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18/ENG01061
MATHATRONICS

①

Flow rate (Q) = 10 dm³/min
Pressure change (ΔP) = 12 bar
Speed (N) = 1500 rpm
Normal displacement = 10 cm³/rev
Torque (T) = 12.5 N.m

∴ Ideal flow rate = Normal displacement × speed
= 10 cm³/rev × 1500 rpm
= 15000 cm³/min = 15 dm³/min

Volumetric efficiency = Actual flow / Ideal flow
= 10 / 15 = 0.6667 or 66.67%

∴ Q = $\frac{10 \times 10^{-3}}{60} \text{ m}^3/\text{sec} = 16.7 \times 10^{-5} \text{ m}^3/\text{sec}$

ΔP = 12 × 10⁵ N/m²
Fluid power = ΔP × Q = 16.7 × 10⁻⁵ m³/sec × 12 × 10⁵ N/m² = 200 watts

Shaft power = $\frac{2\pi NT}{60} = \frac{2\pi \times 1500 \times 12.5}{60}$

= 1963.5 Watts

Overall efficiency = $\frac{F.P.}{S.P.} = \frac{200}{1963.5} = 10.2\%$

Fluid Power can be either increased by the change in pressure or discharge

②

flow rate (Q) = 35 dm³/min
Pressure change (ΔP) = 100 bar

Overall efficiency = 87%

Shaft power = $\frac{2\pi NT}{60}$

Q = $\frac{35 \times 10^{-3}}{60} \text{ m}^3/\text{sec}$

= 58.3 × 10⁻⁵ m³/sec

Fluid power ΔP × Q

ΔP = 100 × 10⁵ N/m²

58.3 × 10⁻³ × 100 × 10⁵

= 5830 watts

Overall efficiency = $\frac{\text{fluid power}}{\text{Shaft power}}$

0.87 = 5830

Shaft power

Shaft power = $\frac{5830}{0.87} = 6701.14 \text{ Watts}$

③

Normal displacement = 50 cm³/sec

Pressure change (ΔP) = 100 bar

Shaft power = 15 kilowatts = 15000

Overall efficiency = ?

Volumetric efficiency = ?

Flow rate (Q) = 35 dm³/min

Speed (N) = 850 rpm

Continuation of
No 3

Ideal flow rate = Normal displacement \times speed

$$= 50 \text{ cm}^2 (\text{rev}) \times 650 \text{ rev} \\ = 42500 \text{ cm}^3 (\text{min}) = 42.5 \text{ dm}^3 (\text{min})$$

Volume efficiency = Actual flow / Ideal flow

$$= 35 / 42.5 = 0.8235 \text{ or } 82.35\%$$

$$Q = \frac{35 \times 10^{-2} \text{ m}^3/\text{sec}}{60} = 58.3 \times 10^{-5} \text{ m}^3/\text{sec}$$

$$\Delta P = 100 \times 10^5 \text{ N/m}^2$$

fluid power = $\Delta P \times Q$

$$= 58.3 \times 10^{-5} \text{ m}^3/\text{sec} \times 100 \times 10^5 \\ = 5830 \text{ watts}$$

Shaft power = 15000 watts

$$\text{Overall efficiency} = \frac{\text{fluid power}}{\text{Shaft power}} = \frac{5830}{15000}$$

