d_1)^3} \text{kw}$$

$$\frac{(\tau_{max})_2}{(\tau_{max})_1} = \frac{2 \times 2}{8} = \frac{1}{2}$$

$$\% \text{ change} = 100\frac{(\tau_{max})_2 - (\tau_{max})_1}{(\tau_{max})_1} = \frac{1/2 - 1}{1} \times 100 = -50\%$$

22. (c)

Here,

$$F_R = \mu R_N$$

$$\text{Torque of drum} = 400 \text{ N-m}$$

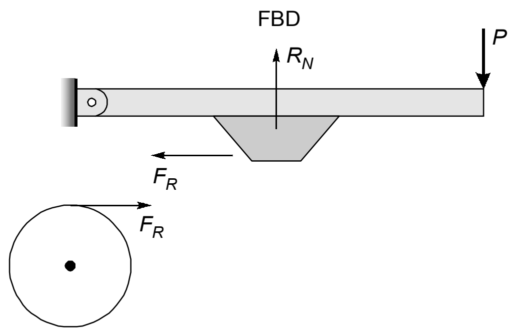
$$= 400 \times 10^3 \text{ N-mm}$$

$$\text{Torque} = F_R \times R$$

$$= \mu R_N \times R$$

$$400 \times 10^3 = 0.25 \times R_N \times 250$$

$$R_N = 6400 \text{ N}$$



23. (a)

$$\omega_1 = \frac{2\pi N_1}{60} = \frac{2 \times \pi \times 600}{60} = 62.8318 \text{ rad/s}$$

$$\omega_2 = \frac{2\pi N_2}{60} = \frac{2 \times \pi \times 900}{60} = 94.278 \text{ rad/s}$$

$$r_d = 160 \text{ mm} = 0.160 \text{ m}$$

$$r_g = 130 \text{ mm} = 0.130 \text{ m}$$

$$n = 4$$

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$$T_f = \frac{60 \times 10^6 \times (\text{kW})}{2\pi N_2} = \frac{60 \times 10^6 \times 30}{2 \times \pi \times 900} = 318309.88 \text{ N-mm}$$

$$= 318.3099 \text{ N-m}$$

$$T_f = n\mu r_g r_d m(\omega_2^2 - \omega_1^2)$$

$$318.3099 = 4 \times 0.35 \times 0.130 \times 0.160 \times m\,(94.278^2 - 62.8318^2)$$

$$m = 2.21 \text{ kg}$$

24. (b)

$$\text{Power} = \frac{2\pi N T_f}{60} \qquad \text{...(i)}$$

$$T_f = n \times \frac{2}{3}\mu\pi p_{\text{perm}}\left(R_0^3 - R_i^3\right)$$

$$= n \times \frac{2}{3} \times 0.25 \times \pi \times 2 \times 10^6 \times \left(0.1^3 - 0.06^3\right) = 821 \text{ N-m}$$

From (i), $\quad \text{Power} = 68780.17 \text{ kW} = 68.78 \text{ kW}$

25. (d)

$$\omega_1 = \frac{2\pi N_1}{60} = \frac{2 \times \pi \times 1200}{60} = 125.60 \text{ rad/s}$$

$$P = 2000 \text{ W}$$

$$T = \frac{P}{W} = 15.915 \text{ N-m}$$

$$I_q = mk^2 = 15 \times 0.2^2 = 0.6$$

$$\cancel{\frac{-T_1}{I_1}t}^{\,0} + \omega_1 = \frac{-T_2}{I_2}t + \cancel{\omega_2}^{\,0}$$

Initial speed of flywheel is zero and assuming motor is running at constant speed.

$$\omega_1 = \frac{T_2}{I_2}t$$

$$t = \frac{I_2\omega_1}{T} = \frac{0.6 \times 125.66}{15.915} = 4.74 \text{ sec}$$

26. (a)

$$\mu = 0.3$$

$$2\theta = 80^\circ$$

$$\Rightarrow \qquad \theta = 40^\circ$$

$$2\theta = \frac{80}{180} \times \pi = 1.3962$$

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$$\mu' = \mu \times \frac{4\sin\theta}{2\theta + \sin 2\theta}$$

$$= 0.28 \times \frac{4\sin 40^\circ}{1.3962 + \sin 80^\circ} = 0.30$$

27. (b)

