**S.No. : 02 PT_CE_A_080519**

**Hydraulic Machine**

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# CLASS TEST 2019-2020

# CIVIL ENGINEERING

## Subject : Hydraulic Machine

### Date of test : 08/05/2019

## *Answer Key*

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

## DETAILED EXPLANATIONS

6. (b)

Head of operation for Pelton turbine is between (100 – 1760) m.

Specific speed for Kaplan turbine is between 380 - 950. Therefore these two turbines can be eliminated. Francis is the only turbine which may have criteria matching the given data.

8. (a)

Given,
$$H = 24.5 \text{ m}$$
$$Q = 10.1 \text{ m}^3/\text{s}$$
$$N = 4 \text{ rev/sec} = 4 \times 60 = 240 \text{ rpm}$$
$$\eta_0 = 0.90$$

Power generated
$$= \rho g H \times 0.9 \times Q$$
$$= 1000 \times 9.81 \times 10.1 \times 24.5 \times 0.9 = 2184.74 \text{ kW}$$

$$N_S = \frac{N\sqrt{P}}{H^{5/4}} = \frac{240\sqrt{2184.7}}{(24.5)^{5/4}} = 205.80$$

| Types of turbine | | Specific speed (S.I.) |
|---|---|---|
| Pelton wheel with single jet | : | 8.5 to 30 |
| Pelton wheel with two or more jets | : | 30 to 51 |
| Francis turbine | : | 51 to 225 |
| Kaplan or propeller turbine | : | 255 to 860 |

Hence, turbine is Francis.

9. (a)

The specific speed for turbines is given by

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

The specific speed for pumps is given by

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

11. (d)

$N_s$ or specific speed is related to the rpm ($N$), net head $H$ and power $P$ as:

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

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

$$\Rightarrow \quad \sqrt{P} = \frac{32 \times (256)^{5/4}}{420}$$

$$\therefore \quad \sqrt{P} = \frac{32 \times (4^4)^{5/4}}{420}$$

$$\therefore \quad \sqrt{P} = \frac{32 \times 4^5}{420} = \frac{32768}{420}$$

$$\sqrt{P} = 78.02$$

$$\therefore \quad P = 6087.12 \text{ W}$$

$$P \simeq 6 \text{ kW}$$

12. (d)

Equating the head coefficients, we get

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

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

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

13. (d)

By similarity laws,

$$\frac{P_1}{\gamma D_1^5 N_1^3} = \frac{P_2}{\gamma D_2^5 N_2^3}$$

For a centrifugal pump, $D_1 = D_2$

$$\therefore \quad \frac{P_1}{N_1^3} = \frac{P_2}{N_2^3}$$

$$\Rightarrow \quad \frac{1000}{(2000)^3} = \frac{P_2}{(4000)^3}$$

$$\Rightarrow \quad 2^3 \times 1000 = P_2$$

$$\therefore \quad P_2 = 8000 \text{ W} = 8 \text{ kW}$$

14. (a)

$$F = \rho a V(V - u)$$

Area of jet, $a = \frac{\pi}{4} \times \left(\frac{100}{1000}\right)^2$

$$= 7.854 \times 10^{-3} \text{ m}^2$$

Velocity of jet, $V = 25$ m/s

$$\therefore \quad F = 1000 \times 7.854 \times 10^{-3} \times 25\,(25 - 10) \text{N} = 2.95 \text{ kN}$$

15. (a)

$$Q_t = \frac{ALN}{60}$$

$$A = \frac{\pi}{4} \times \left(40 \times 10^{-2}\right)^2 = \frac{\pi}{25} \text{ m}^2$$

$$L = ?, \quad N = 100$$

$\Rightarrow \quad 0.0314 = \frac{\pi}{25} \cdot \frac{1}{60} \cdot L \cdot 100$

$\Rightarrow \quad L = \frac{0.0314 \times 25 \times 60}{3.14 \times 100} = 0.15 \text{ m} = 15 \text{ cm}$

16. (d)

Peripheral velocity, $u = \phi\sqrt{2gH}$

where, $\phi$ = Speed ratio

$u = 0.45\sqrt{2 \times 9.81 \times 900} \simeq 60$ m/s

17. (d)

Discharge, $Q = \pi D_1 b_1 V_{f1}$

$= \pi \times 1.5 \times 0.3 \times 4 = 1.8\pi = 5.65 \text{ m}^3/\text{s}$

18. (b)

$$Q = \frac{\pi}{4}\left(D^2 - D_b^2\right) \times V_{f_1} = \frac{\pi}{4}\left(D^2 - (0.4D)^2\right) \times 16$$

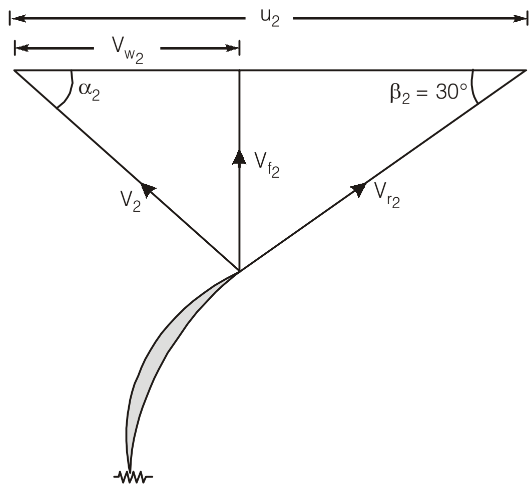
$= \pi/4 \times 3^2 \times (1 - 0.4^2) \times 16 = 95 \text{ m}^3/\text{s}$

