S.No. : 01 PT_ME_A_080519

Hydraulic Machine

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Subject : Hydraulic Machine

Date of test : 08/05/2019

Answer Key

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

DETAILED EXPLANATIONS

3. (c)

Unit power

$$\Rightarrow \quad P_u = \frac{P}{H^{\frac{3}{2}}}$$

Unit discharge,

$$Q_u = \frac{Q}{\sqrt{H}}$$

$$\Rightarrow \quad \frac{P_u}{Q_u} = \frac{P.H^{\frac{1}{2}}}{Q.H^{\frac{3}{2}}} = \frac{100(200)^{\frac{1}{2}}}{0.125(200)^{\frac{3}{2}}} \times 10^3 = 4000$$

4. (b)

$$\text{Specific speed of turbine}(N_s) = \frac{N\sqrt{P}}{H^{5/4}}$$

$$N_s = \frac{140 \times \sqrt{3000}}{(10)^{5/4}}$$

$$N_s = 431.2098 \quad \text{(SI unit)}$$

5. (a)

$$d = 50 \text{ mm}$$
$$\theta = 30°$$
$$F_x = 1471.5 \text{ N}$$
$$F_x = \rho A V^2 \sin^2\theta$$
$$A = \frac{\pi}{4} \times 0.05^2 = 0.001963 \text{ m}^2$$
$$1471.5 = 1000 \times 0.001963 \times V^2 \times \sin^2(30)$$
$$V = 54.7583 \text{ m/s}$$
$$Q = AV = 0.001963 \times 54.7583 = 0.1075 \text{ m}^3\text{/s} = 107.5 \text{ liter/s}$$

6. (a)

Power available at the nozzle is

$$P = \frac{\rho g Q H}{1000} \text{ kW} = \frac{1000 \times 9.81 \times 0.1 \times 700}{1000} = 686.7 \text{ kW}$$

7. (a)

$$H \propto D^2 N^2$$
$$Q \propto D^3 N$$
$$P \propto D^5 N^3$$

9. (b)

$$F = \rho a (v - u)^2$$
$$150 = 1000 \times 0.0015 \times (15 - u)^2$$
$$\Rightarrow \quad u = 5 \text{ m/s}$$

11. (b)

For similar turbines, specific power will be same

$$\frac{N_m D_m}{\sqrt{H_m}} = \frac{N_p D_p}{\sqrt{H_p}}$$

$$\frac{N_m D_m}{\sqrt{10}} = \frac{N_p D_p}{\sqrt{40}}$$

$$\frac{1000 \times D_p}{\sqrt{40}} = \frac{N_m D_m}{\sqrt{10}}$$

$$\therefore \quad N_m = \frac{1000 \times 4 \times \sqrt{10}}{\sqrt{40}}$$

$$\Rightarrow \quad N_m = 2000$$

Now, for the same specific speeds

$$\frac{N_m \sqrt{P_m}}{H_m^{\frac{5}{4}}} = \frac{N_p \sqrt{P_p}}{H_p^{\frac{5}{4}}}$$

$$\Rightarrow \quad P_m = 2.34 \text{ kW}$$

12. (b)

Linear scale ratio = 36

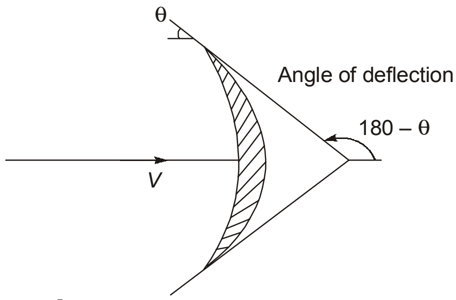
$$\Rightarrow \quad \frac{Q_p}{Q_m} = L_r^{2.5}$$

$$\Rightarrow \quad \frac{Q_p}{Q_m} = (36)^{2.5}$$

$$\Rightarrow \quad Q_p = Q_m \times (36)^{2.5} = 2 \times 36^{2.5}$$

$$\Rightarrow \quad Q_p = 15552 \text{ m}^3/\text{s}$$

13. (d)



Diameter of Jet = 60 mm

$$\therefore \quad \text{Area} = \frac{\pi}{4} \times (0.06)^2 = 2.827 \times 10^{-3} \text{ m}^2$$

