Unah, Benjamin Sunday.
18/ENG05/064
Fluid Mechanics.
Mechatronics Engineering.

1. $Q = 10\,dm^3/min = \frac{10}{1000 \times 60}$

$= 1.667 \times 10^{-4}\ m^3/s$

$\Delta P = 12\,bar = 12 \times 10^5\ N/m^2$

Speed of rotation $= 1500\,rev/min$

$= 1500/60$

$= 25\,rev/s$

Nominal displacement $= 10\,cm^3/rev$

$= 10/1000000$

$= 1 \times 10^{-5}\ m^3/rev$

Torque Input $= 12.5\,Nm$

a) Volumetric Efficiency $= \frac{Q}{\text{Ideal Flow rate}}$

Ideal Flow rate = Nominal displacement $\times$ speed $= 1 \times 10^{-5} \times 25$.

$= 2.5 \times 10^{-4}\ m^3/s.$

$\therefore$ Volumetric Efficiency $= \dfrac{1.667 \times 10^{-4}}{2.5 \times 10^{-4}}$

$= 0.6668 \times 100\%$

$= 66.68\%.$

(ii) Fluid Power $= Q \times \Delta P$

$= (1.667 \times 10^{-4}) \times (12 \times 10^{5})$

$= 200.04\ W$

(iii) Shaft Power $= 2\pi T \times$ Speed

$= 2 \times 3.14 \times 12.5 \times 25$

$= 2 \times \pi \times 12.5 \times 25$

$= 1963.50\ W$

(iv) Overall Efficiency $= \dfrac{\text{Fluid Power}}{\text{Shaft Power}}$

$= \dfrac{200.04}{1963.50}$

$= 0.102 \times 100$

$= 10.2\%.$

2. $Q = 35 dm^3/min = \frac{35 \times 0.001}{60}$

$= 5.83 \times 10^{-4} m^3/s$.

$\Delta P = 100$ bar $= 100 \times 10^5 N/m^2$.

Overall Efficiency = 87%

$$\text{Shaft Power} = \frac{\text{Fluid Power}}{\text{Overall Efficiency}}$$

$$= \frac{Q \times \Delta P}{87 \div 100}$$

$$= \frac{5.88 \times 10^{-4} \times 100 \times 10^5}{0.87}$$

$$= \frac{5830}{0.87}$$

$$= 6701.15 W$$

3. $Q = 35 dm^3/min = \frac{35 \times 0.001}{60}$

$= 5.83 \times 10^{-4} m^3/s$.

$\Delta P = 100$ bar $= 100 \times 10^5 N/m^2$

Shaft Power = 15 KW
Speed of Rotation = 850 rev/min

$= \frac{850}{60}$

$= 14.167$ rev/s

(i) Volumetric Efficiency = $\frac{\text{Actual Flow rate, Q}}{\text{Ideal Flow rate}}$

Ideal Flow rate = Nominal displacement × speed.

$= 50 cm^3/rev \times 14.167$

$= 5 \times 10^{-5} \times 14.167$

$= 7.0835 \times 10^{-4} m^3/s.$

∴ Volumetric Efficiency = $\frac{5.83 \times 10^{-4}}{7.0835 \times 10^{-4}}$

$= 0.823 \times 100\%$

$= 82.3\%$

(ii) Overall Efficiency = $\frac{\text{Fluid Power}}{\text{Shaft Power}}$

$= \frac{Q \times \Delta P}{\text{Shaft Power}}$

$$= \frac{5.83 \times 10^{-4} \times (100 \times 10^{5})}{(15 \times 10^{2})}$$

$$= \frac{5830}{15000}$$

$= 0.$[redacted]$3887 \times 100\%$

$= 38.87\%$.

No. (10)

Difference of Mercury level, $x = 170\,mm$
$= 0.17m$

Speed of submarine = ?

S. gravity of mercury = 13.6

S. gravity of sea water = 1.026

Differential Head, $h = x \left[\frac{S_g}{S_o} - 1 \right]$

$$= 0.17 \left(\frac{13.6}{1.026} - 1 \right)$$

$= 2.0834\,m$ of water.

