CLASS TEST

Sl. 01SPME_ABCD_18092023

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MACHINE DESIGN

MECHANICAL ENGINEERING

Date of Test : 18/09/2023

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)
The point where the cross-section changes abruptly experiences maximum stress due to stress concentration.

5. (a)
For shearing failure,

$$\text{load}(P_s) = \tau_{max.}\left(\frac{\pi}{4}d^2\right) = 95\times\left(\frac{\pi}{4}\times16^2\right) = 19.1\text{ kN}$$

For bearing (crushing failure),

$$\text{load }(P_c) = \sigma_c\,(d\times t) \qquad [t = \text{thickness, take minimum thickness}]$$

$$= 280\times16\times10 = 44.8\text{ kN}$$

$\therefore \quad P_s < P_c$

$\therefore \quad \text{strength} = 19.1\text{ kN}$

6. (a)
Rankine theory is used primarity for brittle materials as these are weakest in tension.

7. (c)
When a material is fully sensitive to notches,

$\Rightarrow \quad q = 1$

So, $\quad k_f = 1 + q(k_t - 1) = 1 + (k_t - 1)$

$k_f = k_t$

8. (b)

$$T_e = \sqrt{(k_bM)^2 + (k_TT)^2} = \sqrt{(1.5\times1200)^2 + (1.1\times530)^2} = 1892.05\text{ Nm}$$

9. (c)

$$T = \frac{\mu\pi p_a}{8}d_i\left(D^2 - d_i^2\right)$$

For maximum torque, $\dfrac{dT}{d(d_i)} = 0$

$$= \frac{d}{d(d_i)}\left[D^2d_i - d_i^3\right] = 0$$

On solving, $\quad d_i = \dfrac{D}{\sqrt{3}}$

10. (c)

$\sigma_1 = 360\text{ MPa}$

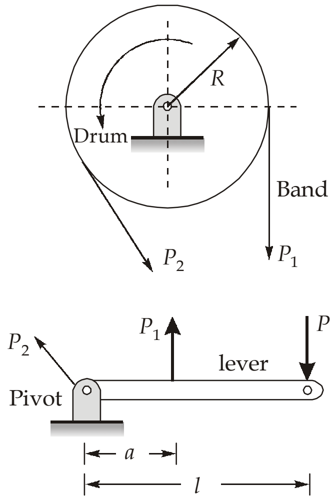
$\sigma_2 = 140\text{ MPa}$

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

$$= \sqrt{(360)^2 - 140\times360 + 140^2}$$

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

11. (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 $$M_t = (P_1 - P_2) \times R$$

$$= (4500 - 1800) \times 250$$

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

12. (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

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

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

13. (a)

Given: $P = 40$ kW $\quad N_2 = 900$ rpm

$$\omega_2 = \frac{2\pi N_2}{60} = \frac{2\pi \times 900}{60} = 94.24 \text{ rad/s}$$

$$\omega_1 = 0.7 \times 94.24 = 65.97 \text{ rad/s}$$

$R = 0.15$ m $\quad r = 0.12$ m

$\mu = 0.3 \quad n = 3$

Torque, $$T = \frac{P \times 60}{2\pi N_2} = \frac{40 \times 1000 \times 60}{2\pi \times 900} = 424.41 \text{ Nm}$$

$$T = n\mu r m R\left(\omega_2^2 - \omega_1^2\right)$$

$$424.41 = 3 \times 0.3 \times 0.12 \times m \times 0.15\,(94.24^2 - 65.97^2)$$

Mass of each shoe, m = **5.78 kg**

14. (a)

$$k_t = \frac{A_t E}{L_t} \text{ (Stiffness in threaded portion)}$$

$$k_t = \frac{84.3 \times 200 \times 10^3}{30 \times 10^{-3}} = 562 \times 10^6 \text{ N/m} = 562 \text{ MN/m}$$

