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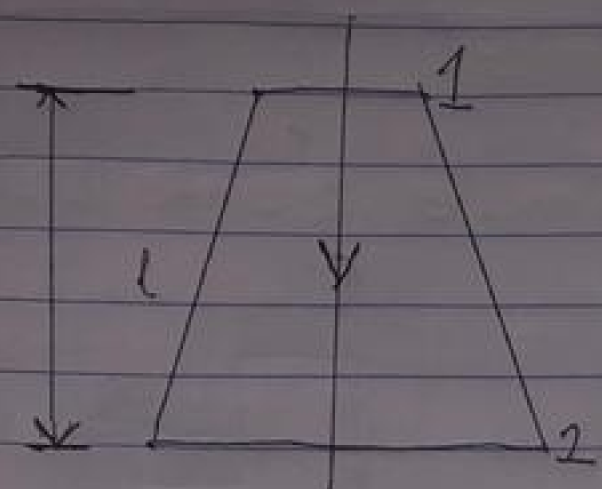
CHEMICAL ENGINEERING
FLUID MECHANICS

1)



Length, $L = 2.0m$

The velocity flow at smaller end
$V_1 = 5m/s$
The velocity flow at lower end
$V_2 = 2m/s$
Let the pressure head at the smaller end
$P_s = 2.5m$ of liquid
Let the loss of head $= H_L = \frac{0.35(V_1 - V_2)^2}{2g}$

$$= \frac{0.35(5-2)^2}{2 \times 9.81} = 0.161m$$

Let the pressure head at the lower end $= P_L = P$

Applying Bernoulli's Equation

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

where $P_s = \frac{P_1}{\rho g}$ and $P_L = \frac{P_2}{\rho g}$

$Z_1 = 2.0$ and $Z_2 = 0$ (datum line passes through section 2.

Inputing values into the equation

$$2.5 + \frac{5^2}{2 \times 9.81} + 2.0 = P_L + \frac{2^2}{2 \times 9.81} + 0 + 0.161$$

$$2.5 + \frac{25}{2 \times 9.81} + 2 = P_L + \frac{4}{19.62} + 0.161$$

$$2.5 + \frac{25}{19.62} + 2 - \left(\frac{4}{19.62} + 0.161\right) = P_L$$

$$5.774 - 0.365 = P_L$$

$$P_L = 5.409 m \text{ of fluid}$$

(2) Let Inlet diameter = $D_1 = 20 cm$

Let throat diameter $= D_2 = 10 cm$

Let Inlet area $= A_1 = \frac{\pi D_1^2}{4} = \frac{\pi (20)^2}{4} = 314.16 cm^2$

Let throat area $= A_2 = \frac{\pi D_2^2}{4} = \frac{\pi (10)^2}{4} = 78.54 cm^2$

Density of water $\rho = 1000 kg/m^3$.

pressure at Inlet $= 17.658 N/cm^2 = 17.658 \times 10^4 N/m^2$

$$\therefore \frac{P_1}{\rho g} = \frac{17.658 \times 10^4}{1000 \times 9.81} = 18 m$$

$\frac{P_2}{\rho g} = -30 cm$ of mercury, $S.g_{Hg} = 13.6$

$$\frac{P_2}{\rho g} = -30 \times 10^{-2} m \text{ of mercury} \times 13.6$$

$$= -4.08 m$$

Let Differential Head $= H = \frac{P_1}{\rho g} - \frac{P_2}{\rho g}$

$$= 18 - (-4.08)$$

$$= 18 + 4.08 = 22.08 m \times 100$$

$$H = 2208 cm$$

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

$$= \frac{0.98 \times \sqrt{2 \times 981 \times 2208} \times 314.16 \times 78.54}{\sqrt{(314.16)^2 - (78.54)^2}}$$

$$= \frac{0.98 \times 2081.37 \times 24674.1264}{304.184112}$$

$$= 165455.3 \, cm^3/s$$

$$= \frac{165455.3}{1000} = 165.455 \, lit/sec$$

(3) Diameter of pipe $d_1 = 30cm$

$$A_1 = \frac{\pi d_1^2}{4} = \frac{\pi (30)^2}{4} = 706.86 cm^2$$

Diameter of Orifice, $d_2 = 15cm$

$$A_2 = \frac{\pi d_2^2}{4} = \frac{\pi (15)^2}{4} = 176.72 cm^2$$

Specific gravity of oil, $S_o = 0.9$
Specific gravity of mercury, $S_{hg} = 13.6$
Differential manometer reading, $x = 50cm$ of mercury
Coefficient of discharge, $C_d = 0.64$
Differential head, $h = x\left(\frac{S_{hg}}{S_o} - 1\right)$

$$h = 50\left(\frac{13.6}{0.9} - 1\right)$$

$$h = 705.56cm \text{ of oil}$$

∴ The rate of flow of oil is

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

$$Q = 0.64 \times \frac{\sqrt{2 \times 9.81 \times 705.56} \times 706.86 \times 176.72}{\sqrt{(706.86)^2 - (176.72)^2}}$$

$$Q = 137443.29 \, cm^3/s$$

$$Q = \frac{137443.29}{1000} = 137.44 \, lit/s$$

(4) The difference of mercury load, $x = 170mm = 170 \times 10^{-3} = 0.17m$
The Specific gravity of mercury, $S_g = 13.6$
The Specific gravity of water, $S_0 = 1.026$
The speed, $V = ?$

$$V = \sqrt{2gh}, \quad h = ?$$

$$h = x\left[\frac{S_g}{S_0} - 1\right] = 0.17\left[\frac{13.6}{1.026} - 1\right]$$

$$= 2.0834 m$$

$$\therefore V = \sqrt{2 \times 9.81 \times 2.0834} = 6.393 m/s$$

In km/hr

$$V = \frac{6.393 \times 60^2}{1000} = 23.07 km/hr$$

(5) $Q = 0.05 m^3/min = 50 dm^3/min$
$P_s = 15 bar = 15 \times 100000 = 15 \times 10^5 N/m^2$
speed $= 1700 rev/min$
$T = 15 Nm$, $ND = 10 cm^3/rev$

(i) Volumetric efficiency $= \frac{\text{Actual flow rate}}{\text{Ideal flow rate}}$

Ideal flow rate = Nominal flow rate x speed
$= 10 cm^3/rev \times 1700 rev/min$
$= 17000 cm^3/min$

Ideal flow rate $= \frac{17000}{1000000} = 0.017 m^3/min$

Actual flow rate $= 0.05 m^3/min$

$\therefore$ Volumetric Efficiency $= \frac{0.05}{0.017} = 2.94\% = 294\%$

ii) Fluid Power $= P \times Q$
$P = 15 \times 10^5 N/m^2$
$Q = 0.05 m^3/min = \frac{0.05}{60} = 8.33 \times 10^{-4} m^3/s$

$$\text{Fluid Power} = 15\times10^{5} \times 8.3\times10^{-4}$$
$$= 15\times10^{5} \times 83.3\times10^{-5}$$
$$= 12495 \times10^{5-5}$$

Fluid power = 1249.5 watts

(iii) $$\text{Shaft power} = \frac{2\pi NT}{60} = \frac{2\pi\times1700\times15}{60}$$

Shaft power = 2670.35 watts

(iv) $$\text{Overall Efficiency} = \frac{\text{Fluid Power}}{\text{Shaft Power}}$$

$$\frac{\text{Fluid power}}{\text{Shaft Power}} = \frac{1249.5}{2670.35} = 0.468$$

Overall Efficiency = $0.468\times100 = 46.8\%$