ALE-ALABA OLUWASEUN OLUMIDE 19/ENG06/064 MECHANICAL

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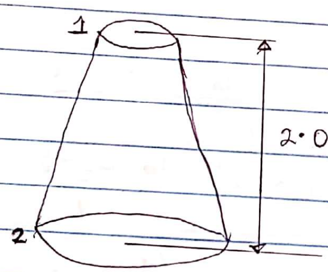
Question 1

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

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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 $17.658 N/cm^2$ 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 $$Q_{act} = \frac{C_d \times A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$$

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

P_2 = 30cm of Mercury = 0.3m of Mercury

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

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

$h = 18 + 4.08$

$h = 22.08$ m of water

~~$Q_{act} = Q.9$~~

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

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

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

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

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

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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 $= 0.138 m^3/s$

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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 = 170mm of Mercury

= 0.17m of Mercury

To find difference in Mercury level in terms of sea water

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

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

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

$$V = \sqrt{40.86846}$$

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

$\therefore$ Speed of Sub marine $= 6.393\ \text{m/s}$

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

Solution

Parameters

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

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

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

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

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

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

$$V = 1700 \text{ rev/min}$$

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

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

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

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

Ideal flow rate = normal displacement $\times$ speed

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

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

8.

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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 X pressure

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

$= 124.995$ watt

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

τ = Torque $\quad w$ = angular speed

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

and angular speed is in rads/sec

$360^\circ \rightarrow 1 rev$

π rad $\rightarrow 180^\circ$

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

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

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

$= 178.021$ rad/s

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

$= 2670.315$ watt

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

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

$= 4.68\%$