$$k_d = \frac{A_d E}{L_d} \text{ (Stiffness in unthreaded region)}$$

A_d (major diameter c/s area)

$$= \frac{\pi}{4} d^2 = 0.785 \times 144 = 113.04 \text{ mm}^2$$

L_d (length of unthreaded portion) = 8 mm

$$\therefore \quad k_d = \frac{113.04 \times 200 \times 10^3}{8 \times 10^{-3}}$$

$$= 2826 \times 10^6 \text{ N/m} = 2826 \text{ MN/m}$$

$$\frac{1}{k} = \frac{1}{k_t} + \frac{1}{k_d}$$

$$\Rightarrow \quad k = \frac{k_d k_t}{k_d + k_t} = \frac{2826 \times 562}{2826 + 562} = 468.77 \text{ MN/m}$$

16. (b)

$$L(P)^3 = \text{Constant}$$

$$\frac{L_1}{L_2} = \left(\frac{P_2}{P_1}\right)^3$$

$$\Rightarrow \quad \frac{1000 \times 60 \times 3000}{2000 \times 60 \times t_2} = \left(\frac{4900}{9800}\right)^3$$

$$t_2 = 12000 \text{ hours}$$

17. (b)

$$\text{Torque} = \text{Force} \times \text{Radius}$$

$$1000 = (T_1 - T_2) \times \left(\frac{0.24}{2}\right)$$

$$(T_1 - T_2) = 8333.33 \text{ N}$$

$$\frac{T_1}{T_2} = e^{\mu\theta} = e^{0.3 \times 240 \times \frac{\pi}{180}} = 3.514$$

$$\frac{T_1}{T_2} = 3.514$$

$$T_1 = 3.514\, T_2$$

$$T_1 - T_2 = 8333.33 \text{ N}$$

$$3.514\,T_2 - T_2 = 8333.33 \text{ N}$$
$$T_2 = 3314.77 \text{ N}$$
$$T_1 = \mathbf{11648\ N = 11.65\ kN}$$

18. (d)

$$T = 79.6 \times 10^3 \text{ Nmm}$$
$$M = (W + T_1 + T_2)\,300 = (507 + 1303 + 200) \times 300$$
$$= 603 \times 10^3 \text{ Nmm}$$
$$T_e = \sqrt{M^2 + T^2} = 608.23 \times 10^3 \text{ Nmm}$$
$$\therefore \quad \frac{\pi d^3 \times 35}{16} = 608.23 \times 10^3$$
$$\Rightarrow \quad d = 44.57 \text{ mm}$$

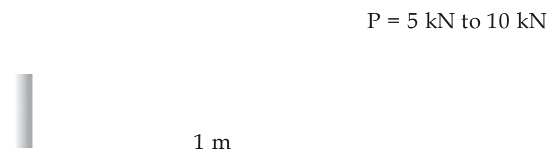
19. (b)

$$\text{Ratio factor, } Q = \frac{2T_g}{T_g + T_P} = \frac{2 \times 60}{60 + 20} = 1.5$$
$$\text{Load stress factor, } K = 0.16\left(\frac{BHN}{100}\right)^2 = 0.16\left(\frac{300}{100}\right)^2 = 1.44 \text{ N/mm}^2$$
$$d_P = mT_P = 2 \times 20 = 40 \text{ mm}$$

Wear strength of pinion teeth,

$$S_w = bQd_PK = 20 \times 1.5 \times 40 \times 1.44 = \mathbf{1728\ N}$$

20. (a)



$$P_a = \frac{P_{max} - P_{min}}{2} = \frac{10 - 5}{2} = 2.5 \text{kN}$$
$$P_m = \frac{P_{max} + P_{min}}{2} = \frac{10 + 5}{2} = 7.5 \text{kN}$$
$$\sigma_a = \frac{M_a}{z} = \frac{2.5 \times 1 \times 10^6}{5 \times 10^4} = 50 \text{ MPa}$$

