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FLUID MECHANICS

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 tube is given as $(0.35(V_1-V_2)^2/2g$ where V_1 is velocity at the smaller end and V_2 is at the lower end respectively. Determine the pressure head at the lower end. Flow takes place in the downward direction.

Sol

$L = z_1 - z_2 = 2.0m$

$V_1 = 5m/s \qquad V_2 = 2m/s$

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

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

Considering loss of head (h_L) in the tube:

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

Applying Bernoulli's equation between points 1 and 2, we have:

$$\frac{P_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + z_2 + h_L$$

$$\frac{P_2}{w} = \frac{P_1}{w} + \frac{1}{2g}(V_1^2 - V_2^2) + (z_1 - z_2) - h_L$$

$$= 2.5 + \frac{(5^2 - 2^2)}{2 \times 9.81} + 2.0 - \frac{0.35(5-2)^2}{2 \times 9.81}$$

$$= 2.5 + \frac{21}{19.62} + 2 - \frac{0.35 \times 9}{19.62} \Rightarrow 2.5 + 1.07 + 2 - 0.16 = \underline{5.41m \text{ of the liquid}}$$

$P_2 = 5.41 \times 9810 \times 10^{-5}$ bar

$= 0.531$ bar or $5.41m$ of liquid

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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 30 cm of mercury. Find the discharge of water through venturimeter. Take $C_d = 0.98$

Soln

$C_d = 0.98$ $\quad d_1 = 20cm = 0.2m$ $\quad d_2 = 10cm = 0.1m$

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

$A_2 = \frac{\pi d_2^2}{4} = \frac{\pi \times 0.1^2}{4} = 0.0079m^2$

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

Note: P_2/w is the pressure head at the exit

$P_1 = 17.658 N/cm^2 = 17.658 \times 10{,}000 \Rightarrow 176{,}580 N/m^2$

Recall, $w = \rho g$

$\therefore \frac{P_1}{w} = \frac{176{,}580}{1000 \times 9.81} = 18m$

Note: The vacuum pressure is always (-) (convert 30 cm to metres = 0.3m)

$\frac{P_2}{w} = -30cm$ of mercury.

$= -0.3m$ of mercury $= -0.3 \times 13.6 = -4.08m$ of water

$h = \frac{P_1}{w} - \frac{P_2}{w} = 18 - (-4.08) = 18 + 4.08 = 22.08m$

Rate of flow, Q:

$Q = \frac{C_d \times A_1 \times A_2 \times \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}} = \frac{0.98 \times 0.0314 \times 0.0079 \times \sqrt{2 \times 9.81 \times 22.08}}{\sqrt{0.0314^2 - 0.0079^2}}$

$= \frac{0.000243 \times 20.814}{0.0304} = 0.166 m^3/s$

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

Solution

Diameter of the pipe, $D_2 = 30cm = 0.3m$

Diameter of the orifice, $D_1 = 15cm = 0.15m$

$A_2 = \frac{\pi D_1^2}{4} = \frac{\pi \times 0.15^2}{4} = 0.018m^2$

$A_1 = \frac{\pi D_2^2}{4} = \frac{\pi \times 0.3^2}{4} = 0.071m^2$

Specific gravity of oil = 0.9

Reading of differencial manometer = 50cm of mercury = 0.5m of mercury = y

Coefficcent of discharge of meter = 0.64

$\therefore$ Differential head, $h = y\left[\frac{S_m}{S_o} - 1\right]$

where Sm is specific gravity of the heavier liquid = 13.6 (for mercury))

$= 0.5\left[\frac{13.6}{0.9} - 1\right] = 7.06$ m of oil

Using the relation, $Q = \frac{C_d \, A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$

$= \frac{0.64 \times 0.018 \times 0.071 \times \sqrt{2 \times 9.81 \times 7.06}}{\sqrt{0.071^2 - 0.018^2}}$

$= \frac{0.00081792 \times 11.76933303}{0.06868}$

$= 0.14 m^3/s$

4 A submarine moves horizontally in sea and has its axis 15 m below the surface of water. A pitot tube properly placed just in front of the submarine 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 170 mm. Find the speed of the submarine knowing the Sp. gr. of mercury is 13.6 and that of sea water is 1.026 with respect to fresh water.

Solution.

Difference of mercury level = 170 mm = 0.17 m of mercury

Specific gravity of mercury, $S_m = 13.6$

Specific gravity of sea water, $S_L = 1.026$

To find the head, using the relation: $h = y\left(\frac{S_m}{S_L} - 1\right)$, we have,

$$h = 0.17\left(\frac{13.6}{1.026} - 1\right) = 2.08$$

∴ Velocity of submarine

$$V = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 2.08}$$

$$= \underline{6.39 \text{ m/s}} \quad \text{or} \quad 23.004 \text{ km/h}$$

5 A pump delivers at the rate of 5.0 dm³/min with a pressure change of 15 bar. The speed of rotation is 1700 rev/min while the normal displacement is given as 10 cm³/rev. If the torque input is 15 N m. Compute

i Volumetric Efficiency (ii) Fluid Power (iii) Shaft Power (iv) Overall efficiency

Solution

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

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

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

Torque Input = 15 N m

Pressure chang = 15 bar = $15 \times 10^3 \text{ N/m}^2$

Ideal flowrate = Nominal displacement × Speed Rotation

$= 10^{-5} \times 28.3 = 2.83 \times 10^{-4} \text{ m}^3/\text{s}$

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

$$= \frac{8.335 \times 10^{-5}}{2.83 \times 10^{-4}} \times 100$$

$$= 29.45\%$$

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

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

$$= 124.95 W$$

c) Shaft Power = $T \times W$

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

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

$\omega = 177.81$ rad/sec

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

$$= 2667.2 W$$

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

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

$$= 4.68\%$$

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