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

PRACTICE ASSIGNMENT

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1. Pump delivery rate: $10 dm^3/min$ (Actual Flow Rate)
Pressure change, ΔP = 12 bar
$1 \text{ bar} = 1 \times 10^5 N/m^2$
Speed of rotation: 1500 rev/min
Normal displacement: $10 cm^3/rev$
Torque input: 12.5 Nm

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

Theoretical flow = Normal displacement x Speed

$= 10 \frac{cm^3}{rev} \times 1500 \frac{rev}{min}$

$= 15,000 \ cm^3/min$

Convert to $dm^3/min = \frac{15,000}{1000} = 15 \ dm^3/min$

$E_v = \frac{10 \ dm^3/min}{15 \ dm^3/min} = 0.67 = 67\%$

ii. Fluid Power = Actual Flow Rate x Change in pressure
Actual flow rate = $10 \ dm^3/min$
Convert to m^3/s

$= \frac{10}{60 \times 1000} = 1.67 \times 10^{-4} \ m^3/s$

$\Delta P = 12 \times 10^5 \ N/m^2$

$F.P = 1.67 \times 10^{-4} \times 12 \times 10^5$

$= 200.4 \ W$

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

where, N = number of revolutions

T = Torque input

$$= \frac{2\pi \times 1500 \times 12.5}{60} = 625\pi$$

$$= 1963.5 \, Nm$$

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

$$= \frac{200.4}{1963.5} = 0.102$$

$$= 10.2\%$$

2. Given,

Pump delivery rate : $35 dm^3/min$

Pressure change : $100 \times 10^5 \, N/m^2$

Overall Efficiency ; $E_o = 87\% = 0.87$

Shaft Power ; ?

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

Shaft power $= \frac{\text{Fluid Power}}{E_o}$

Fluid power $= Q \times \Delta P$

$$Q = \frac{35}{1000 \times 60} = 5.83 \times 10^{-4}$$

$F.P = Q \times \Delta P$

$= 5.83 \times 10^{-4} \times 100 \times 10^5$

$= 5830 W$

Shaft Power $= \frac{F.P}{E_o}$

$= \frac{5830}{0.87} = 6701.1 W$

$= 6.7 kW$

3. Given,

Normal displacement : $50 cm^3/rev$

Pressure rise, $\Delta P = 100$ bar $= 100 \times 10^5 N/m^2$

Shaft power = 15 kW = 15000 W

Actual Flow Rate = $35 dm^3/min$

Speed of rotation = 850 rev/min

Find overall efficiency and volumetric efficiency.

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

Q (Theoretical) = Normal displacement × Speed

$= 50 \frac{cm^3}{rev} \times 850 \frac{rev}{min}$

$= 42500 cm^3/min$

Convert to $dm^3/min = \frac{42500}{1000} = 42.5 dm^3/min$.

$E_V = \frac{\text{Actual } Q}{\text{Theoretical } Q} = \frac{35}{42.5}$

$= 0.82$

$= 82\%$

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

Fluid $= Q \times \Delta P$

$Q = \frac{35}{1000 \times 60} = 5.83 \times 10^{-4}$

Fluid power $= 5.83 \times 10^{-4} \times 100 \times 10^{+5}$
$= 5830 W$

Shaft power $= 15000 W$

$E_0 = \frac{5830}{15000} = 0.39$

$= 39\%$

4. Given,
Water level above datum from reservoir = 24000 cm = 240 m
Flow rate = 13 lits/sec = $0.013 m^3/sec$
Velocity of jet = 66 m/s

1. Power of jet
At the outlet, z = 0 (at datum level),

Power of jet $= \frac{1}{2} m v^2$

$m = \rho a v$
$= \frac{1}{2} (\rho a v) v^2 = \frac{1}{2} \rho a v^3$

$Q = AV$
$= \frac{1}{2} \rho Q V^2$

~~$= \frac{1 \times 1000 \times 0.013 \times (66)^2}{2 \times 9.81}$~~
~~$= \frac{56628}{19.62}$~~
~~$= 2886.2$ kgm/sec~~

CONTINUATION FROM CANCELLATION

Given,

Water level from reservoir = 24000cm = 240m

Flow rate = 13 lits/sec = $0.013 m^3/sec$

*

Power = $\frac{1}{2} \rho Q v^2$

$\rho = 1000 \, kg m^{-3}$

$= \frac{1}{2} \times 1000 \frac{kg}{m^3} \times 0.013 \frac{m^3}{sec} \times 66^2 \frac{m^2}{s^2}$