Similarly $\sigma_m = 150$ MPa

As per soderberg criteria of failure,

$$\frac{1}{FOS} = \frac{\sigma_a \times k_f}{\sigma_e} + \frac{\sigma_m}{\sigma_{yt}}$$ (k_t is not required for ductile material)

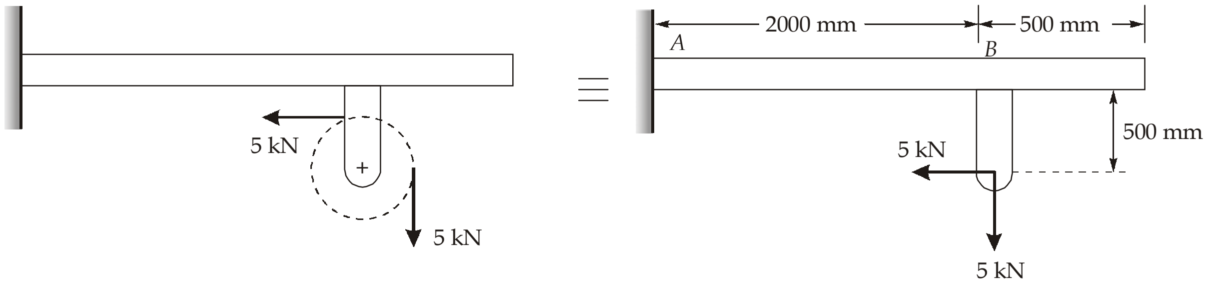
$$k_f = 1 + q(k_t - 1) = 1 + 0.4(2.5 - 1) = 1.6$$
$$\frac{1}{FOS} = \frac{1.6 \times 50}{150} + \frac{150}{250}$$
$$\Rightarrow \quad FOS = 0.8823$$

(Hence, material will fail after certain no. of cycles)

21. (a)

Given: $\frac{d}{w} = 2$

$\sigma_{max} = 80$ MPa



Bending moment at A,

$$= 5 \times 2000 + 5 \times 500 = 12500 \text{ kNmm}$$

$$\text{Section modulus, } z = \frac{wd^2}{6} = \frac{d^3}{12}$$

As, $$\sigma = \frac{M}{z}$$

$$\Rightarrow \quad 80 = \frac{12500 \times 10^3 \text{ Nmm}}{\left(\frac{d^3}{12}\right)}$$

$$\Rightarrow \quad d = 123.31 \text{ mm} \simeq 124 \text{ mm}$$ ....Ans.

$$w = \frac{d}{2} = 62 \text{ mm}$$ ....Ans.

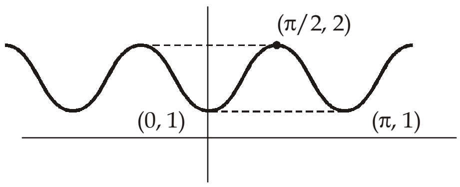
22. (b)

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

23. (d)

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

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



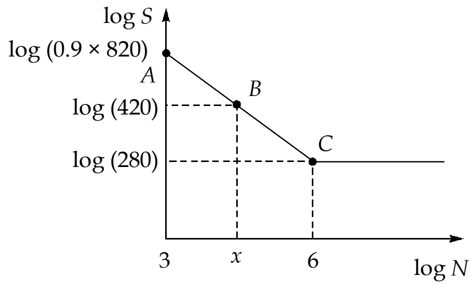
$$P_{max} = 50 \times 2 = 100 \text{ N}$$
$$P_{min} = 50 \text{ N}$$

$$P_m = \frac{1}{2}(P_{max} + P_{min}) = \frac{1}{2}(100 + 50) = 75 \text{ N}$$

$$P_a = \frac{1}{2}(P_{max} - P_{min}) = \frac{1}{2}(100 - 50) = 25 \text{ N}$$

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

24. (c)



