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DEPARTMENT: BIOMEDICAL ENGINEERING
COURSE: FLUID MECHANICS (ENG 214)
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1) Actual flow rate $= 10\ dm^3/min = ~~1.667\ m^3/s~~\ 1.667 \times 10^{-4}\ m^3/s$

Pressure change $= 12\ bar = 12 \times 10^5\ kN/m^2$.

Speed rotation $= 1500\ rev/min = 25.05\ rev/sec$.

Nominal displacement $= 10\ cm^3/rev = 1 \times 10^{-5}\ m^3/rev$.

Torque input $= 12.5\ Nm$.

(i) Volumetric Efficiency $= \dfrac{\text{Actual flowrate}}{\text{Ideal flowrate}} \times 100\%$

Ideal flowrate = Nominal displacement × speed rotation.

$= 1 \times 10^{-5} \times 25.05$

$= 2.505 \times 10^{-4}\ m^3/s$.

Volumetric Efficiency $= \dfrac{1.667 \times 10^{-4}}{2.505 \times 10^{-4}} \times 100$

$= 0.665 \times 100$

$= 66.5\%$

ii) Fluid power = Actual flowrate × pressure change.

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

$= 200.04\ Nm/sec$.

(iii) Shaft power = Torque input × Angular speed.

Angular speed $= 2 \times \pi \times$ speed of rotation

$= 2 \times \pi \times 25.05$

$= ~~155~~\ 157.39\ rev/sec$.

Shaft power $= 12.5 \times 157.39$

$= 1967.42\ Nm/sec$

iv) Overall Efficiency = $\frac{\text{Fluid power}}{\text{Shaft power}} \times 100\%$

$= \frac{200.04}{1967.42} \times \frac{100}{1}$

$= 0.102 \times 100$

$= 10.1676\%$

$\simeq 10.2\%$

2) Flow rate = $35 dm^3/min = 5.8345 \times 10^{-4} m^3/sec$

Pressure change = 100 bar = $100 \times 10^5 KN/m^2$.

Overall Efficiency = 87%

Shaft power = ? x

Fluid power = $5.8345 \times 10^{-4} \times 100 \times 10^5$

$= 5834.5 W$

Overall Efficiency = $\frac{\text{Fluid power}}{\text{Shaft power}} \times \frac{100}{1}$

$87 = \frac{5834.5 \times 100}{x}$

$87 \times x = 5834.5 \times 100$

$x = \frac{5834.5 \times 100}{87}$

$= \frac{583450}{87}$

$= 6706.32 W$

3S Nominal Displacement = $50 cm^3/rev$ = $5\times10^{-5} m^3/rev$

Pressure change = 100bar = 100×10^5 N/m²

Shaft power = 15 KW = 15,000 W

Actual flow rate = $35 dm^3/min$ = $5.8345\times10^{-4} m^3/sec$?

speed of rotation = 850 rpm. = 14.195 rev/sec.

(i) Overall Efficiency = $\frac{\text{Fluid power}}{\text{Shaft power}} \times 100$.

Fluid power = $5.8345\times10^{-4} \times 100\times10^5$

= 5834.5 W.

Overall Efficiency = $\frac{5834.5}{15,000} \times 100$

= 0.38897 ×100

= 38.897%

≃ 38.9%.

(ii) Volumetric Efficiency = $\frac{\text{Actual flow rate}}{\text{Ideal flow rate}} \times 100$

Ideal flow rate = Nominal displacement × speed of rotation.

= ~~5×10⁻⁵~~ $5\times10^{-5} \times 14.195$

= $7.0975\times10^{-4} m^3/sec$.

Volumetric Efficiency = $\frac{5.8345\times10^{-4}}{7.0975\times10^{-4}} \times 100$

= 0.822 ×100

= 82.2%

4S Water level (z) = 24,000 cm = 240m.

(a) Volumetric flow rate = 13 liters/sec = $13\times10^{-3} m^3/sec$.

Velocity of jet = 66m/sec.

The jet issuing from the nozzle will be at atm pressure and at datum le

P=0, z=0.

Density for water = 1000 kg/m³

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Pressure change = 100bar = $100\times10^5\ N/m^2$

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Actual flow rate = $35 dm^3/min$ = $5.8345\times10^{-4}\ m^3/sec$

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Fluid power = $5.8345\times10^{-4} \times 100\times10^5$

= 5834.5 W.