$= \frac{56628}{2}$

$= 28314 W$

$= 28.314 KW$

i Power supplied from reservoir

$P = 0 \; , Z = 0$

Power = $\rho g Q z$

$= 1000 \times 9.81 \times 0.013 \times 240$

$= 1000 \frac{kg}{m^3} \times 9.81 \frac{m}{s^2} \times 0.013 \times \frac{m^3}{s} \times 240 \, m$

$= 30607.2 W$

$= 30.6072 kW$

ii ~~H = Total h~~

H_1 = Total head ~~lost~~ at the jet, H_2 = Total head at the reservoir.

h = Head loss

Power of jet = ~~ρg~~ 28314 W

Power supplied from reservoir = 30607.2W

Power loss = 30607.2W − 28314W

$= 2293.2\,W$

Head loss, $h = \dfrac{\text{Power loss}}{\rho g Q}$

$= \dfrac{2293.2}{1000 \times 9.81 \times 0.013} = 17.98\,m$

d. Efficiency of the pipeline and nozzle in transmitting operation

$E_{transmission} = \dfrac{\text{Power of jet}}{\text{Power of reservoir}}$

$= \dfrac{30.6072}{28.314}$

$= \dfrac{28.314}{30.6072}$

$= 0.925$

$= 92.5\%$

5. Given,

Specific gravity = 0.89

Oil level above datum from reservoir = 30,000 cm = 300m

Flow rate = 220 lits/sec = $0.22 \, m^3/sec$

Velocity of jet = 7m/sec

$$S.G = \frac{\text{Density of fluid}}{\text{Density of water}}$$

$$0.89 = \frac{x}{1000}$$

$$x = 890 \, kg/m^3$$

i Power of jet = $\frac{1}{2}mv^2$

$$m = \rho a v$$

$$= \frac{1}{2}(\rho a v)v^2 = \frac{1}{2}\rho a v^3$$

$$Q = AV$$

$$= \frac{1}{2}\rho Q V^2$$

$$= \frac{1}{2} \times 890 \frac{Kg}{m^3} \times 0.22 \frac{m^3}{s} \times 7^2 \frac{m^2}{s^2}$$

$$= \frac{9594.2}{2}$$

$$= 4797.1 W$$

$$= 4.7971 KW$$

ii Power supplied from reservoir

$$P = 0, z = 0$$

$$Power = \rho g Q z$$

$$= 890 \times 0.89 \times 0.22 \times 300$$

$$= 52278.6 W$$

$$= 52.2786 KW$$

6. Given,

$h = 20m$

$d = 10cm = 0.1m$

$A = \frac{\pi d^2}{4} = \frac{\pi \times (0.1)^2}{4} = \frac{0.01\pi}{4} = 7.854 \times 10^{-3} m^2$

$V_{final} = 0$

$V_{initial} = ?$

$V_f^2 = V_1^2 - 2gh$

$V_1^2 = V_f^2 + 2gh$

$V_1^2 = 0^2 + 2(9.81)(20)$

$V_1^2 = 0 + 392.4$

$V_1^2 = 392.4$

$V_1 = \sqrt{392.4}$

$= 19.81 \ m/s$

$Q = Va$

$= 19.81 \times 7.854 \times 10^{-3}$

$= 0.1556 \ m^3/s$

$W = \rho g Q h$

$= 1000 \times 9.81 \times 0.1556 \times 20$

$= 1000 \frac{kg}{m^3} \times 9.81 \frac{m}{s^2} \times 0.1556 \frac{m^3}{s} \times 20 m$

$= 30528.72 \ kg \ m^2/s^3$

$= 30.53 \times 10^3 W$

$= 30.5 KW$

7. Given,

$c_d = 0.96$

$d_1 = 0.3m$

$d_2 = 0.2m$

$\rho_g g = 19.62 N/m^2$

$$A_1 = \frac{\pi d^2}{4} = \frac{\pi \times (0.3)^2}{4} = \frac{0.09\pi}{4} = 0.0707\ m^2$$

$$A_2 = \frac{\pi d^2}{4} = \frac{\pi (0.2)^2}{4} = \frac{0.04\pi}{4} = 0.0314 m^2$$

$$Q = a_1 u_1 = a_2 u_2$$

$$u_1 = \frac{Q}{a_1} \quad \text{and} \quad u_2 = \frac{Q}{a_2}$$

For manometer

$$P_1 + \rho_g g z_1 = P_2 + \rho_g g (z_2 - R_p) + \rho_w g R_p$$

$$P_1 - P_2 = 19.62 (z_2 - z_1) + 587.423$$

For venturimeter

$$\frac{P_1}{\rho_g g} + \frac{u_1^2}{2g} + z_1 = \frac{P_2}{\rho_g g} + \frac{u_2^2}{2g} + z_2$$

$$P_1 - P_2 = 19.62 (z_2 - z_1) + 0.803 u_2^2$$

Combining equ.

