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CIVIL ENGINEERING
ENG 214

1. Actual flowrate = $10dm^3/min = \frac{10}{1000 \times 60} = 1.67 \times 10^{-4} m^3/s$

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

Speed = 1500 rev/min = 25 rev/s

Nominal displacement = $10 cm^3/rev = 10^{-5} m^3/rev$

Torque input = 12.5 Nm

Volumetric efficiency = $\frac{\text{Actual flowrate}}{\text{Ideal flowrate}} \times 100$

Ideal flow rate = Speed × Displacement = 25×10^{-5}
$= 2.5 \times 10^{-4} m^3/s$

∴ Volumetric efficiency = $\frac{1.67 \times 10^{-4}}{2.5 \times 10^{-4}} \times 100$
= 66.8%

ii. Fluid Power = $Q\Delta P$
$= (1.67 \times 10^{-4}) \times (12 \times 10^5)$
= 200.4 Nm/s

iii Shaft power = Torque × angular speed

Angular speed (ω) = $2\pi N$
$= \frac{2 \times 22}{7} \times 25$

= 157.07 rad/sec

∴ Shaft power = 12.5 × 157.07
= 1963.375 W
= 1.963 KW

iv Overall efficiency = $\frac{\text{Fluid Power}}{\text{Shaft Power}} \times 100$
$= \frac{200.4}{1963.375} \times 100 = 10.21\%$

2. Actual flowrate = $35 dm^3/min$ = $5.83 \times 10^{-4} m^3/s$

ΔP = 100 bar = $10^7 N/m^2$

Overall efficiency = 87%

Shaft power = ?

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

Fluid Power = $Q\Delta P$

$= (5.83 \times 10^{-4}) \times 10^7$

$= 5830 \, Nm/s$

~~Shaft Power = Overall Efficiency~~

$$\text{Shaft Power} = \frac{5830 \times 100}{87}$$

$= 6701.15 W$

$= 6.701 kW$

3. Displacement = $50 cm^3/rev$ = $5 \times 10^{-5} m^3/rev$

ΔP = 100 bar = $10^7 N/m^2$

Shaft Power = 15 kW = $15 \times 10^3 W$

Actual flowrate = $35 dm^3/min$ = $5.83 \times 10^{-4} m^3/s$

Speed of rotation = 850 rev/min = 14.17 rev/s

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

$$= \frac{(5.83 \times 10^{-4}) \times 10^7}{15 \times 10^3} \times 100$$

$$= \frac{5830}{15000} \times 100$$

$= 38.87\%$

$$\text{Volumetric Efficiency} = \frac{\text{Actual Flow}}{\text{Ideal Flow}} \times 100$$

$$= \frac{5.83 \times 10^{-4}}{(5 \times 10^{-5}) \times 14.17} \times 100 = \frac{5.83 \times 10^{-4}}{7.085 \times 10^{-4}} \times 100$$

$= 82.29\%$

4. $Q = 13L/s = 0.013 m^3/s$

velocity of jet $= 66 m/sec$

$Z = 24000 cm = 240 m$

Volumetric flow rate $Q = 13L/s = 0.013 m^3/s$

Since jet issues from a nozzle at datum ~~pressure~~ level

Hence,

$P = 0$, $Z = 0$

ρ for water $= 1000 kg/m^3$

$P = \text{Pressure} \cdot Q + \frac{\rho Q V^2}{2} + \rho g \cdot QZ$

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

$= \frac{1000 \times 0.013 \times 66^2}{2} = 28314 W$

$P = 28.3 KW$

ii) Power supplied at reservoir

Pressure $= 0$, $V = 0$

$P = \rho g \cdot QZ$

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

$P = 30607.2 W$

$P = 30.6 KW$

iii) Power loss in transmission = Power in reservoir − Power of jet

$30.607 - 28.314$

$= 2.293 KW$

Head loss in pipeline

$h = \frac{\text{Power lost in transmission}}{\rho g Q}$

$= \frac{2293}{1000 \times 9.81 \times 0.013}$

$h = 17.98 m$

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iv Efficiency = $\frac{\text{Power of Jet}}{\text{Power of reservoir}} \times 100$

$= \frac{28314}{30607} \times 100 = 92.5\%$

5. S.g of oil = 0.89

$z = 30,000\,cm = 300\,m$

$Q = 220\,L/s = 0.22\,m^3/s$

velocity = 7 m/s

Density of oil = $0.89 \times 1000 = 890\,kg/m^3$

i At datum

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

$= \frac{890 \times 0.22 \times 7^2}{2} = 4797.1\,w$

$= 4.797\,kW$

ii Power supplied from reservoir

$\rho g Q z$

$= 890 \times 9.81 \times 0.22 \times 300$

$= 576239.4 = 576.24\,kW$

iii Head used to overcome losses

$h = \frac{\text{Power lost in transmission}}{\rho g Q}$

Power lost in transmission = $576.24 - 4.797$

$= 571.44\,kW$

$h = \frac{571443}{1000 \times 9.81 \times 0.22}$

$= 264.78\,m$

iv Efficiency = $\frac{\text{Power of Jet}}{\text{Power of resistor}} \times 100$

$\frac{4.797}{576.24} \times 100$

$= 0.83\%$

6\. $z = 20m$ $d = 10cm = 0.1m$

$A = \frac{\pi \times 0.1^2}{4} = 0.00786m^2$

$\rho = 1000kg/m^3$ $g = 9.81m/s^2$

At the highest point, final velocity $v = 0$

To obtain velocity at height z

$v^2 = u^2 \mp 2gh$

$0 = u^2 - 2 \times 9.81 \times 20$

$0 = u^2 - 392.4$

$u^2 = 392.4$

$u = 19.81m/s$

$\therefore Q = Av$

$= 0.00786 \times 19.81$

$= 0.156m^3/s$

Power $= \rho g Q z$

$1000 \times 9.81 \times 0.156 \times 20$

$= 30607W$

$= 30.607KW$

7\. $d_1 = 0.3m$ $C_d = 0.96$

$d_2 = 0.2m$ s.w of gas $= 19.62N/m^3$

manometer differential reading $(x) = 0.06m$ of water.