$$= 0.3886$$

$$= 38.86\%$$

4

$$H_2 = 240 \text{ m}$$

$$Q = 0.013 \text{ m}^3/\text{s}$$

$$v = 66 \text{ m/sec}$$

power of jet (P_{jet}) = $\frac{1}{2} \rho Q v^2_{jet}$

$$= \frac{1}{2} \rho Q v^2_{jet}$$

$$= \frac{1}{2} \times 1000 \times 0.013 \times 66^2 \text{ watt}$$

$$= 28314$$

$$= 28.314 \text{ kilowatts}$$

Power supplied by (Pump) = $\rho g h$

$$= \rho g h$$

$$= 1000 \times 9.81 \times 240$$

$$= 30607.2$$

$$= 30.6072 \text{ kilowatt}$$

(c) Heat used to overcome losses

$$H_f = H - \frac{v^2_{jet}}{2g}$$

$$= 240 - \frac{66^2}{2 \times 9.81}$$

$$= 17.98 \text{ m}$$

(d) Efficiency of pipeline & nozzle = $\frac{P_{jet}}{P_{res}} \times 100$

$$= \frac{28.314}{30.6072} \times 100 = 92.51\%$$

$$= 92.51\%$$

5

$$Z_1 = 30,000 \text{ cm} = 300 \text{ m}$$

$$Q_1 = 220 \text{ litres/s} = (220 \times 10^{-3}) \text{ m}^3/\text{s}$$

$$N = 7 \text{ m/s}$$

Power of Jet = $\rho g Q H$

$$\text{where } \rho = 0.89 \times 1000 = 890 \text{ kg/m}^3$$

$$g = 9.81 \text{ m/s}^2$$

$$Q = (220 \times 10^{-3}) \text{ m}^3/\text{s}$$

$$H = Z_2 + \frac{\rho}{\rho g} + \frac{v^2}{2g}$$

$$H = 0 + \frac{0}{9.81} + \frac{(7)^2}{2 \times 9.81}$$

$$H = 49 / 19.62 = 2.497 \text{ m}$$

$$\text{Power} = 890 \times 9.81 \times 220 \times 10^{-3} \times 2.497$$

$$= 4797.1 \text{ Watts}$$

Continuation of
Number **(5)**

(a) Power supplied from reservoir

$$H = Z_1 + \frac{P}{\rho g} + \frac{v^2}{2g}$$

$$\frac{200 + 0 + 0}{\rho g}$$

$$2g$$

$$= 300$$

$$\therefore \text{Power} = 890 \times 9.81 \times 220 \times 10^{-3} \times 300$$

$$= 576239.4$$

$$v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 20}$$

$$= 19.7989 \text{ m/s}$$

$$P = \rho \pi r^2 v g h$$

$$\text{Power} = \frac{1000 \text{ kg}}{\text{m}^3} \times \left(\frac{10 \times 10^{-2}}{2} \right)^2 \times 19.7989 \text{ m/s}$$

$$\times 9.8 \text{ m/s}^2 \times 20 \text{ m}$$

$$= 1000 \times \pi \times 2.5 \times 10^{-3} \times 19.7989 \times 9.8 \times 20$$

$$= 30478.03 \text{ W}$$

(a) Head used to overcome the loss

$$= \text{Power loss} / \rho g Q$$

$$= \frac{(576239.4 - 4797.1)}{1000 \times 9.81 \times 220 \times 10^{-3}}$$

$$= 571.4423$$

$$2158.2$$

$$\Rightarrow 264.7772681$$

$$\text{Power} = 30478.03 \text{ W}$$

(7)

$$\text{Diameter } (D_1) = 0.3 \text{ m}$$

$$A_1 = \frac{\pi}{4} \times 0.3^2$$

$$A_1 = 0.070685 \text{ m}^2$$

$$\text{throat diameter } (D_2) = 0.2 \text{ m}$$

$$A_2 = \frac{\pi}{4} \times (0.2)^2$$

$$A_2 = 0.031416 \text{ m}^2, \text{ coefficient of}$$

$$\text{discharge} = 0.96$$

$$\text{Specific weight of gas } (\gamma) = 19.62 \text{ N/m}^3$$

$$\text{density of gas } (\rho) = 19.62$$

$$9.81$$

$$S_g = 2 \text{ kg/m}^3$$

$$P_1 = 220 \text{ m head difference } (h) = \frac{S_g}{S_g - 1}$$

$$= 0.06 \left(\frac{1000}{2} - 1 \right)$$

$$h = 29.94$$

$$\text{Volume flow rate } (Q) = \frac{A_1 - A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

$$= 0.96 \times 0.070685 + 0.031416 \sqrt{2 \times 9.81 \times 29.94}$$

$$\sqrt{(0.070685)^2 - (0.031416)^2}$$

$$Q = 0.81599 \text{ m}^3/\text{s}$$

(a) Efficiency = $\frac{\text{Power of Jet}}{\text{Power of Reservoir}} \times 100$

$$= \frac{4797.1}{576239.4} \times 100$$

$$= 0.83248386\%$$

$$= 0.83248386\%$$

(6)

Power = $\frac{\text{work done}}{\text{time}}$

time

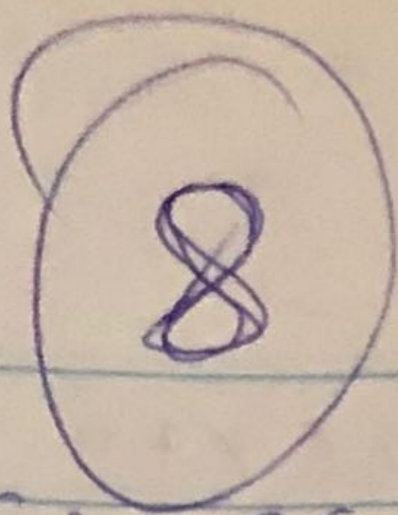
$$\text{work done} = \rho g h$$

time

V_2 Velocity of steam

ρ density of water (1000 kg/m^3)

$$m = \rho \times V$$



$$A_1 = \frac{\pi}{4} d^2 = \frac{\pi}{4} (0.152)^2 = 0.018146 \text{ m}^2$$

$$A_2 = \frac{\pi}{4} d^2 = \frac{\pi}{4} (0.0766)^2 = 4.5365 \times 10^{-3} \text{ m}^2$$

$$Q = A_1 A_2 \sqrt{2gh}$$

$$20.97 \times 0.018146 \times 4.5365 \times 10^{-3} \sqrt{2 \times 9.81 \times 0.97}$$