$$0.803 u_2^2 = 587.423$$

$$u_2^2 = 731.535$$

$$u_2 = \sqrt{731.535}$$

$$= 27.047\ m/s$$

$$Q_{ideal} = u \times A$$

$$= 27.047 \times 0.0314$$

$$= 0.85 m^3/s$$

$$Q = Cd \times Q_{ideal}$$

$$= 0.96 \times 0.85$$

$$= 0.816\ m^3/s$$

8. Given,

$d_1 = 0.152 m$ $A_1 = \pi d^2/4 = \frac{\pi \times (0.152)^2}{4} = 0.01814 m^2$

$d_2 = 0.076 m$ $A_2 = \frac{\pi \times (0.076)^2}{4} = 0.00454 m^2$

$\rho = 800 kg/m^3$ $z_1 = 0.914$

$Cd = 0.97$

$$\frac{P_1}{\rho g} + \frac{u_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{u_2^2}{2g} + z_2$$

a. $P_1 = P_2$

$$\frac{u_1^2}{2g} + z_1 = \frac{u_2^2}{2g} + z_2$$

Continuity equ:

$$Q = u_1 A_1 = u_2 A_2$$

$$u_2 = u_1 \frac{A_1}{A_2} = u_1 \times \frac{0.01814}{0.00454} = u_1 \times 4 = 4u_1$$

$$\frac{u_1^2}{2g} + 0.914 = \frac{16u_1^2}{2g}$$

$$\frac{16u_1^2}{2g} - \frac{u_1^2}{2g} = 0.914$$

$$\frac{15u_1^2}{2g} = 0.914$$

$$u_1^2 = \frac{0.914 \times 2 \times 9.81}{15}$$

$u_1^2 = 1.195512$ $u_1 = \sqrt{1.195512}$

$u_1 = 1.0934 m/s$

$$Q = Cd A_1 u_1$$

$$= 0.97 \times 0.01814 \times 1.0934$$

$$= 0.0192 m^3/s$$

$$P_1 - P_2 = 15170$$

$$\frac{P_1 - P_2}{\rho g} = \frac{u_2^2 - u_1^2}{2g} - 0.914$$

$$\frac{15170}{\rho g} = \frac{Q^2(220.43^2 - 55.11^2)}{2g} - 0.914$$

$$55.8577 = Q^2(220.43^2 - 55.11^2)$$

$$Q \simeq 0.035 m^3/s$$

9. Section I | Section 2

Diameter $= 300mm = 0.3m$ | Diameter $= 150mm = 0.15m$

$Z_1 = 10m$ | $Z_2 = 6m$

Discharge $= 40$ lit/sec $= 0.04 m^3/s$

$P_1 = 400 kN/m^2$ $\quad$ $P_2 = ?$

$= 40 \times 10^4 N/m^2$

$$A_1 = \frac{\pi d^2}{4} = \frac{\pi \times (0.3)^2}{4} = 0.0707 m^2$$

$$A_2 = \frac{\pi d^2}{4} = \frac{\pi \times (0.15)^2}{4} = 0.0177 m^2$$

Continuity equation:

$$Q = A_1 V_1 = A_2 V_2$$

$$V_1 = \frac{Q}{A_1} = \frac{0.04}{0.0707} = 0.566 m/s$$

$$V_2 = \frac{Q}{A_2} = \frac{0.04}{0.0177} = 2.26 m/s$$

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

$$= \frac{40 \times 10^4}{1000 \times 9.81} + \frac{(0.566)^2}{2 \times 9.81} + 10 = 50.7910$$

$$\frac{P_2}{\rho g} + \frac{(2.26)^2}{2\times 9.81} + 6 = \frac{P_2}{\rho g} + 6.2603$$

$$\frac{P_2}{\rho g} = 50.7910 - 6.2603$$

$$\frac{P_2}{\rho g} = 44.5307$$

$$P_2 = 44.5307 \times 1000 \times 9.81$$

$$= 436846.167 \ N/m^2$$

$$= 436.85 \ KN/m^2$$

10. Reading on manometer $= 0.17m$

Sg of mercury $= 13.6$

Sg of water $= 1.026$

$$h = R_m \left[\frac{S_m}{S_w} - 1\right]$$

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

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

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

$$= 6.39 m/s$$