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

$A_2 = \frac{\pi \times 0.2^2}{4} = 0.0314m^2$

$h = x\left[\frac{s.g\ water}{s.g\ gas} - 1\right]$

$s.g\ gas = \frac{s.w\ gas}{w_{water}} = \frac{19.62}{9.807 \times 10^3}$

$S.g_{gas} = 0.002$

$$h = 0.06\left[\frac{1}{0.002} - 1\right]$$

$h = 29.94m$

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

$$= 0.96 \times 0.0314 \times 0.0707 \times \sqrt{\frac{2 \times 9.81 \times 29.94}{0.0707^2 - 0.0314^2}}$$

$$= 2.13 \times 10^{-3} \times 382.62$$

$$= 0.815 m^3/s$$

8. $d_1 = 0.152m$, $d_2 = 0.076m$
$S.g = 0.8$, $\rho = 0.8 \times 1000 = 800 kg/m^3$
$C_d = 0.97$, $z_1 = 0.914$, $z_2 = 0$

$$A_1 = \frac{\pi \times 0.152^2}{4} = 0.01814 m^2$$

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

9. when $P_1 = P_2$

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

This becomes

$$\frac{v_1^2}{2g} + z_1 = \frac{v_2^2}{2g} + z_2$$

By continuity

$$Q = A_1 v_1 = A_2 v_2$$

$$v_2 = \frac{A_1 v_1}{A_2}$$

Substituting this, we have

$$\frac{v_1^2}{2g} + z_1 = \frac{A_1^2 v_1^2}{A_2^2 \times 2g} + z_2$$

$$\frac{v_1^2}{19.6} + 0.914 = \frac{15.96 v_1^2}{19.6}$$

$$v_1^2 - \frac{15.96 v_1^2}{19.6} = -0.914$$

$$-14.96 v_1^2 = -17.9144$$

$$v_1^2 = 1.197$$

$$v_1 = 1.09 \text{ m/s}$$

$\therefore Q = A_1 v_1$

$= 0.01814 \times 1.09$

$= 0.019 \text{ m}^3/\text{s}$

8. $P_1 = P_2 + 15170$

$P_1 - P_2 = 15170$

$$\frac{P_1 - P_2}{\rho g} = \frac{v_2^2 - v_1^2}{2g} + (z_2 - z_1)$$

$$\frac{15170}{1000 \times 9.81} = \frac{\frac{Q^2}{A_2^2} - \frac{Q^2}{A_1^2}}{2g} - 0.914$$

$$\frac{15170}{9810} = \frac{Q^2 (220^2 - 55.13^2)}{2g} - 0.914$$

$$2.847 = Q^2 (2320.28)$$

$$Q^2 = 0.00123$$

$$Q = 0.035 \text{ m}^3/\text{s}$$

9. $d_1 = 300 \text{ mm} = 0.3 \text{ m}$, $z_1 = 10 \text{ m}$

$d_2 = 150 \text{ mm} = 0.15 \text{ m}$, $z_2 = 6 \text{ m}$

$Q = 40 \text{ L/s} = 0.04 \text{ m}^3/\text{s}$

$P_1 = 400 \times 10^3 \text{ N/m}$

$P_2 = ?$

$$A_1 = \pi \times \frac{0.3^2}{4} = 0.0707 \text{ m}^2$$

$$A_2 = \pi \times \frac{0.15^2}{4} = 0.0177 \text{ m}^2$$

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$

$$\frac{P_1 - P_2}{\rho g} = \frac{v_2^2 - v_1^2}{2g} + (z_2 - z_1)$$

$$v_1 = \frac{Q}{A_1} = \frac{0.04}{0.0707} = 0.566 \text{ m/s}$$

$$v_2 = \frac{Q}{A_2} = \frac{0.04}{0.0177} = 2.26 \text{ m/s}$$

$$\frac{(400 \times 10^3) - P_2}{1000 \times 9.81} = \frac{2.26^2 - 0.566^2}{2 \times 9.81} + (6 - 10)$$

$$\frac{(400 \times 10^3) - P_2}{9810} = 0.244 - 4$$

$$(400 \times 10^3) - P_2 = -36846.378$$

$$P_2 = 400000 + 36846.378$$

$$P_2 = 436846.378 \text{ N/m}^2$$

$$\therefore P_2 = 436.8 \text{ KN/m}^2$$

10 No value for the coefficient of velocity is given, therefore we use formula for theoretical velocity.

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

Difference of mercury level (x) = 170mmHg = 0.17m

S.g of mercury = 13.6

S.g of sea water = 1.026

$$h = x\left[\frac{\text{S.g mercury}}{\text{S.g sea water}} - 1\right]$$

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

$h = 2.08$ m of sea water

$$\therefore v = \sqrt{2 \times 9.81 \times 2.08} = \sqrt{40.8096}$$

$$\therefore v = 6.39 \text{ m/s}$$

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