Velocity of Jet = 50 m/s

Angle of deflection = 120°

$$\therefore \quad \theta = 180° - 120° = 60°$$

$$F = \rho a v^2 [1 + \cos\theta]$$

$$F = 1000 \times 2.827 \times 10^{-3} \times 50^2 [1 + \cos 60°]$$

$$F = 10601.25 \text{ N} = 10.601 \text{ kN}$$

14. (d)

Force on spring will be the force in horizontal direction.

$$\therefore \quad F_H = \rho Q V \cos\theta = 1000 \times 0.1 \times 4 \cos 30° = 400 \times \frac{\sqrt{3}}{2} = 200\sqrt{3} \text{ N}$$

15. (a)

The specific speed for turbines is given by

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

The specific speed for pumps is given by

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

16. (a)

$$\text{NPSH} = \frac{P_a}{\rho g} - \frac{P_v}{\rho g} - h_s - h_f$$

NPSH = Net positive suction head

$\frac{P_a}{\rho g}$ = Atmospheric pressure head

$\frac{P_v}{\rho g}$ = Vapour pressure head

h_s = Suction head

h_f = head loss

$$\frac{P_a}{\rho g} = \frac{100 \times 10^3}{1000 \times 9.81} = 10.1936 \text{ m}$$

$$\frac{P_v}{\rho g} = 0.40 \text{ m}$$

$$h_f = 0.5 \text{ m}$$

$$\text{NPSH} = 3.3 \text{ m}$$

$$h_s = 10.1936 - 3.3 - 0.40 - 0.5$$

$$= 5.9936 = 5.99 \text{ m}$$

17. (d)

Equating the head coefficients, we get

$$\frac{N_1 D_1}{\sqrt{H_1}} = \frac{N_2 D_2}{\sqrt{H_2}}$$

$$\therefore \quad D_1 = \left(\frac{N_2}{N_1}\right) \cdot \sqrt{\frac{H_1}{H_2}} \times D_2$$

$$= \left(\frac{1200}{1200}\right) \sqrt{\frac{25}{9}} \times 300 = 500 \text{ mm}$$

18. (c)

Pelton turbine — Specific speed from 10 to 50 + tangential flow.

Francis turbine — Specific speed from 60 to 300 + mixed flow.

Propeller turbine — Specific speed from 300 to 600 + axial flow with fixed runner vanes.

Kaplan turbine — Specific speed from 600 to 1000 + axial flow with adjustable runner vanes.

19. (b)

$$\text{Time ratio, } T_r = \frac{L_r}{V_r} = \frac{L_r}{\sqrt{L_r}} = \sqrt{L_r}$$

$$\Rightarrow \quad \frac{t_m}{t_p} = \sqrt{\frac{1}{100}} = \frac{1}{10}$$

Given, $t_p = 15$ hrs.

$$t_m = \frac{15}{10} = 1.5\,\text{hrs.}$$

20. (a)

Given, $N_1 = 200$ rpm, $P_1 = 5200$ kW, $H_1 = 250$, $\eta_0 = 82\% = 0.82$

$$\eta_0 = \frac{P_1}{\rho \times g \times Q_1 \times H_1}$$

$$\Rightarrow \quad 0.82 = \frac{5200 \times 1000}{1000 \times 9.81 \times Q_1 \times 250}$$

$$Q_1 = 2.5857\ \text{m}^3/\text{s}$$

Now, $$\frac{Q_1}{\sqrt{H_1}} = \frac{Q_2}{\sqrt{H_2}} \quad \text{[By definition of unit discharge]}$$

$$\frac{2.5857}{\sqrt{250}} = \frac{Q_2}{\sqrt{150}}$$

$$\Rightarrow \quad Q_2 = 2.0028\ \text{m}^3/\text{s}$$

21. (c)

On splitting of jet into two stream, the larger discharge would be

$$Q_1 = \frac{Q}{2}(1+\cos\theta)$$

and smaller discharge would be, $Q_2 = \dfrac{Q}{2}(1-\cos\theta)$

So, $$\frac{\text{Smaller discharge}}{\text{Larger discharge}} = \frac{\frac{Q}{2}(1-\cos\theta)}{\frac{Q}{2}(1+\cos\theta)} = \frac{1-\cos\theta}{1+\cos\theta}$$

$$= \frac{1-\cos(90-30°)}{1+\cos(90-30°)} = \frac{1-\frac{1}{2}}{1+\frac{1}{2}} = \frac{1}{3}$$

