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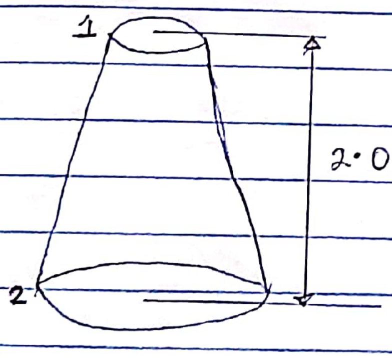
Question 1

A conical tube of length 2.0m is fixed vertically with its smaller end upwards. The velocity of flow at the smaller end is 5m/s while at the lower end it is 2m/s. The pressure head at the smaller end is 2.5m of liquid. The loss of head in the tube is given as $\left(\frac{0.35(V_1 - V_2)^2}{2g}\right)$ where V_1 is the velocity at the smaller end and V_2 at the lower end respectively. Determine the pressure head at the lower end. Flow takes place in the downward direction.

Solution



Parameters

Length = 2.0m

$V_1 = 5m/s$

$V_2 = 2m/s$

$\frac{P_1}{w} = 2.5m$ of liquid.

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

$h_2 = \frac{P_2}{w} = ??$

Using Bernoulli's Equation

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

NB $Z_1 = 2m$ & $Z_2 = 0m$

$$2.5 + \frac{5^2}{2 \times 9.81} + 2 = \frac{P_2}{w} + \frac{2^2}{2 \times 9.81} + 0 + \frac{0.35(5-2)^2}{2 \times 9.81}$$

$$2.5 + 1.274 + 2 = \frac{P_2}{w} + 0.204 + 0.161$$

$$5.774 - 0.365 = \frac{P_2}{w} \quad \therefore \frac{P_2}{w} = 5.409 \text{ m of liquid}$$

Pressure head at lower end = 5.409m of liquid

Question 2

A horizontal Venturimeter with inlet diameter 20cm and throat diameter 10cm is used to measure the flow of water. The pressure at inlet is 17.658 N/cm² and the vacuum pressure at the throat is 30cm of mercury. find the discharge of water through Venturimeter. Take $C_d = 0.98$

Solution

Parameters

$d_1 = 20cm \longrightarrow 0.2m$

$d_2 = 10cm \longrightarrow 0.1m$

$P_1 = 17.658\ N/cm^2$

P_2 [Vacuum Pressure i.e negative pressure] = 30cm of Hg

$Q_{act} = ??$

$C_d = 0.98$

and $Q_{act} = \dfrac{C_d \times A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$

$P_1 = \dfrac{17.658\ N}{cm^2} \times \dfrac{(100\ cm)^2}{1m^2} = 176580\ N/m^2$

$P_2 = 30cm$ of Mercury $= 0.3m$ of Mercury

$h = \dfrac{P_1 - P_2}{w} = \dfrac{P_1}{w} - \left(-\dfrac{P_2}{w}\right)$ Due to negative Pressure

$h = \dfrac{176580}{9.81 \times 1000} + \dfrac{0.3 \times 13.6 \times \cancel{9.81 \times 1000}}{\cancel{9.81 \times 1000}}$

$h = 18 + 4.08$

$h = 22.08$ m of water

$A_1 = \dfrac{\pi d_1^2}{4} = \dfrac{\pi \times 0.2^2}{4} = 0.0314\ m^2$

~~$Q_{act} = 0.9$~~

$A_2 = \dfrac{\pi d_2^2}{4} = \dfrac{\pi \times 0.1^2}{4} = 7.854 \times 10^{-3}\ m^2$

$Q = 0.98 \times \dfrac{0.0314 \times 7.854 \times 10^{-3}}{\sqrt{0.0314^2 - (7.854 \times 10^{-3})^2}} \times \sqrt{2 \times 9.81 \times 22.08}$

$Q = 0.98 \times 8.112 \times 10^{-3} \times 20.814$

discharge of water (Q) $= 0.165\ m^3/s$

Question 3: An Orifice Meter with Orifice diameter 15cm is inserted in a pipe of 30cm diameter. The pressure difference measured by a mercury oil differential manometer on the two sides of the orifice meter gives a reading of 50cm of Mercury. Find the rate of flow of oil of specific gravity of 0.9, when the coefficient of discharge of the meter is 0.64

Solution

Parameters

$d_0 = 15cm \rightarrow 0.15m \therefore A_0 = \frac{\pi d_0^2}{4} = \frac{\pi \times 0.15^2}{4} = 0.0177m^2$

$d_1 = 30cm \rightarrow 0.3m$ and $A_1 = \frac{\pi d_1^2}{4} = \frac{\pi \times 0.3^2}{4} = 0.0707m^2$

Rate of flow of Oil = ??

