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Machine Design

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Date of Test : 18/09/2019

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.	(b)

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)

Safe load = no. of rivets × projected area of rivet on one plate × bearing stress
= 2 × 20 × 25 × 150 = 150000 N = 150 kN

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)

$$t = 15 \text{ mm}$$
$$l = 40 \text{ mm}$$
$$D = 50 \text{ mm}$$

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

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

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, Gear ratio $= \dfrac{72 \times 60}{36} = 120$

7. (a)

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

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

8. (b)

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)

$$V = \frac{\pi DN}{60} = \frac{\pi \times 0.25 \times 1200}{60} = 15.708 \text{ m/s}$$

$$\sigma_{max} = \rho V^2 = 6500 \times 15.708^2$$

$$= 1603.810 \text{ kPa}$$

11. (d)

For single parallel fillet weld

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

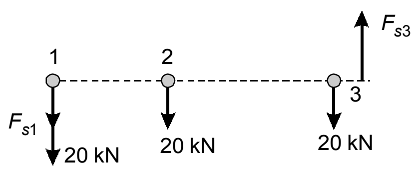
for double parallel fillet weld

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

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

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

12. (c)



CG of system of rivets is at rivet 2.

Transferring the force at rivet 2.

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

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

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

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

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

From (i) and (ii)

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

$$\Rightarrow \quad K = 0.25$$

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

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

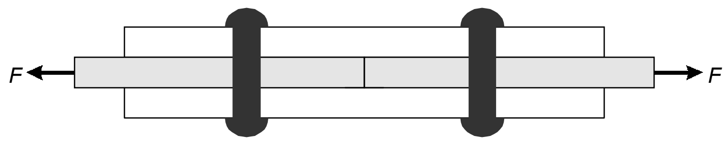
Rivet 1 has maximum amount of force

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

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

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

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

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

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)

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

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

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

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

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

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

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

16. (a)

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

$$= \frac{22\times10^{-3}\times30\times22.5\times10^{-3}}{0.0225\times10^{-3}} = 660 \text{ N/m}^2$$

Force, $F = \tau A = 660\times\pi\times0.045\times0.045$ $(\because A = \pi dl)$

$$= 4.1987 \text{ N}$$

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

$$= 4.1987\times22.5\times10^{-3}$$

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

17. (b)

$$z = 16\times10^{-3} \text{ Pa-s}$$

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

$$p = \frac{W}{ld} = \frac{60\times10^3}{0.1\times0.1} = 60\times10^5 \text{ N/m}^2$$

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

$$= 2\pi^2\times\frac{16\times10^{-3}\times25}{60\times10^5}\times\left(\frac{50}{0.12}\right)$$

$$= 5.4831\times10^{-4}$$

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

$$= 5.4831\times10^{-4}\times60\times10^3\times\frac{\pi\times0.1\times1500}{60}$$

$$= 258.38 \text{ W}$$

18. (c)

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

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

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

$\Rightarrow$

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

From (i) and (ii)

$$5z_P = 160$$

$$z_P = 32$$

19. (b)

$$P = 3500\text{ W}$$
$$N = 800\text{ rpm}$$
$$y = \text{form factor} = 0.25$$
$$b = \text{face width} = 44\text{ mm}$$
$$C_v = \text{velocity factor} = 1.4$$
$$m = 4\text{ mm}$$
$$z = 20$$
$$F_t = \frac{2T}{D}$$
$$D = mz = 4 \times 20 = 80\text{ mm}$$
$$P = 2\pi NT = 2\pi \times \frac{800}{60} \times T = 3500$$
$$T = 41.778\text{ N-m} = 41.778 \times 10^3\text{ N-mm}$$
$$F_{dynamic} = F_t \,.\, C_v \,.\, s$$
$$= \frac{2T}{D} \times 1.4 \times 1 \qquad \text{(Assuming, } s = 1\text{)}$$
$$= \frac{2 \times 41.778 \times 10^3}{80} \times 1.4 = 1462.236\text{ N}$$
$$F_{dynamic} \leq (F_t)_{max}$$
$$1462.236 \leq bmy(\sigma_b)_{permissible}$$
$$(\sigma_b)_{permissible} = \frac{1462.236}{44 \times 4 \times 0.25} = 33.23\text{ MPa}$$

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), $$\delta \propto \frac{1}{d^4}$$

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

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,

$$F_R = \mu R_N$$

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

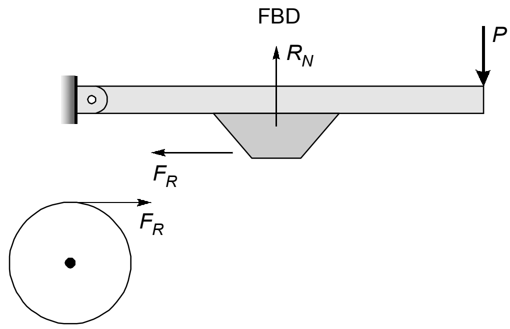
$$= 400\times 10^3 \text{ N-mm}$$

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

$$= \mu R_N \times R$$

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

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



23. (a)

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

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

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

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

$$n = 4$$

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

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

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

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

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

24. (b)

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

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

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

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

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)

$$\mu = 0.3$$

$$2\theta = 80°$$

$$\Rightarrow \quad \theta = 40°$$

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

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

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

27. (b)

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

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

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

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

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

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

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

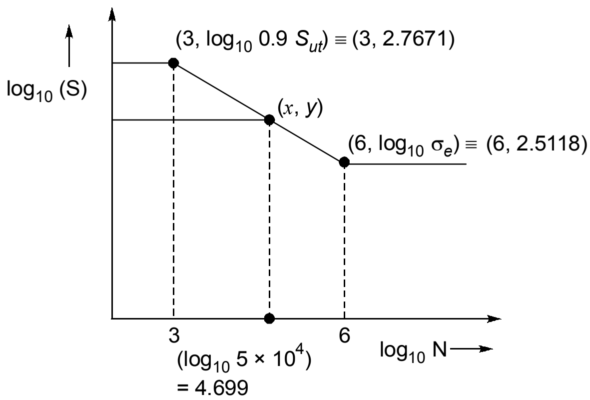
$$r^3 = 611153.55 \text{ mm}^3$$

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

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

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

28. (c)



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

$$y = 2.6225$$

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

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

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. (b)

$$(\sigma)_{max} = \frac{\sigma v^2}{10^6} \frac{(\mu + 3)}{8}$$

$$25 = \frac{8000 \times v^2 \times (3 + 0.26)}{8 \times 10^6}$$

$$v = 87.57 \text{ m/s}$$

$$v = R \times \omega$$

$$\omega = 437.856 \text{ rad/s}$$

$$E_{max} = \frac{1}{2} I \times \omega^2 = 143.785 \text{ kJ}$$

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