$N = 2$, $\mu = 0.25$, $P_{max} = 100$ KPa, $R/r = 1.5$

$$T_f = N \times \mu \times W\left(\frac{R+r}{2}\right)$$

$$P_{max} \times r = \frac{W}{2\pi(R-r)}$$

$$0.1 \times r = \frac{W}{2\pi(1.5r - r)}$$

$$W = 0.31416\, r^2$$

$$T_f = 2 \times 0.25 \times 0.31416 r^2 \left(\frac{r + 1.5r}{2}\right)$$

$$120 \times 10^3 = 0.19635\, r^3$$

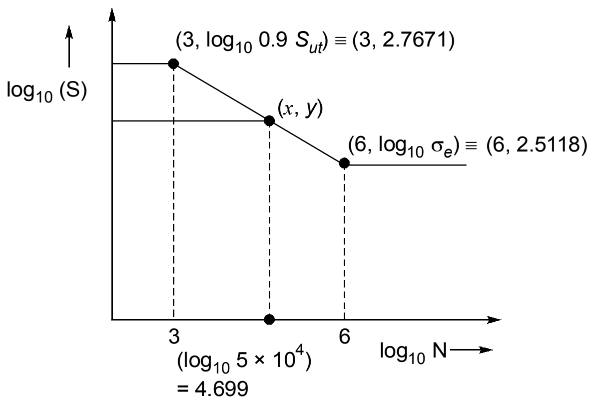
$$r^3 = 611153.55 \text{ mm}^3$$

$$r = 84.862 \text{ mm}$$

$$R = 127.294 \text{ mm}$$

$$\text{diameter} = 254.588 \text{ mm}$$

28. (c)



$$(y - 2.7671) = \frac{2.5118 - 2.7671}{6 - 3} \times (4.699 - 3)$$

$$y = 2.6225$$

$$y = \log_{10} \sigma_f$$

$$\sigma_f = 419.29 \text{ MPa}$$

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29. (b)

According to Goodman,

$$\frac{\sigma_m}{S_{ut}} + \frac{\sigma_a}{S_e} \le \frac{1}{N} \quad \text{...(i)}$$

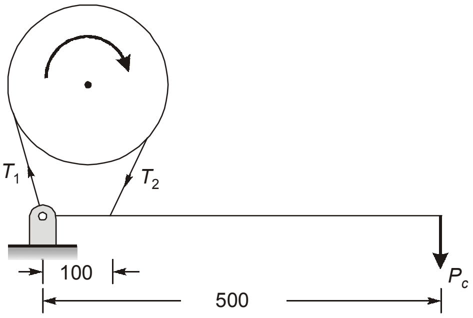
Given,

$$\sigma_{max} = 350 \text{ MPa}$$
$$\sigma_{min} = -150 \text{ MPa}$$
$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2} = \frac{350 - 150}{2} = 100 \text{ MPa}$$
$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{350 + 150}{2} = 250 \text{ MPa}$$

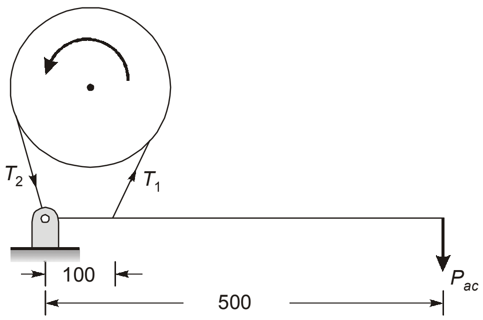
From equation (i),

$$\frac{100}{S_{ut}} + \frac{250}{0.5 S_{ut}} = \frac{1}{2.5}$$
$$S_{ut} = 1500 \text{ MPa}$$

30. (d)



(Figure a)



(Figure b)

The tension ratio,

$$\frac{T_1}{T_2} = e^{\mu\theta}$$
$$= e^{\frac{\pi}{180} \times 270 \times 0.2}$$
$$= e^{0.94298} = 2.566$$

$$\Rightarrow \quad \frac{T_1}{T_2} = 2.566 \quad \text{...(i)}$$

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$$\text{Torque, } T = (T_1 - T_2)r$$

$$\frac{P \times 60}{2\pi N} = (T_1 - T_2)0.5$$

$$\Rightarrow \quad \frac{50000 \times 60}{2\pi \times 300} = (T_1 - T_2) \times 0.5$$

$$\Rightarrow \quad (T_1 - T_2) = 3183.1 \quad \text{...(ii)}$$

From equation (i) and (ii), we get

$$T_1 = 5215.72 \text{ N}$$

$$T_2 = 2032.63 \text{ N}$$

For minimum force and its direction: It is required to be checked which direction gives less force.

Considering clockwise direction [figure (a)].

For equilibrium,

$$P_c \times 500 = T_2 \times \frac{100}{\cos 45°}$$

$$P_c = \frac{2032.63 \times 100}{500 \times \cos 45°} = 574.9 \text{ N}$$

Considering anticlockwise direction, [figure (b)]

For equilibrium,

$$P_{ac} \times 500 = T_1 \times \frac{100}{\cos 45°}$$

$$\Rightarrow \quad P_{ac} = 1475.23 \text{ N}$$

In clockwise direction pull is minimum.

575 N in clockwise direction.

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