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18/ENG05/021
Civil Engineering.
Fluid Mechanics (ENG 214)

1) Given:

$L = 2.0m$

$V_1 = 5m/s$

$P_1/\rho g = 2.5m$ of liquid

$V_2 = 2m/s$

The loss of head in the tube:

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

$= \frac{0.35[5-2]^2}{2g} = \frac{0.35 \times 9}{2 \times 9.81}$

$= 0.16m$

Pressure head $= \frac{P_2}{\rho g}$;

Applying Bernoulli's equation we get:

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

Let the datum line pass through the lower end; $Z_2 = 0$, $Z_1 = 2.0$.

$\therefore 2.5 + \frac{5^2}{2 \times 9.81} + 2.0 = \frac{P_2}{\rho g} + \frac{2^2}{2 \times 9.81} + 0 + 0.16$

$2.5 + 1.27 + 2.0 = \frac{P_2}{\rho g} + 0.203 + 0.16$

$\frac{P_2}{\rho g} = (2.5 + 1.27 + 2.0) - (0.203 + 0.16)$

$= 5.77 - 0.363$

2) Inlet Diameter; $d_1 = 20cm$

$a_1 = \frac{\pi}{4} \times (20)^2 = 314.16 cm^2$

Throat diameter $d_2 = 10cm$

$a_2 = \frac{\pi}{4} \times 10^2 = 78.74 cm^2$

$P_1 = 17.658 N/cm^2$

$= 17.658 \times 10^4 N/m^2$

density of water $= 1000 kg/m^3$

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

$\frac{P_2}{\rho g} = -30cm$ of mercury

$= -0.30m = -0.30 \times 13.6$

$= -4.08m$ of water.

$\therefore$ Differential head:

$= h = \frac{P_1}{\rho g} - \frac{P_2}{\rho g} = 18 - (-4.08)$

$= 18 + 4.08 = 22.08m$ of water.

$= 2208$ cm of water.

The discharge $Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$

$= 0.98 \times \frac{314.16 \times 78.54}{\sqrt{(314.16)^2 - (78.74)^2}}$

$\times \sqrt{2 \times 9.81 \times 2208}$

$= 16548.3 cm^3/s = 165.48$ lit/s

3)

3> Orifice diameter : $d_0 = 15cm$

∴ Area $a_0 = \frac{\pi}{4}(15)^2 = 176.7cm^2$

Diameter of pipe $d_1 = 30cm$

Area $a_1 = \frac{\pi}{4}(30)^2 = 706.85cm^2$

Specific gravity of oil $S_0 = 0.9$

Reading on differential manometer;

$x = 50cm$ of mercury

∴ Differential head ;

$$h = x\left[\frac{S_g}{S_0} - 1\right] = 50\left[\frac{13.6}{0.9} - 1\right]$$

$= 50 \times 14.11 = 705.5$ cm of oil.

Where $C_d = 0.64$

$$Q = C_d \cdot \frac{a_0 a_1}{\sqrt{a_1^2 - a_0^2}} \times \sqrt{2gh}$$

$$= 0.64 \times \frac{176.7 \times 706.85}{\sqrt{(706.85)^2 - (176.7)^2}}$$

$$\times \sqrt{2 \times 9.81 \times 705.5}$$

$= 13741.26 cm^3/s$

$= 137.41$ litres/s

4> Diff. of mercury level;

$x = 170mm = 0.17m$

Sp. gr. of mercury $= 13.6$

Sp. gr. of sea water $= 1.026$

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

$$\therefore 0.17\left[\frac{13.6}{1.026} - 1\right] = 2.0834 m$$

$V = \sqrt{2gh}$

$$\therefore V = \sqrt{2 \times 9.81 \times 2.0834}$$

$= 6.393 m/s$

$$= \frac{6.393 \times 60 \times 60}{1000}$$

$= 23.01 km/h$

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

m^3/min to m^3/sec

60 secs → 1 min

$$= \frac{0.05}{60} = 8.33 \times 10^{-4} m^3/sec$$

$\therefore Q = 8.33 \times 10^{-4} m^3/sec$

Speed of rotation $(N) = 1700$ rev/min

$$= \frac{1700}{60} = 28.3 \text{ rev/sec}$$

$= 28.3$ rps

Pressure change $= 15$ bar
$= 15 \times 10^5$ N/m²

Norminal displacement $= 10 cm^3/rev.$

$100 cm = 1 m$

$100^3 cm^3 = 1 m^3$

$10 cm^3 = x$

$\therefore x = \frac{10}{1000000} = 1 \times 10^{-5} m^3/rev.$

Ideal flow rate = Norminal × speed displacement

$= 28.3 \times 1 \times 10^{-5}$

$= 2.83 \times 10^{-4} m^3/sec$

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

$= \frac{8.33 \times 10^{-4}}{2.83 \times 10^{-4}} \times 100\%$

$= 294.3\%$

ii) P_f = Actual flowrate (Q) × pressure change (H)

$= 8.33 \times 10^{-4} \times 15 \times 10^5$

$= 1249.5$ watts or Nm/sec

iii) Shaft power $= T \cdot \omega$

Where; T = Torque input (N/m)

ω = angular speed (rad/sec)

$T = 15 Nm$

$\omega = 2\pi N = 2 \times \frac{22}{7} \times 28.3$

$= 177.89$ rad/sec.

Shaft Power $= 15 \times 177.89$

$= 2668.35$ watts

iv) Overall Efficiency:

$= \frac{\text{fluid power}}{\text{Shaft power}} \times 100\%$

$= \frac{1249.5}{2668.35} \times 100\%$

$= 46.8\%$