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Machine Design

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Date of Test : 25/09/2019

ANSWER KEY ➤ Machine Design

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

Detailed Explanations

1. (d)

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

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

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

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

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

2. (b)

Since the key is wider than its depth or thickness, it fail due to compression, before it will fail due to shear.

$$T = F \times \frac{d}{2}$$

$$= \left(l \times \frac{t}{2}\right) \times \sigma_c \times \frac{d}{2}$$

$$700 = \left(l \times \frac{0.009}{2}\right) \times 110 \times 10^6 \times \frac{0.04}{2}$$

$$l = 0.07 \text{ m}$$

$$= 70 \text{ mm}$$

4. (c)

$$\text{Length of arc of contact} = \frac{\text{Length of line of action}}{\cos\phi} = \frac{20}{\cos 20^\circ} = 21.28 \text{mm}$$

$$\text{Circular pitch, } P_c = \pi m = 5\pi$$

$$\text{Contact ratio} = \frac{\text{Length of arc of contact}}{\text{Circular pitch}} = \frac{21.28}{5\pi} = 1.355$$

5. (b)

$$\text{Energy of impact, } U = \frac{1}{2} P \cdot \delta \qquad \left(\delta = \frac{PL}{AE}\right)$$

$$= \frac{P^2 L}{2AE}$$

$$\Rightarrow \quad P \propto \frac{1}{\sqrt{L}} \text{ and } P \propto \sqrt{A}$$

7. (b)

$$a = \frac{V}{t} = \frac{10}{10} = 1 \text{ m/s}^2$$

Additional load due upward acceleration of rope,

$$W_a = \frac{W}{g} \times a = \frac{50 \times 10^3}{9.81} \times 1 = 5097 \text{ N}$$

8. (a)

$$T_s = \frac{2.83T}{\pi h d^2}$$

$$\Rightarrow \quad 140 = \frac{2.83 \times 5000 \times 10^3}{\pi \times h \times 100^2}$$

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

11. (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

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

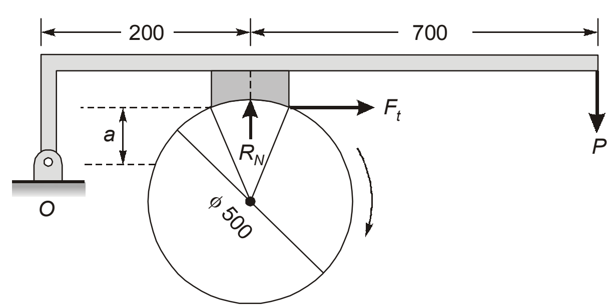
$$= \frac{8000}{2\pi(0.2-0.1)0.1} = 127323.9 \text{ N/m}^2$$

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

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

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

12. (a)



$$T = F_t \times r$$

$$= \mu R_N \times r$$

$$500 = 0.3 \times R_N \times 0.25$$

$$\Rightarrow \quad R_N = 6666.67 \text{ N}$$

$$F_T = \mu R_N = 0.3 \times 6666.7 = 2000 \text{ N}$$

Taking moment about O :

$$P \times (200 + 700) + F_t \times a = R_N \times 200$$

For self locking $P = 0$

$$\Rightarrow \quad 0 + 2000 \times a = 6666.67 \times 200$$

$$\Rightarrow \quad a = 666.67 \text{ mm}$$

13. (c)

In 1932, 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.

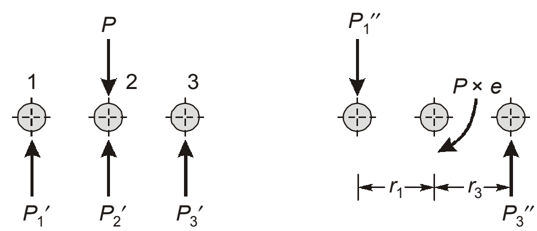
Buckingham has incorporated the effect of inaccuracies of tooth profile.

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.

14. (d)

$$\text{Permissible shear stress, } \tau_{per} = \frac{\tau_y}{N} = \frac{0.5\sigma_y}{N} = \frac{0.5 \times 380}{3} = 63.33\,\text{MPa}$$

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).