Overall Efficiency = $\frac{5834.5}{15,000} \times 100$

= 0.38897×100

= 38.897%

≃ 38.9%.

(ii) Volumetric Efficiency = $\frac{\text{Actual flow rate}}{\text{Ideal flow rate}} \times 100$

Ideal flow rate = Nominal displacement x speed of rotation.

= ~~5x10^5~~ $5\times10^{-5} \times 14.195$

= $7.0975\times10^{-4}\ m^3/sec$.

Volumetric Efficiency = $\frac{5.8345\times10^{-4}}{7.0975\times10^{-4}} \times 100$

= 0.822×100

= 82.2%

4S Water level (z) = 24,000 cm = 240m.

(a) Volumetric flow rate = 13 liters/sec = $13\times10^{-3}\ m^3/sec$.

Velocity of jet = 66m/sec.

The jet issuing from the nozzle will be at atm pressure and at datum level, P=0, z=0.

Density of water = $1000 kg/m^3$

i) Power of Jet

① $P = PQ + \frac{\rho \cdot QV^2}{2} + \rho g Q z$

Introducing $P = 0$ and $z = 0$ in the equation above;

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

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

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

$= \frac{5662.8}{2}$

~~$P = 2831.4$ KW~~

~~$P = 28.314$ W~~

~~$P = 2831.4$ W~~ $P = 28314$ W

~~$P = 28.314$ KW~~. $P = 28.314$ KW

ii) Power supplied from reservoir.

The reservoir operates at atm pressure, $P = 0$, and $v = 0$.

$P = PQ + \frac{\rho \cdot QV^2}{2} + \rho g Q z$

Introducing $P = 0$ and $v = 0$ into the above equation.

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

$P = \rho g Q z$.

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

$P = 30607.2$ W

$P = 30.6072$ KW.

iii) Head used to overcome losses.

~~Power loss~~ : Head loss = $\frac{\text{Power lost in transmission}}{\rho g Q}$

Power lost in transmission = Power of reservoir − Power of jet.
= 30607.2 − ~~28314~~ 28314
= 2293.2 W.

Head loss = $\frac{2293.2}{1000 \times 9.81 \times 13 \times 10^{-3}}$

$h = \frac{2293.2}{127.53}$

$h = 17.98$ m.

iv) Efficiency of the pipeline and nozzle in transmitting operation -

Efficiency = $\frac{\text{Power of jet}}{\text{Power of reservoir}} \times 100$

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

$= 0.925 \times 100$

$= 92.5\%$.

5). $Z = 30{,}000$ cm = 300m.
$Q = 220$ litres/sec $= 220 \times 10^{-3}$ m³/sec
$V = 7$ m/sec.
S.g = 0.89. , $\rho = 0.89 \times 1000 = 890$ kg/m³.

① Power of jet.

$P = PQ + \frac{\rho \cdot QV^2}{2} + \rho g Q z$.

$P = 0$, $z = 0$

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

$P = \frac{\rho \cdot QV^2}{2}$.

$= \frac{890 \times 220 \times 10^{-3} \times (7)^2}{2}$

$P = \frac{9594.2}{2}$ ~~P = 4~~

$P = 4797.1 N$

$P = 4.7971 KN$

iii) Power supplied from reservoir

Reservoir operates at atm pressure; $P=0$, $V=0$

$$P = PQ + \frac{\rho Q V^2}{2} + \rho g Q Z$$

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

$$P = \rho g Q Z$$

$$P = 890 \times 9.81 \times 220 \times 10^{-3} \times 300$$

$$P = 576239.4 N$$

~~$P = 576.4$~~

$$P = 576.2394 KN$$

iv) Head used to overcome losses.

$$\text{Head loss} = \frac{\text{Power lost in transmissions}}{\rho g Q}$$

Power lost in transmissions = Power of reservoir − power of jet = 576239.4 − 4797.1 = 571442.3 W

$$\text{Head loss} = \frac{571442.3}{890 \times 9.81 \times 220 \times 10^{-3}} = \frac{571442.3}{1920.798} = 297.50 m.$$

v) Efficiency of the pipline and nozzle in transmitting operation.

$$\text{Efficiency} = \frac{\text{Power of jet}}{\text{Power of reservoir}} \times 100$$

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

$$= 8.32 \times 10^{-3} \times 100$$

$$= 0.832\%$$

6) $h = 20m$
$d = 10cm = 0.1m$
$r = 5cm = 0.05m$.
$g = 9.8ms^{-2}$.