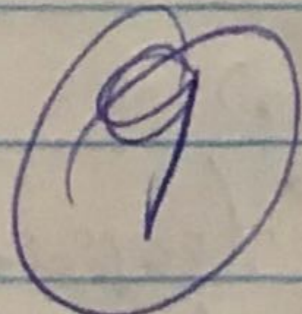
$$Q = 0.492 \text{ m}^3/\text{s}$$

$$h = \frac{(P_1 - P_2)}{\rho g} = \frac{15170}{0.8 \times 10^3 \times 9.81} = 1.933 \text{ m}$$

$$Q = \frac{C_d A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

$$0.492 = \frac{0.018146 \times 4.5365 \times 10^{-3} \sqrt{2 \times 9.81 \times 1.933}}{\sqrt{(0.018146)^2 - (4.5365 \times 10^{-3})^2}}$$

$$Q = 0.62798 \text{ m}^3/\text{s}$$



$$d = 300 \text{ mm} = 0.3 \text{ m}$$

$$A_1 = \frac{\pi d^2}{4} = \frac{\pi (0.3)^2}{4} = 0.0707 \text{ m}^2$$

$$d = 150 \text{ mm} = 0.15 \text{ m}$$

$$A_2 = \frac{\pi d^2}{4} = \frac{\pi (0.15)^2}{4} = 0.0177 \text{ m}^2$$

$$Q = 40 \text{ l/s}$$

$$= (40 \times 10^{-3}) \text{ m}^3/\text{s}$$

$$z_1 = 10 \text{ m}$$

$$z_2 = 6 \text{ m}$$

$$P_1 = ?$$

$$P_2 = 400 \text{ kN/m}^2 = 400,000 \text{ N/m}^2$$

$$Q = VA$$

$$V_1 A_1 = Q = (V_1 \times 0.0707) = (40 \times 10^{-3})$$

$$V_1 = \frac{(40 \times 10^{-3})}{0.0707}$$

$$V_1 = 0.5658 \text{ m/s}$$

$$Q = V_1 A_1$$

$$V_2 (0.0177) = 40 \times 10^{-3}$$

$$V_2 = (40 \times 10^{-3}) / 0.0177$$

$$V_2 = 2.2599 \text{ m/s}$$

$$z_1 + \frac{P_1}{\rho g} + \frac{V_1^2}{2g} = z_2 + \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

$$\Rightarrow z_1 + \frac{P_1}{\rho g} + \frac{V_1^2}{2g} = z_2 + \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

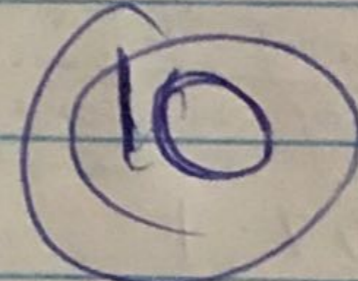
$$10 + \frac{400000}{9.81 \times 1000} + \frac{(0.5658)^2}{2(9.81)} = 6 + \frac{P_2}{9.81 \times 1000} + \frac{(2.2599)^2}{2 \times 9.81}$$

$$50.79 + \frac{P_2}{9.81 \times 1000} + 6.2603 = 6 + \frac{P_2}{9.81 \times 1000} + 6.2603$$

$$\frac{P_2}{9.81 \times 1000} = 50.79 - 6.26$$

$$P_2 = (9.81 \times 1000) (44.53)$$

$$P_2 = 436,836 \text{ N/m}^2$$



Calculate the head

$$h = y \left(\frac{\rho_m}{\rho_f} - 1 \right)$$

$$= 0.17 \left[\frac{13.6}{1.026} - 1 \right]$$

$$h = 2.0834$$

Calculate the vel of submarine

$$V = \sqrt{2gh}$$

$$= \sqrt{2 \times 9.81 \times 2.0834}$$

$$= 6.393 \text{ m/s}$$

ρ_m = density of mercury

ρ_f = density of fluid

y = manometric reading