Mechatronics

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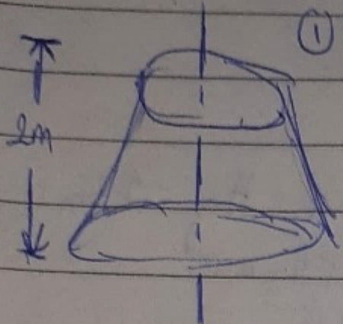
Fluid Mechanics

1.



① $V_1 = 5\,m/s$

$V_2 = 2\,m/s$

$P_1 = \frac{P_1}{w} = 2.5\,m$

$H_L = \frac{0.35(V_1 - V_2)^2}{2g}$

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

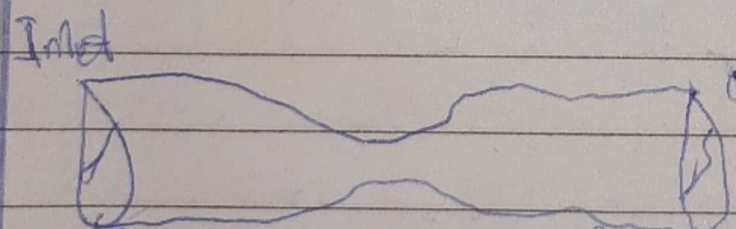
$$\frac{P_2}{w} = \frac{P_1}{w} = \frac{V_1^2 - V_2^2}{2g} + (Z_1 - Z_2) - \frac{0.35(V_1 - V_2)^2}{2g}$$

$$\frac{P_2}{w} = 2.5 + \frac{5^2 - 2^2}{2(9.81)} + 2 - \frac{0.35(5-2)^2}{2(9.81)}$$

$$\frac{P_2}{w} = 2.5 + 1.07 + 2.0161$$

$$\frac{P_2}{w} = 5.409\,m \text{ of liquid}$$

2



Inlet ; $d_1 = 20\,cm = 20 \times 10^{-2}\,m$

$A = \frac{\pi d^2}{4} = \frac{\pi \times (20 \times 10^{-2})^2}{4}$

$A_1 = 0.0314\,m^2$

$P_1 = 17.668\,N/cm^2$

Throat Diameter, $d_2 = 10\,cm = 10 \times 10^{-2}\,m$

$A = \frac{\pi d^2}{4} = \frac{\pi \times (10 \times 10^{-2})^2}{4}$

$C_d = 0.98$

$A_2 = 7.85 \times 10^{-3}\,m^2$

To get h:

$\frac{P_1}{w} - \frac{P_2}{w} = h$

$P_1 = 17.068 \times 10^4 \; N/m^2$

$w = 9.81 \times 10^3 \; N/m^3$

but we have that throat vacuum pressure = 30cm of Hg = 0.3m Hg

$= 0.3 \times 13.6 = 4.08$

$\frac{P_2}{w} = -4.08$

Then $\frac{P_1}{w} = \frac{17.658 \times 10^4}{9.81 \times 10^3} = 18$

$\therefore \frac{P_1}{w} - \frac{P_2}{w} ; 18 - (-4.08) = 22.08$

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

$= 0.98 \times 0.0314 \times 7.85 \times 10^{-3} \times \sqrt{\frac{2 \times 9.81 \times 22.08}{(0.0314^2 - (7.85 \times 10^{-3})^2)}}$

$= 2.4156 \times 10^{-4} \times 684.59$

$= 0.1653$

$Q_{actual} = 0.1653 \; m^3/s$

3. Orifice meter; Given that

$d_0 = 15cm = 15 \times 10^{-2} \; m$ $\quad A_P = \frac{\pi \times (30 \times 10^{-2})^2}{4}$

$A_0 = \frac{\pi \times (15 \times 10^{-2})^2}{4}$

$= 0.01767 \; m^2$ $\quad = 0.07069 \; m^2$

S.P.G of oil = 0.9 (S_0)

Coefficient of discharge = 0.64

Reading of differential = 50cm Hg

Differential head $h_1 = y\left[\frac{S_{hL}}{S_0} - 1\right]$

$S_{hL} = 13.6$

$y = 50 \times 10^{-2}$

$h = 50 \times 10^{-2}\left[\frac{13.6}{0.9} - 1\right]$

$h = 50 \times 10^{-2} \times 14.11$

$= 7.055\,m$

$Q = \frac{C_d A_1 A_0 \sqrt{2gh}}{\sqrt{A_1^2 - A_0^2}}$

$\frac{0.64 \times 0.1767 \times 0.07069 \times \sqrt{2 \times 9.81 \times 7.055}}{\sqrt{(0.07069^2) - (0.1767^2)}}$

$= \frac{7.994 \times 10^{-4} \times 11.765}{\sqrt{4.08 \times 10^{-3}}}$

$= 0.1374\, m^3/s$

4. $y = 170\,mmHg = 0.17\,mHg$, $S.g_{Hg} = 13.6$, $S.g_{sw} = 1.026$

$\Delta h = y\left(\frac{S.g_{Hg}}{S.g_{sw}} - 1\right)$

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

$\Delta h = 2.08\,m$

$v = \sqrt{2g\Delta h}$

$v = \sqrt{2 \times 9.81 \times 2.08}$

$v = 6.388\,m/s$

5. $Q = 0.05\,dm^3/min = 8.33 \times 10^{-5}\,m^3/s$

Speed of Rotation = 1700 Rev/min = 28.3 Rev/sec

Nominal Displacement = $10\,cm^3/rev = 10^{-5}\,m^3/rev$

Torque Input = 15 Nm

Pressure Change = 15 bar = $15 \times 10^5\,N/m^2$

Ideal Flow rate = Nominal Displacement x speed Rotation,

a) Volumetric Efficiency $= \frac{\text{Actual flowrate}}{\text{Ideal flowrate}} \times 100$

$= \frac{8.33 \times 10^{-5}}{2.03 \times 10^{-4}} \times 100$

b) Fluid Power, $P_F = Q \times \Delta p$

$= 8.33 \times 10^{-5} \times 15 \times 10^{5}$

$= 124.95$ watts

c) Shaft Power $= \tau \times \omega$

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

$\omega = 2 \times \pi \times 28.3$

$\omega = 177.81$ ~~rad/sec~~ rad/sec

$\therefore$ shaft power $= 15 \times 177.81$

$= 2667.2$ watts

d) Overall Efficiency $= \frac{\text{Fluid Power}}{\text{Shaft Power}} \times 100$

$= \frac{124.95}{2667.2} \times 100$

$= 4.68\%$