22. (b)

$$\text{Speed } (V) = \sqrt{2gH}$$

$$\therefore \quad V \propto H^{1/2}$$

$$\text{Discharge } (Q) = AV$$

$\therefore \quad Q \propto D^2\sqrt{H}$

$\therefore \quad Q \propto H^{1/2}$

Now,

$$\text{Power } (P) = \rho QgH$$
$$P \propto \sqrt{H} \times H$$
$$P \propto H^{3/2}$$

23. (a)

For similar turbines, specific power will be same

$$\frac{N_m D_m}{\sqrt{H_m}} = \frac{N_p D_p}{\sqrt{H_p}}$$

$\Rightarrow \quad N_m = 2000$

Now, for the same specific speeds

$$\frac{N_m\sqrt{P_m}}{H_m^{\frac{5}{4}}} = \frac{N_p\sqrt{P_p}}{H_p^{\frac{5}{4}}}$$

$\Rightarrow \quad P_m = 2.34$ KW

24. (a)

$$\text{B.P.} = \frac{\dot{m}gh}{\eta_m} = \frac{80 \times 9.81 \times 30}{0.8} = 29.4 \text{ kW}$$

25. (d)

When diameter constant

(i) $\quad U_1 = \frac{\pi DN}{60} \propto \sqrt{H}$

$\therefore \quad H \propto N^2$

(ii) $\quad Q = \pi D_1 b_1 \times V_f$

$$Q \propto V_f \,\alpha\, N$$

$\therefore \quad Q \propto N$

(iii) $\quad \text{Power } P = \rho gQH$

$$P \propto N \times N^2$$
$$P \propto N^3$$

Now, $\quad \frac{H_2}{H_1} = \left(\frac{N_2}{N_1}\right)^2$

$$H_2 = 10 \times \left(\frac{2000}{1000}\right)^2 = 40 \text{ m}$$

$$\frac{P_2}{P_1} = \left(\frac{N_2}{N_1}\right)^3; P_2 = 1 \times \left(\frac{2000}{1000}\right)^3 = 8 \text{ kW}$$

26. (b)

$$\eta_{\text{Overall}} = \frac{SP}{gQH}$$

$$Q = \frac{500}{0.53} \times \frac{1}{9.81} \times \frac{1}{30} = 2.0469 \text{ m}^3/\text{s}$$

27. (b)

$$V_1 = C_V\sqrt{2gH}$$

$$\Rightarrow \quad V_1 = 0.985\sqrt{2 \times 9.81 \times 45}$$

$$= 29.27 \text{ m/s}$$

$$\beta = 165°, \quad \beta' = 180 - 165 = 15°, \quad k = 1 \text{ (assumed)}$$

$$\text{Power, } P = \rho Qu\,(V_1 - u)\,(1 + \cos\beta')$$

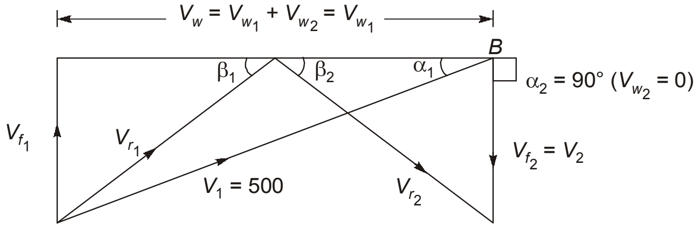
$$= 1000 \times 0.8 \times 14 \times (29.27 - 14) \times (1 + \cos 15) = 336.22 \text{ kW}$$

$$\therefore \text{ Power delivered to shaft} = 336.22 \times 0.95$$

$$= 319.411 \text{ kW}$$

28. (b)

Given, $u = 200$ m/s, $\alpha = 20°$, $V_1 = 500$ m/s



$$V_w = V_{w_1} + V_{w_2} = V_{w_1} = V_1\cos\alpha_1$$

$$= 500 \times \cos 20° = 469.84 \text{ m/s}$$

Specific power output of the turbine $= uV_w$

$$= 200 \times 469.8$$

$$= 93960 \text{ Watt/kg}$$

$$= 93.96 \text{ kW/kg of steam flow}$$

29. (d)

$$\text{Force} = \dot{m}[V\cos\theta - (-V\cos\theta)]$$

$$200 = \dot{m} \times 2V \times \cos\theta$$

$$200 = 20 \times 2 \times 10 \times \cos\theta$$

$$\cos\theta = 0.5$$

$$\theta = 60°$$

30. (c)

Specific speed is independent of dimensions, size of both actual and specific turbine.

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