Velocity / speed of submarine,

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

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

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

No. 7

Specific Weight = 19.62 N/m³

$C_d = 0.96$.

$d_1 = 0.3\text{m}$

$d_2 = 0.2\text{m}$

Calculate Q,

$$V_1 = \frac{Q}{0.0707} \qquad V_2 = \frac{Q}{0.0314}$$

for the manometer,

$$P_1 + S_o g Z = P_2 + S_o g (Z_2 - R_F) + S_o g R_F$$

$$P_1 - P_2 \Rightarrow 19.62(Z_2 - Z_1) + 587.423 \text{[illegible]}$$

For the Venturimeter,

$$\frac{P_1}{S_o g} + \frac{V_1^2}{2g} + Z_1 \Rightarrow \frac{P_2}{S_o g} + \frac{V_2^2}{2g} + Z_2$$

$P_1 - P_2 = 19.62\,(Z_2 - Z_1) + 0.803\,V_2^2$ — (2)

Combining (1) & (2) we get

$0.803\,V_2^2 = 587.423$

V_2 ideal $= 27.047$ m/s

$Q_{ideal} = 27.047 \times \pi \times \left(\frac{0.2}{2}\right)^2$

$= 0.85\,m^3/s$

$Q = C_d\,Q_{ideal} = 0.96 \times 0.85 = 0.816\,m^3/s$

No. 6

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

work done = mgh/time

V = Velocity of stream

ρ = density of water (1000 Kg/m³)

$\dot{m} = \rho \times V$

$V = \sqrt{2gh} \Rightarrow \sqrt{2 \times 9.8 \times 20} = 19.7989$ m/

$P \Rightarrow \rho \pi r^2 \frac{v g h}{r}$

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

$\times 19.7989 \frac{m}{s} \times 9.8 \frac{m}{s^2} \times 20$

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

$\Rightarrow 30478.03 W$

$\text{Power} \Rightarrow 30.5 KW$

No. 8

$d_1 = 0.152m \Rightarrow A_1 = \frac{\pi}{4}(0.152)^2$

$= 0.01814 m^2$

$d_2 = 0.076m \Rightarrow A_2 = \frac{\pi}{4}(0.076)^2$

$= 0.00464 m^2$

$\rho = 0.8 \times 1000 = 800 kg/m^3$

$C_d = 0.97$

⇒ Apply Bernolli :-

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

(a) $P_1 = P_2$.

$$\frac{V_1^2}{2g} + Z_1 = \frac{V_2^2}{2g} + Z^2$$

By continuity :-

$$Q = V_1 A_1 = V_2 A_2$$

$$V_2 = V_1 \frac{A_1}{A_2}$$

$$\frac{U_1^2}{2g} + 0.314 = \frac{16(U_1^2)}{2g}$$

$$U_1 = \sqrt{\frac{0.314 \times 2 \times 9.81}{15}} = 1.0934 \text{ m/s}$$

$$Q = C_d A_1 V_1 = 0.37 \times (0.01514) \times (1.0934)$$

$$Q = 0.0172 \text{ m}^3/\text{s}.$$

(b) $P_1 - P_2 = 15170$

$$\Rightarrow \frac{P_1 - P_2}{\rho g} = \frac{U_2^2 - U_1^2}{2g} - 0.914$$

$$\frac{15170}{800 \times 9.81} = \frac{Q^2\left[(220.43)^2 - (55.11)^2\right]}{2 \times 9.81}$$

$- 0.914$;

$\Rightarrow Q = 0.035 \, m^3/s$,

No. 9.

→ At section 1 -

$P_1 = 300 mm = 0.3m$,

Area $= \pi/4 \times (0.3)^2$

$= 0.07068 \, m^2$

Pressure $P_1 = 400 \, KN/m^2$

Height of upper end above the datum. $(Z_1) = 10m$

→ At section 2,

$P_2 = 150 m = 0.15m$,

Area $= \frac{\pi}{4}(0.15)^2$

$a_2 = 0.01767 m^2$

Height of lower end of datum (Z₂) = 6m.