Using conservation of energy,

$\frac{1}{2}mv^2 = mgh$.

$V^2 = \frac{2mgh}{m} = 2gh$
$V^2 = 2 \times 9.81 \times 20$
$V^2 = 392.4 m/s$
$V = 19.8 m/s$.

Flow rate at the base,

$\pi r^2 v = \pi \times (0.05)^2 \times 19.8$
$= 0.1555 m^3/s$

To find the amount of water that emerges from the fountain ea

$\frac{m}{t} = \rho \pi r^2 v$

$\frac{m}{1} = 1000 \times \pi \times (0.05)^2 \times 19.8$

$m = 155.5088 Kg$.

$P = \frac{W}{t} = mg\frac{h}{t}$

$= (\rho \pi r^2 v) g \frac{h}{t}$

$= 155.5088 \times (9.8) \times \left(\frac{20}{1}\right)$

$P = 30479.72W$
$P = 30.47972 KW$.

7) $\rho_g g = 19.62 N/m^2$
$Cd = 0.96$
$d_1 = 0.3m$
$d_2 = 0.2m$

$u_1 = \frac{Q}{0.0707}$ $u_2 = \frac{Q}{0.0314}$

For the manometer;

$P_1 + \rho_g g z = P_2 + \rho_g g (z_2 - R_p) + \rho_w g R_p$

$P_1 - P_2 = 19.62 (z_2 - z_1) + 587.423$ — (i)

For the venturimeter;

$$\frac{P_1}{\rho_g g} + \frac{u_1^2}{2g} + z_1 = \frac{P_2}{\rho_g g} + \frac{u_2^2}{2g} + Z_2$$

$P_1 - P_2 = 19.62 (Z_2 - z_1) + 0.803 u_2^2$ — (ii)

Combining equation (i) and (ii).

$0.803 u_2^2 = 587.423$

$u_{2ideal} = 27.047 m/s$

$Q_{ideal} = 27.047 \times \pi \left(\frac{0.2}{2}\right)^2 = 0.85 m^3/s$

$Q = C_d Q_{ideal} = 0.96 \times 0.85$

$Q = 0.816 m^3/s$

$d_1 = 0.152 m$

$d_2 = 0.076 m$

$\rho = 860 kg/m^3$

$C_d = 0.97$

$A_1 = \frac{\pi d_1^2}{4} = \frac{\pi (0.152)^2}{4} = 0.0181 m$

$A_2 = \frac{\pi d_2^2}{4} = \frac{\pi (0.076)^2}{4} = 4.5 \times 10^{-3} m$

Apply Bernoulli's equation;

$$\frac{P_1}{\rho g} + \frac{u_1^2}{2g} + z_1 = \frac{P_1}{\rho g} + \frac{u_2^2}{2g} + Z_2$$

8) ⓐ $p_1 = p_2$.

$$\frac{u_1^2}{2g} + z_1 = \frac{u_2^2}{2g} + z_2$$

By continuity; $Q = u_1 A_1 = u_2 A_2$,

$$u_2 = u_1 \frac{A_1}{A_2} = u_1 \cdot \frac{0.0181}{4.5\times10^{-3}} = u_1 \cdot 4.02$$

$$\frac{u_1^2}{2g} + 0.914 = \frac{16.178 u_1^2}{2g}$$

~~$u_1 = \sqrt{0.}$~~ $0.914 = \frac{16.178 u_1^2}{2g} - \frac{u}{2}$

$$0.914 = \frac{15.178 u_1^2}{2g}.$$

$$2g \times 0.914 = 15.178 u_1^2.$$

$$u_1^2 = \frac{2\times9.81\times0.914}{15.178}$$

$$u_1 = \sqrt{\frac{2\times9.81\times0.914}{15.178}}$$

$$u_1 = 1.08696 \text{ m}^3/\text{s}.$$

$$Q = C_d A_1 u_1$$

$$Q = 0.96 \times 0.0187 \times 1.08696$$

$$= 0.018887 \text{ m}^3/\text{s}.$$

ⓑ $p_1 - p_2 = 15170$.