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

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

Resultant shear force on bolt (3) is maximum.

$$P_3 = P_3' + P_3'' = 3333.33 + 20333.33$$

$$= 23666.67\,\text{N}$$

$$\tau = \frac{P_3}{A} = \frac{23666.67}{\frac{\pi}{4} d_c{}^2} \le 63.33 \qquad [\text{Given } \tau_{yt} = 0.5\sigma_{yt}]$$

$\Rightarrow$ Size of bolt, $d_c \geq 21.8$ mm

15. (a)

Given, $P = 10\text{ kN} = 1000\text{ N}$

Permissible tensile stress,

$$(\sigma_t)_{max} = \frac{\sigma_{yt}}{N} = \frac{400}{3} = 133.33$$

Given, $k_c = 3k_b$

$$\Delta p = p\left(\frac{k_b}{k_b + k_c}\right) = 1000\left[\frac{k_b}{k_b + 3k_b}\right] = 2500\,\text{N}$$

Resultant load on the bolt,

$$p_b = p_i + \Delta p \qquad (p_i \text{ will be tensile in bolt})$$

$$= 3000 + 2500 = 5500\text{ N}$$

$$(\sigma_t)_{max} = \frac{p_b}{\frac{\pi}{4}d^2} \Rightarrow 133.33 = \frac{5500 \times 4}{\pi \times d_c^2}$$

$$\Rightarrow \quad d_c = 7.25 \text{ mm}$$

16. (a)

Strength of transverse fillet weld,

$$P_t = 0.707\, h\, l\, \sigma_t$$

$$= 0.707 \times 20 \times 150 \times 70 = 148470 \text{ N}$$

Strength of double parallel fillet weld,

$$P_p = 2 \times 0.707\, h\, l\, \tau_s$$

$$= 1.414 \times 20 \times l \times 50 = 1414\, l$$

$$220 \times 10^3 = 148470 + 1414\, l$$

$$\Rightarrow \quad l = 50.58 \text{ mm}$$

17. (d)

$$\sigma_{nominal} = \frac{P}{(w-d)t} = \frac{12 \times 10^3}{40 \times 10} = 30 \text{ N/mm}^2$$

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

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

$$\Rightarrow \quad k_t = 2.5 \text{ (from table)}$$

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

18. (c)

As $t = 6 \text{ mm} < 8 \text{ mm}$

$\therefore$ We should equate shear resistance and crushing resistance to get the value of 'd'. We should not use Unwin's formula as $t < 8$ mm

Now, Shear resistance $P_s = n \times \dfrac{\pi}{4} d^2 \times \tau$

$$= 3 \times \frac{\pi}{4} \times d^2 \times 60 \quad \text{...(i)}$$

Crushing resistance, $P_c = n d t \sigma_c$

$$= 3 \times d \times 6 \times 100 \quad \text{...(ii)}$$

$$P_s = P_c$$

$$3 \times \frac{\pi}{4} \times d^2 \times 60 = 3 \times d \times 6 \times 100$$

$$\Rightarrow \quad d = \frac{3 \times 6 \times 100 \times 4}{3 \times \pi \times 60} = 12.732 \text{ mm}$$

19. (b)

$$\sigma_{min} = -100 \text{ MPa}$$

$$\sigma_{max} = 200 \text{ MPa}$$

$$\sigma_{mean}(\sigma_m) = \frac{\sigma_{max} + \sigma_{min}}{2} = 50 \text{ MPa}$$

$$\sigma_{variable}(\sigma_v) = \frac{\sigma_{max} - \sigma_{min}}{2} = 150 \text{ MPa}$$

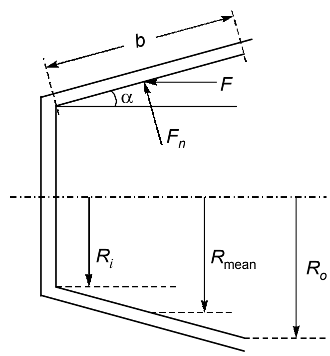
Now, $$\frac{\sigma_m}{\sigma_u} + \frac{\sigma_v k_f}{\sigma_e k_{size} k_{surface\ finish} k_{bending}} = \frac{1}{FS}$$

$$\Rightarrow \quad \frac{50}{\sigma_u} + \frac{150 \times 1}{0.5\sigma_u \times 1 \times 0.85 \times 0.9} = \frac{1}{2}$$

$$\Rightarrow \quad \sigma_u = 884.3137 \text{ MPa}$$

21. (c)