→ Rate of flow

$Q = 40 \text{ lit/sec} = 0.04 m^3/sec$

→ As the flow is continuous,

$Q = A_1 V_1 = A_2 V_2$ (Continuity Equation).

$V_1 = Q/A_1 = \frac{0.04}{0.07068} = 0.5658 m/s.$

$V_2 = Q/A_2 = \frac{0.04}{0.01767} = 2.2635 m/s.$

→ Apply Bernoulli equation at section 1 & 2,

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

$$\frac{P_2}{\rho g} = \frac{P_2}{\rho g} + \frac{V_1^2 - V_2^2}{2g} + (Z_1 - Z_2)$$

$$\frac{P_2}{\rho g} = \frac{400 \times 10^3}{1000 \times 9.81} + \frac{(0.5658^2 - 2.2635^2)}{2 \times 9.81}$$

$$+ (10 - 6)$$

$$\frac{P_2}{\rho g} = 44.53 \Rightarrow P_2 = 44.53 \times 9.81 \times 1000$$

$$\therefore P_2 = 486.838 \ KN/m^2.$$

No 4.

$Z = 24000 \ cm$

$Z = 240 m$

Volumetric flow rate = 13 l/sec

$$= \frac{13}{1000} \ m^3/sec = 13 \times 10^{-3} \ m^3/sec$$

Jet Velocity = 60 m/s

Water Density = 1000 Kg/m³.

Since $p = 0$ and $z = 0$,

$$P = (0 \cdot Q) + \frac{\rho Q \cdot V^2}{2} + \rho g Q(0)$$

$$\Rightarrow P = \frac{\rho Q \cdot V^2}{2}$$

$$= 1000 \times \frac{13 \times 10^{-3}}{2} \times 66^2$$

$P = 28314$ Watts, Power of Jets.

⇒ Power supplied from resovoir:

Since $p = 0$ and $V = 0$,

$$P = (0 \times Q) + \frac{\rho (0)^2 Q}{2} + \rho g Q z$$

$$\Rightarrow P = \rho g Q z$$

$$= 1000 \times 9.81 \times 13 \times 10^{-3} \times 240$$

$$= 30607.2 \text{ Watts.}$$

⇒ Power lost in transmission = Power of reservoir − Jet power

$$= 30607.2 - 28314$$

$$= 2293.2 \text{ Watts.}$$

Head loss in pipline ⇒

$$h = \frac{\text{power lost in transmission}}{\rho g Q}$$

$$= \frac{22293.2}{1000 \times 9.81 \times 13 \times 10^{-3}}$$

$$= 17.982 m.$$

⇒ $$\text{Efficiency} = \frac{\text{Jet Power}}{\text{Resorvoir Power}} \times 100\%$$

$$= \frac{28314}{30607.2} \times 100\%$$

$$= 92.5\%.$$

No 5.

s.g of oil = 0.89

Z = 30000 cm = 300 m

Q = 200 l/sec = 0.22 m^3/sec.

V = 7 m/sec

Introducing z = 0, and p = 0,

⇒ $P = \rho Q V^2/2$ — Jet Power.

Recall, $S_g = 0.89$

$$S_g = \frac{x}{1000} \quad \therefore x = 890$$

$$\rho = x = 890$$

$$P = \frac{890 \times 0.22 \times 7^2}{2}$$

$$P = 4797.1 \text{ watts.}$$

⇒ Power supplied from resovor,

$$P = \rho g Q h$$

$$= 890 \times 9.81 \times 0.22 \times 300$$

$$= 576239.4 \text{ Watts.}$$

$$\simeq 576.24 \text{ KWatts.}$$

⇒ Power Loss

= (576.24 [redacted] − 4.7971) KWatts.

$$= 571.4423 \text{ KW}$$

$$= 571442.3 \text{ Watts.}$$

⇒ Head used to overcome losses,

$$= \frac{571442.3}{890 \times 9.81 \times 0.22} = 297.51 \text{m.}$$