~~$\frac{P_1 - P_2}{\rho g} = u_2^2 - u_1$~~ $\frac{P_1}{\rho g} + \frac{u_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{u}{2}$

$$\frac{P_1 - P_2}{\rho g} = \frac{u_2^2 - u_1^3}{2g} - 0.914$$

8) (a) $p_1 = p_2$.

$$\frac{u_1^2}{2g} + z_1 = \frac{u_2^2}{2g} + z_2$$

By continuity; $Q = u_1 A_1 = u_2 A_2$,

$$u_2 = u_1 \frac{A_1}{A_2} = u_1 \cdot \frac{0.0181}{4.5 \times 10^{-3}} = u_1 \cdot 4.02.$$

$$\frac{u_1^2}{2g} + 0.914 = \frac{16.178 u_1^2}{2g}$$

~~$u_1 = \sqrt{0.}$~~

$$0.914 = \frac{16.178 u_1^2}{2g} - \frac{u_1^2}{2g}$$

$$0.914 = \frac{15.178 u_1^2}{2g}.$$

$$2g \times 0.914 = 15.178 u_1^2.$$

$$u_1^2 = \frac{2 \times 9.81 \times 0.914}{15.178}$$

$$u_1 = \sqrt{\frac{2 \times 9.81 \times 0.914}{15.178}}$$

$$u_1 = 1.08696 \text{ m}^3/\text{s}.$$

$$Q = C_d A_1 u_1$$

$$Q = 0.96 \times 0.0181 \times 1.08696$$

$$= 0.018887 \text{ m}^3/\text{s}.$$

$p_1 - p_2 = 15170.$

~~$\frac{P_1 - P_2}{\rho g} = u_2^2 - u_1$~~

$$\frac{P_1}{\rho g} + \frac{u_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{u_2^2}{2g} + z_2$$

$$\frac{P_1 - P_2}{\rho g} = \frac{u_2^2 - u_1^3}{2g} - 0.914$$

~~$\frac{15170}{\rho g} = Q^2 ($~~

~~$u_1 = 1.08696$~~

~~$u_2 = 16.178 u_1^2$~~

~~$u_2 = 16.178 (1.08696)$~~

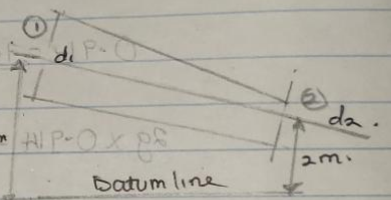
$$\frac{15170}{\rho g} = Q^2 \frac{(220.43^2 - 55.11^2)}{2g} - 0.914$$

~~$\frac{15170}{}$~~ ~~55.85~~

$55.8577 = Q^2 (220.43^2 - 55.11^2)$

$Q = 0.035 m^3/s.$

9) 1000 litre = $1m^3$



At section 1

$d_1 = 300mm = ~~3m~~. 0.3$

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

$z_1 = 10m$

$V_1 = ?$

$p_1 = 400 \times 10^3 N/m^2.$

At Section 2.

$d_2 = 150mm = 0.15m^2$

$A_2 = \frac{\pi d^2}{4} = \frac{\pi (0.15)^2}{4} = 0.01767 m^2.$

$Z_2 = 6m.$

$V_2 = ?$

$p_2 = ?$

$A_1V_1 = A_2V_2$

$A_1V_1 = 40 lit/sec = 40 \times 10^{-3} m^3/sec$

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

$V_1 = 0.566\ m/s$.

$V_2 = \frac{40 \times 10^{-3}}{0.01767} = 2.264\ m/s$

Applying Bernoulli's equation;

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

$$\frac{400 \times 10^3}{9800} + \frac{(0.566)^2}{2 \times 9.8} + 10 = \frac{P_2}{w} + \frac{(2.264)^2}{2 \times 9.8} + 6.$$

$$40.816 + 0.016 + 10 = \frac{P_2}{w} + 0.26 + 6.$$

$$50.832 = \frac{P_2}{w} + 6.26$$

$$\frac{P_2}{w} = 44.572.$$

$P_2 = 44.572 \times 9800$

$P_2 = 436805.6\ N/m^2$

$P_2 = 436.8056\ kN/m^2$.

105. $r = 170mm = 0.17m$.

$S_m = 13.6$

$S = 1.025$

$C = 1$

$V = ?$

$$V = C\sqrt{2gr\left(\frac{S_m}{S} - 1\right)}$$

$$V = 1\sqrt{2 \times 9.81 \times 0.17\left(\frac{13.6}{1.025} - 1\right)}$$

$$V = \sqrt{3.354\,(13.268 - 1)}$$

$$V = \sqrt{3.3354 \times 12.268}$$
$$V = \sqrt{40.91966}$$
$$V = 6.4 \text{ m/s}.$$