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

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

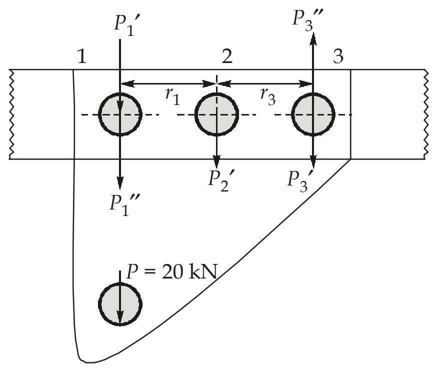
$$x = 4.7448$$

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

25. (c)

$r_1 = 80$ mm, $r_2 = 0$

$r_3 = 80$ mm, $e = 80$ mm



Primary direct force, $P_1' = P_2' = P_3' = \dfrac{P}{3} = \dfrac{20\times10^3}{3}$

$= 6666.67$ N

Secondary shear force, $c = \dfrac{P.e}{r_1^2+r_2^2+r_3^2} = \dfrac{20\times10^3\times80}{(80)^2+(0)^2+80^2}$

$= \dfrac{20\times10^3\times80}{2\times(80)^2} = 125$ 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

26. (d)

$F = 20$ kN, $R_0 = 2.5\,R_i$

$P = 300$ kN/m^2, $N = 150$ rpm

$\mu = 0.04$, $\alpha = \frac{110°}{2} = 55°$

$$p = \frac{F}{\pi(R_0^2 - R_i^2)}$$

$$300 \times 10^3 = \frac{20 \times 10^3}{\pi[(2.5R_i)^2 - R_i^2]}$$

$$(2.5R_i)^2 - R_i^2 = \frac{20 \times 10^3}{\pi \times 300 \times 10^3} = 0.0212$$

$R_i = 0.06354$ m

$R_0 = 0.15886$ m

$D_0 = 317.73$ mm

27. (c)

$$\tau = \frac{S_{ys}}{fos} = \frac{0.5S_{yt}}{fos} = \frac{0.5 \times 400}{3} = 66.66 \text{ MPa}$$

$$\text{Shear area of 4 bolts} = 4\left(\frac{\pi}{4}d^2\right)$$

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

$$66.66 = \frac{6 \times 1000}{\pi \times d^2}$$

$d = 5.35$ mm

28. (c)

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

29. (c)

Given: $d_2 = 200$ mm, $r_2 = 100$ mm

$d_1 = 80$ mm, $r_1 = 40$ mm

$P = 3$ MPa, $\mu = 0.3$

$$R_m = \frac{2}{3}\left(\frac{r_2^3 - r_1^3}{r_2^2 - r_1^2}\right) = 74.28 \text{ mm}$$

$$W = P.\pi(r_2^2 - r_1^2) = 3 \times \pi\,(100^2 - 40^2)$$

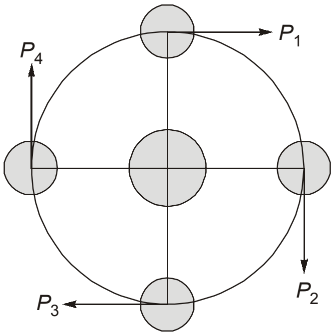
$= 79.168$ kN

Torque, $T = \mu W R_m = 0.3 \times 79.168 \times 74.28$

$= 1764.18$ kNmm.

$=$ **1764.18 Nm**

30. (a)



$$\therefore P_1 \times r + P_2 \times r + P_3 \times r + P_4 \times r - T = 0$$

$$P_1 = P_2 = P_3 = P_4 \quad \text{[By symmetry]}$$

$$4Pr = T$$

$$P = \frac{T}{4r} = \frac{300}{4 \times \frac{100}{1000}} = 750 \text{ N}$$

$$\text{Shear stress} = \frac{P}{\text{Area}} = \frac{750}{30} = \mathbf{25 \text{ MPa}}$$

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