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



$$350 = 0.3 \times F_n \times \frac{300}{2} \times 10^{-3}$$

$$\Rightarrow \quad F_n = 7777.778 \text{ N}$$

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

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

$$7777.778 = 2 \times \pi \times 150 \times 10^3 \times \frac{300}{2} \times 10^{-3} \times b$$

$$\Rightarrow \quad b = 0.055 \text{ m} = 55 \text{ mm}$$

22. (c)

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

Wear strength, $$S_w \text{ (or) } P_w = kQwd_p$$

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

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

$$w = 100 \text{ mm}$$

$$d_p = 400 \text{ mm}$$

Now, $P_w = kQwd_p$

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

23. (b)

p_{max} occurs at the inner radius of the disk clutch

$$p_i = 10^5 \text{ N/m}^2$$
$$r_o = 100 \text{ mm} = 0.1 \text{ m}$$
$$r_i = 60 \text{ mm} = 0.06 \text{ m}$$
$$I = 6.5 \text{ kg-m}^2$$
$$P = 2\pi C(r_o - r_i) = 2\pi p_i r_i (r_o - r_i)$$
$$= 2\pi C(r_o - r_i) = 2\pi p_i r_i (r_o - r_i)$$
$$= 2 \times \pi \times 100{,}000 \times 0.06(0.1 - 0.06) = 1507.964 \text{ N}$$

Now, $T = \mu P r_{mean} \times n$ (n = no. of effective surfaces)

$$= 0.3 \times 1507.964 \times \left(\frac{0.1 + 0.06}{2}\right) \times 2 = 72.3822 \text{ N-m}$$

Now, $T = I\alpha$

$$72.3822 = 6.5 \times \alpha$$
$$\omega = \omega_o + \alpha t$$
$$\omega_o = 0$$

$\therefore$ $$\alpha = \frac{\omega}{t}$$

$\therefore$ $$72.3822 = \frac{6.5 \times \dfrac{2 \times \pi \times 250}{60}}{t}$$

$\Rightarrow$ $$t = 2.35098 \approx 2.351 \text{ second}$$

24. (c)

$$P_{min} = -20 \text{ kN}$$
$$P_{max} = 30 \text{ kN}$$
$$P_{mean}(P_m) = \frac{P_{min} + P_{max}}{2} = 5 \text{ kN}$$
$$P_{variable}(P_V) = \frac{P_{max} - P_{min}}{2} = 25 \text{ kN}$$

Now, $$\sigma_m = \frac{5000}{\frac{\pi}{4}d^2}, \quad \sigma_v = \frac{25000}{\frac{\pi}{4}d^2}$$ [σ_m = mean stress, σ_v = variable stress]

$$k_f = 1 + q(k_t - 1) = 1 + 0.8 \times (2.5 - 1) = 2.2$$

From Soderberg equation,

Now, $$\frac{\sigma_m}{\sigma_y} + \frac{k_f \sigma_v}{\sigma_e} = \frac{1}{FS}$$ (where FS = factor of safety)

$$\frac{5000}{\frac{\pi}{4}d^2 \times 920} + \frac{2.2 \times 25000}{\frac{\pi}{4}d^2 \times 540} = \frac{1}{2}$$

$\Rightarrow$ $d^2 = 273.203$

$\Rightarrow$ $d = 16.528 \text{ mm} \approx 17 \text{ mm}$

25. (c)

$$\mu = 2\pi^2\left(\frac{Zn}{P}\right)\left(\frac{D}{C}\right)$$

$$= 2\pi^2\left(\frac{0.0207 \times n}{\frac{2800}{0.075 \times 0.065}}\right)\left(\frac{0.065}{0.05 \times 10^{-3}}\right)$$

$$= 9.248 \times 10^{-4}\, n$$

As $H_g = H_d$

$\Rightarrow$ $\mu WV = 80$

$\Rightarrow$ $(9.248 \times 10^{-4}\, n) \times (2800) \times (\pi \times 0.65\, n) = 80$

$\Rightarrow$ $n^2 = 151.293$

$\Rightarrow$ $n = 12.30$

$\Rightarrow$ $N = 738 \text{ rpm}$

26. (c)