19. (a)

At the outlet $\quad u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.30 \times 1200}{60} = 18.85$ m/s

$V_{f2} = 2.0$ m/s and $\beta_2 = 30°$

From the outlet velocity triangle,




$$\tan\beta_2 = \frac{V_{f_2}}{u_2 - V_{w_2}}$$

$$\tan 30° = \frac{2.0}{18.85 - V_{w_2}}$$

$18.85 - V_{w_2} = 3.464$; and hence $V_{w_2} = 15.386$ m/s

Manometric efficiency

$$\eta_H = \frac{gH}{u_2 V_{w_2}}$$

Head developed, $$H = \eta_H \frac{u_2 V_{w_2}}{g} = \frac{0.85 \times 18.85 \times 15.386}{9.81} = 25.13 \text{ m}$$

20. (c)

Velocity with which the plate moves

$$u = \frac{2\pi r N}{60} = \frac{2\pi \times 1 \times 30}{60} = \pi \text{ m/s}$$

Force exerted on the plate

$$F = \rho . A . v (v - u) = 1000 \times \frac{40}{(100)^2} \times 25(25 - \pi) = 2185.8 \text{ N}$$

Torque on the wheel $= F.r$

$= 2185.8 \text{ N} \times 1 \text{ m} = 2185.8 \text{ N-m}$

21. (b)

$$\frac{\text{Water delivered}}{\text{Water wasted}} = \frac{1}{20}$$

$$\text{Efficiency of pump} = \frac{\text{Output}}{\text{Input}} \times 100 = \frac{16}{4 \times 20} \times 100 = 20\%$$

22. (c)

Minimum starting speed,

$$\left[\left(\frac{\pi N_{min}}{60}\right)^2 \left(D_1^2 - D^2\right)\right] = 2gH_m$$

Given $D_1 = 80 \text{ cm} = 0.8 \text{ m}$

$H_m = 15.3 \text{ m}$

$Q = 260 \; l/\text{s} = 0.26 \text{ m}^3/\text{s}$

$N = 600 \text{ rpm}$

Inner diameter of the impeller is approximately half of outer diameter

$$\therefore \quad \frac{\pi N_{min}}{60} = \sqrt{\frac{2 \times 9.81 \times 15.3}{(0.8^2 - 0.4^2)}}$$

$$\Rightarrow \quad N_{min} = 477.6 \simeq 475 \text{ rpm}$$

23. (a)

Net positive suction head is the minimum pressure required at the suction port of the pump to keep the pump from cavitating.

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

Increase in pressure at supply reservoir increases NPSH

Reduction in suction friction reduces $h_f$ thereby increasing NPSH.

24. (d)

$$\text{Speed ratio} = \frac{u}{\sqrt{2gH}}$$

$$\therefore \quad u = 0.48 \times \sqrt{2 \times 9.81 \times 225} = 0.48 \times 4.43 \times 15 = 31.90 \text{ m/s}$$

But
$$u = \left(\frac{\pi DN}{60}\right)$$

$$\therefore \quad D = \frac{60 \times 31.90}{\pi \times 320} = 1.90\,\text{m}$$

25. (c)

$$\because \quad Q_1 = \frac{Q}{2}(1-\cos\theta) = \frac{Q}{2}(1-\cos 60°) = \frac{Q}{2}\left(1-\frac{1}{2}\right) = \frac{Q}{4}$$

and
$$Q_2 = \frac{Q}{2}(1+\cos\theta) = \frac{Q}{2}(1+\cos 60°) = \frac{Q}{2}\left(1+\frac{1}{2}\right) = \frac{3}{4}Q$$

$$\therefore \quad Q_1 : Q_2 = 1 : 3$$

26. (b)

If $H_m$ is the manometric head developed by each pump, then

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

Given,
$$N_s = 720 \text{ rpm}$$
$$N = 720 \text{ rpm}$$
$$Q = 3840 \text{ litres per minute} = 64 \text{ lps} = 0.064 \text{ m}^3\text{/s}$$

$$\therefore \quad 720 = \frac{720 \times \sqrt{64}}{{H_m}^{3/4}}$$

$$\therefore \quad (H_m)^{3/4} = 8$$

$$\therefore \quad H_m = (8)^{4/3} = 16$$

$$\therefore \quad \text{Number of impellers required} = \frac{80}{16} = 5$$

29. (d)

NPSH (Net positive suction head) = Cavitation coefficient × Manometric head = 0.1 × 50 = 5 m

$$\text{Now, NPSH} = \frac{p_{atm} - p_v}{\rho \times g} - h_s - h_{f_s}$$

$$\text{Safe height of runner, } h_s = \frac{P_{atm} - P_v}{\rho \times g} - \text{NPSH} = \frac{P_{atm}}{\rho \times g} - \frac{P_v}{\rho \times g} - \text{NPSH} \qquad (\because \; h_{f_s} = 0)$$

$$= 10 - 2 - 5 = 3 \text{ m}$$

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