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MATRIC NO: 19/ENG08/009
DEPARTMENT: BIOMEDICAL ENGINEERING
COURSE CODE AND TITLE: ENG 214 - FLUID MECHANICS

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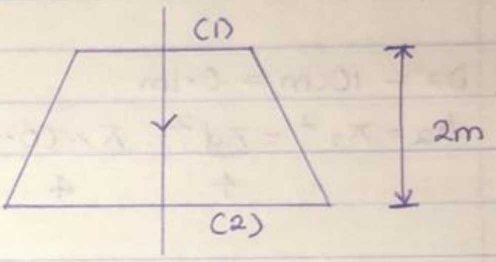
1. Length = 2m
Velocity at smaller end, $V_1 = 5m/s$
Velocity at lower end, $V_2 = 2m/s$
Pressure head at smaller end = 2.5m of liquid
Pressure head at lower end = ?
Loss of head = $\frac{(0.35(V_1 - V_2)^2)}{2g}$



Solution

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

Substitute $V_1, V_2, 2g$

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

$$= \frac{0.35 \times 9}{2 \times 9.81} = \frac{3.15}{19.62} = 0.16m$$

Applying Bernoulli's Equation

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

Section (1) is 2.5m above datum, $z_1 = 2m$
Section (2) is at datum level, $z_2 = 0$
$P_1/\rho g = 2.5$, $P_2/\rho g = ?$

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

$$2.5 + 1.27 + 2 = P_2/\rho g + 0.20 + 0 + 0.16$$

$$5.77 = P_2/\rho g + 0.36$$

$$P_2/\rho g = 5.77 - 0.36$$

$$= 5.41m \text{ of liquid.}$$

Inlet diameter = 20 cm
Throat diameter = 10 cm
Pressure at inlet = 17.658 N/cm^2
Vaccum pressure at throat = 30 cm of mercury
$Cd = 0.98$
Discharge of water = ?

Solution

$D_1 = 20 cm = 0.2 m$

$$A_1 = \pi r^2 = \pi\left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4} = \frac{\pi \times (0.2)^2}{4} = \frac{0.04\pi}{4} = 0.0314 m^2$$

$D_2 = 10 cm = 0.1 m$

$$A_2 = \pi r^2 = \frac{\pi d^2}{4} = \frac{\pi \times (0.1)^2}{4} = \frac{0.01\pi}{4} = 0.00785 m^2$$

3.

$P_1 = 17.658 N/cm^2$

convert to N/m^2

$P_1 = 17.658 \times 10^4$

$= 176580 N/m^2$

$$\text{Pressure head} = \frac{P_1}{\rho g} = \frac{176580}{1000 \times 9.81} = 18 m \text{ of water.}$$

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

Convert to m

$$\frac{-30}{100} = -0.3 m$$

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

$$\text{Differential head} = \frac{P_1}{\rho g} - \frac{P_2}{\rho g}$$

$= 18 - (-4.08)$

$= 22.08 m$ of water.

Discharge, $Q = Cd \times \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$

$= 0.98 \times \frac{0.0314 \times 0.00785}{0.0304} \times \sqrt{2 \times 9.81 \times 22.08}$

$= 0.98 \times 0.008108 \times \sqrt{433.2096}$

$= 0.98 \times 0.008108 \times 20.814$

$= 0.1653847 \, m^3/s$

Convert to lit/s

$0.1653847 \, m^3/s \times 1000$

$= 165.3847$ lit/s

3. Given,

Orifice diameter = 15cm

Pipe diameter = 30cm

Pressure difference = 50cm = 0.5m

Specific gravity = 0.9

Cd = 0.64

Solution

$D_o = 15cm = 0.15m$

$A_o = \pi (d/2)^2 = \frac{\pi d^2}{4} = \frac{\pi \times (0.15)^2}{4} = \frac{0.0225\pi}{4} = 0.01767 \, m^2$

$D_p = 30cm = 0.3m$

$A_p = \frac{\pi d^2}{4} = \frac{\pi \times (0.3)^2}{4} = \frac{0.09\pi}{4} = 0.07069 \, m^2$

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

$= 14.11 \times 0.5$

$= 7.055m$

(4)

$$\text{Discharge}, Q = C_d \times \frac{A_p A_p}{\sqrt{A_p^2 - A_o^2}} \times \sqrt{2gh}$$

$$= 0.64 \times \frac{0.07069 \times 0.01767}{0.068446} \times \sqrt{2 \times 9.81 \times 7.055}$$

$$= 0.64 \times 0.01825 \times \sqrt{138.4191}$$

$$= 0.64 \times 0.01825 \times 11.765$$

$$= 0.1374152 \ m^3/s$$

Convert to lit/s

$$0.1374152 \ m^3/s \times 1000$$

$$= 137.42 \ lit/s$$

4.

Given,

Reading on manometer = 170mm = 0.17m

~~Special gravity~~ Specific gravity of mercury = 13.6

Specific gravity of water = 1.026

$$H = \left[\frac{13.6}{1.026} - 1\right] \times 0.17$$

$$= 12.255 \times 0.17$$

$$= 2.08 m$$

$$v = \sqrt{2gh}$$

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

$$= \sqrt{40.8096}$$

$$= 6.388$$

$$v = 6.388 \ m/s$$

$$v = 6.39 \ m/s$$

Speed in Km/hr

$$v = \frac{6.39 \times 60 \times 60}{1000}$$

$$= \frac{23004}{1000} = 23 \ Km/hr.$$

5. Given,

Pump delivery rate: $0.05 m^3/min$

Pressure change, ΔP : 15 bar

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

Speed of rotation : 1700 rev/min

Normal displacement : $10 cm^3/rev$

Torque input: 15Nm

i. Volumetric Efficiency, $E_v = \frac{Q \text{ (Actual flow)}}{Q \text{ (Theoretical flow)}}$

Theoretical flow = Normal displacement x Speed

$= 10 \frac{cm^3}{rev} \times 1700 \frac{rev}{min}$

$= 17000 \ cm^3/min$

Convert to $m^3/min = \frac{17000}{1000000} = 0.017 \ m^3/min$

$E_v = \frac{0.05 m^3/min}{0.017 m^3/min} = 2.94 = 294\%$

ii Fluid Power = Actual

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

Convert to m^3/s

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

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

F.P = ~~15~~ $8.33 \times 10^{-4} \times 15 \times 10^5$

$= 1249.5 W$

⑥

iii Shaft Power = $2\pi NT/60$

where, N = number of revolutions.

T = Torque of input

$$= \frac{2\pi \times 1700 \times 15}{60} = \frac{51000\pi}{60}$$

$$= 850\pi = 2670.35\,W$$

iv Overall Efficiency, $E_o = \frac{\text{Fluid Power}}{\text{Shaft Power}}$

$$= \frac{1249.5}{2670.35} = 0.468$$

$$= 46.8\,\%$$