S.G of oil = 0.9

$C_d = 0.64$

h for Mercury = 50cm of Mercury = 0.5m of Mercury

$$h \text{ for Oil} = \left(\frac{\text{specific gravity of Mercury}}{\text{specific gravity of oil}} - 1\right) \times h \text{ for mercury}$$

$$= \left(\frac{13.6}{0.9} - 1\right) \times 0.5$$

$$= 7.056m \text{ of oil}$$

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

$$Q = \frac{0.64 \times 0.0177 \times 0.0707 \times \sqrt{2 \times 9.81 \times 7.056}}{\sqrt{(0.0707)^2 - (0.0177)^2}}$$

$$Q = \frac{9.423 \times 10^{-3}}{0.0684}$$

$$Q = 0.138 \, m^3/s$$

$\therefore$ Rate of flow of Oil = $0.138 \, m^3/s$

Question 4; A submarine moves horizontally in sea and has its axis 15m below the surface of water. A pitot-tube properly placed just in front of the sub-marine and along its axis is connected to the two limbs of a U-tube containing mercury. The difference of mercury level is found to be 170mm. find the speed of the sub-marine knowing the specific gravity of mercury is 13.6 and that of sea water is 1.026 with respect to fresh water.

Solution

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

difference in mercury level = 170 mm of mercury

= 0.17 m of mercury

To find difference in mercury level in terms of sea water

$$\therefore \quad h = \left(\frac{\text{Specific gravity of Mercury}}{\text{Specific gravity of sea water}} - 1 \right) \times 0.17$$

$$h = \left(\frac{13.6}{1.026} - 1 \right) \times 0.17 \quad = 2.083\text{ m of sea water}$$

$$V = \sqrt{2 \times 9.81 \times 2.083}$$

$$V = \sqrt{40.86846}$$

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

$\therefore$ Speed of Submarine = 6.393 m/s

Question 5: A pump delivers at the rate of ~~0.05m³/min~~ $5\,dm^3/min$ with a pressure change of 15bar. The speed of rotation is 1700 rev/min while the normal displacement is given as $10cm^3/rev$ If the torque input is 15Nm Compute (i) Volumetric efficiency (ii) fluid power (iii) Shaft power (iv) overall efficiency.

Solution

Parameters

$Q_{act} = 5dm^3/min$

$10\,dm \rightarrow 1m$ and $60\,s \rightarrow 1min$

$(10dm)^3 \rightarrow (1m)^3$

$$Q_{act} = \frac{5\cancel{dm^3}}{\cancel{min}} \times \frac{1m^3}{(10)^3\cancel{dm^3}} \times \frac{1\cancel{min}}{60s}$$

$$Q_{act} = 8.333 \times 10^{-5}\ m^3/s$$

$$P = 15\ bar = 15 \times 10^5\ N/m^2$$

$$V = 1700\ rev/min$$

$$= \frac{1700\ rev}{\cancel{min}} \times \frac{1\cancel{min}}{60s} = 28.333\ rev/s$$

$$\text{displacement} = 10cm^3/rev$$

$(100cm)^3 \rightarrow (1m)^3$

$$\frac{10cm^3}{rev} \times \frac{1m^3}{(100\,cm)^3} = 1 \times 10^{-5}\ \frac{m^3}{rev}$$

Ideal flow rate = normal displacement × speed

$$= \frac{1 \times 10^{-5} m^3}{\cancel{rev}} \times \frac{28.333\ \cancel{rev}}{s}$$

$$= 2.8333 \times 10^{-4}\ m^3/s$$

1) Volumetric efficiency $= \frac{\text{Actual flow rate}}{\text{Ideal flow rate}} \times 100\%$

$$= \frac{8.333 \times 10^{-5}}{2.8333 \times 10^{-4}} \times 100\%$$

$$= 29.41\%$$

2) fluid power = Actual flow rate $\times$ pressure

$$= 8.333 \times 10^{-5} \frac{m^3}{s} \times 15 \times 10^5 \frac{N}{m^2}$$

$$= 124.995 \text{ watt}$$

3) Shaft power $= \tau \times \omega$

τ = Torque $\quad \omega$ = angular speed

Speed $= 28.333 \frac{rev}{s}$

and angular speed is in rads/sec

$360^\circ \rightarrow 1 rev$

$\pi\, rad \rightarrow 180^\circ$

$\therefore 2\pi\, rad \rightarrow 1 rev$

$28.333 \frac{rev}{s} \times \frac{2\pi}{rev}\, rad$

$$= 2 \times \frac{22}{7} \times 28.333$$

$$= 178.021\, rad/s$$

$\therefore$ shaft power $= 15 \times 178.021$

$$= 2670.315 \text{ watt}$$

4) Overall efficiency $= \frac{\text{fluid power}}{\text{shaft power}} \times 100\%$

$$= \frac{124.995}{2670.315} \times 100\%$$

$$= 4.68\%$$