$C = 33.5 \text{ kN}$

$P = 44.5 \text{ kN}$

$$L_{10} = \left(\frac{C}{P}\right)^n = \left(\frac{C}{P}\right)^3 \qquad (\because \text{ball bearing, } n = 3)$$

$$= \left(\frac{33.5}{44.5}\right)^3 = 0.4266 \text{ million revolutions}$$

$$L_{10} = \frac{60NL_h}{10^6} = \frac{60 \times 1800 \times L_h}{10^6} = 0.4266$$

$\Rightarrow$ $L_h = 3.95 \text{ hours}$

Now, Average life in hours, $L_{50} = 5 \times (L_{10}) \text{ in hours} = 5 \times L_h$

$= 5 \times 3.95 = 19.75 \text{ hours}$

27. (a)

Equivalent load: $F_{eq} = XVF_r + YF_a$

$= 0.56 \times 1 \times 1800 + 1.3205 \times 1200 = 2592.6 \text{ N}$

$$\text{Rated life, } L = \left(\frac{C}{W}\right)^3 \times 10^6 = \left(\frac{14000}{2592.6}\right)^3 \times 10^6$$

$$= 157.46 \times 10^6 \text{ rev}$$

28. (b)

Loss of torque due to viscosity of oil,

$$T = F \times \frac{D}{2} = (\tau \times A) \times \frac{D}{2}$$

$$= \left(\mu \cdot \frac{du}{dy}\right)\pi DL \times \frac{D}{2} = \mu\left(\frac{u}{c}\right)\pi DL \times \frac{D}{2}$$

$$= \left(\frac{\mu \times \pi DN}{60\,c}\right) \times \pi DL \times \frac{D}{2} = \frac{\mu \times \pi^2 \times D^3 \cdot NL}{120\,c}$$

$$= \frac{0.04 \times \pi^2 \times \left(70 \times 10^{-3}\right)^3 \times 1800 \times 70 \times 10^{-3}}{120 \times 0.04 \times 10^{-3}} = 3.55\,\text{Nm}$$

29. (c)

$$T_{\text{mean}} = \frac{T_{\max} + T_{\min}}{2} = \frac{4000 + 1500}{2} = 2750\,\text{Nm}$$

$$T_{\text{variable}} = \frac{T_{\max} - T_{\min}}{2} = \frac{4000 - 1500}{2} = 1250\,\text{Nm}$$

$$\tau_m = \frac{16T_m}{\pi d^3} = \frac{16 \times 2750}{\pi \times (0.06)^3} = 64.84\text{ MPa}$$

$$\tau_v = \frac{16\,T_V}{\pi d^3} = \frac{16 \times 1250}{\pi \times (0.06)^3} = 29.47\,\text{MPa}$$

$$\tau_y = 0.6 \times \sigma_y = 0.6 \times 400 = 240\text{ MPa}$$

$$\tau_e = 0.5 \times \sigma_u = 0.5 \times 600 = 300\text{ MPa}$$

Using Soderberg equation

$$\frac{1}{N} = \frac{\tau_m}{\tau_y} + \frac{\tau_v}{\tau_e} = \frac{64.84}{240} + \frac{29.47}{300}$$

$$\Rightarrow \quad N = 2.7$$

30. (d)

$$T = \frac{P \times 60}{2\pi N} = \frac{20 \times 10^3 \times 60}{2\pi \times 4000} = 47.74 = \mu W R_m$$

$$\Rightarrow \quad R_m = \frac{T}{\mu W}$$

$$\Rightarrow \quad \frac{2}{3}\left(\frac{r_0^3 - r_i^3}{r_0^2 - r_i^2}\right) = \frac{T}{\mu \times P \times \pi\left(r_0^2 - r_i^2\right)}$$

$$\Rightarrow \quad \left(r_0^3 - r_i^3\right) = \frac{3T}{2\mu P\pi}$$

$$\Rightarrow \quad r_0^3 = r_i^3 + \frac{3T}{2\mu P\pi}$$

$$r_i^3 = \left(50 \times 10^{-3}\right)^3 - \frac{3 \times 47.74}{2 \times 0.3 \times 1.2 \times 10^6 \times \pi}$$

$$r_i = 0.0395\text{ m} = 39.5\text{ mm}$$

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