OLOGBOSERE ANTHONIA EFE
MECHATRONICS ENGINEERING
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1. $Q = 10 dm^3/min = 1.67 \times 10^{-4} m^3/sec$

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

Speed of Rotation = 1500 rev/min = 25 rev/sec

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

Torque input = 12.5 Nm

Ideal Flowrate = $10^{-5} \times 25 = 2.5 \times 10^{-4} m^3/sec$

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

$= \frac{1.67 \times 10^{-4}}{2.5 \times 10^{-4}} \times 100$

$= 66.8\%$

b) Fluid Power, $P_F = Q \times \Delta P$

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

$= 200.4 Nm/sec$

c) Shaft Power, P_s = Torque × 2 × π × Speed of Rotation

$= 12.5 \times 2 \times \frac{22}{7} \times 25$

$= 1964.29$ Watts

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

$= \frac{200.4}{1964.29} \times 100$

$= 10.2\%$

2. $Q = 35 dm^3/min = 5.83 \times 10^{-4} m^3/sec$, $\Delta P = 100 bar = 10^7 N/m^2$

Overall Efficiency = 87%

$\therefore \frac{87}{100} = \frac{\text{Fluid Power}}{\text{Shaft Power}}$

But Fluid Power = $Q \times \Delta P$

$\frac{87}{100} = \frac{5.83 \times 10^{-4} \times 10^7}{\text{Shaft Power}}$

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

Shaft Power = 6701.15 Watts

3. Nominal Displacement $= 5 \times 10^{-5} m^3/sec$

$\Delta P = 10^7 N/m^2$, Shaft Power $= 15 \times 10^3$ Watts

Actual flowrate $= 5.83 \times 10^{-4} m^3/sec$

Speed of Rotation = 14.17 rev/sec

Ideal Flowrate = Nominal Displacement X Speed

$= 5 \times 10^{-5} \times 14.17$

$= 7.08 \times 10^{-8} m^3/sec$

a) Volumetric Efficiency $= \frac{5.83 \times 10^{-4}}{7.08 \times 10^{-8}} \times 100$

$= 82.34\%$

b) Overall Efficiency $= \frac{5.83 \times 10^{-4} \times 10^{-7}}{15 \times 10^3}$

$= 38.87\%$

4. $Z = 240m$, $Q = 13 \times 10^{-3} m^3/sec$, $V = 66 m/sec$

$\rho = 1000 kg/m^3$

a) Power of jet, $P = \frac{\rho \times Q \times V^2}{2}$

$= \frac{1000 \times 13 \times 10^{-3} \times 66^2}{2}$

$= 28,314$ Watts (28.3 kWatts)

b) Power supplied from reservoir, $P = \rho \times Q \times g \times Z$

$= 1000 \times 13 \times 10^{-3} \times 9.81 \times 240$

$= 30,607.2$ Watts (30.6 kWatts)

c) Power Lost = Power of Reservor − Power of Jet

$= 30,607.2 - 28,314$

$= 2,293.2$ Watts

Head used to overcome losses $= \frac{\text{Power Lost}}{\rho \times g \times Q}$

$= \frac{2,293.2}{1000 \times 9.81 \times 13 \times 10^{-3}}$

$= 17.98m$

d) Efficiency $= \frac{\text{Power of Jet}}{\text{Power of Reservoir}} \times 100$

$= \frac{28,314}{30,607.2} \times 100$

$= 92.51\%$

5. $S.g = 0.89$, $\rho = 890 kg/m^3$, $Z = 300m$

$Q = 0.22 m^3/sec$, $V = 7 m/s$

a) Power of jet, $P = \frac{\rho \times Q \times V^2}{2}$

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

$= 4,797.1$ Watts (4.8 kWatts)

b) Power of Reservoir, $P = \rho \times Q \times g \times z$

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

$= 576,239.4$ Watts (576 kWatts)

c) Power lost $= 576,239.4 - 4,797.1$

$= 571,442.3$ Watts

$$\text{Head loss} = \frac{\text{Power lost}}{\rho \times g \times Q}$$

$$= \frac{571,442.3}{890 \times 9.81 \times 0.22}$$

$= 297.50$m

d) Efficiency $= \frac{\text{Power of Jet}}{\text{Power of Reservoir}} \times 100$

$$= \frac{4,797.1}{576,239.4} \times 100$$

$= 0.83\%$

6. $z = 20m$, $d = 0.1m$, $A = 7.85 \times 10^{-3} m^2$, $\rho = 1000 kg/m^3$

Applying equations of motion,

where $v = 0 m/s$, $h = 20m$, $g = 9.81 m/s^2$, $u = ?$

$v^2 = u^2 - 2gh$

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

$392.4 = u^2$

$u = \sqrt{392.4}$

$u = 19.81 m/s$

∴ The velocity at the height z is 19.81 m/s

$$Q = A \times V$$
$$= 7.85 \times 10^{-3} \times 19.81$$
$$= 0.156 m^3/sec$$

Power of reservoir, $P = \rho \times g \times Q \times z$
$$= 1000 \times 9.81 \times 0.156 \times 20$$
$$= 30,607.2 \text{ Watts}$$

7. $Cd = 0.96$, $h = 0.06 mHg$, $d_1 = 0.3m$, $d_2 = 0.2m$

$A_1 = 0.070m^2$, $A_2 = 0.031m^2$

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

$$= \frac{0.96 \times 0.070 \times 0.031 \times \sqrt{2 \times 9.81 \times 0.06}}{\sqrt{0.070^2 - 0.031^2}}$$

$$= \frac{2.08 \times 10^{-3} \times 1.08}{0.063}$$

$$Q = 0.036 m^3/sec$$

But $Q = A_1 V_1$

$$\therefore \frac{0.036}{0.070} = V_1$$

$$V_1 = 0.51 m/sec$$

8. $A_1 = 4.54 \times 10^{-3} m^2$, $A_2 = 0.018 m^2$, $Cd = 0.97$

$(z_1 - z_2) = -0.914 m$

$$h = \left[\frac{P_1}{w} - \frac{P_2}{w}\right] + (z_1 - z_2)$$

a) When $P_1 = P_2$

$$\therefore h = (z_1 - z_2) = -0.914 m$$

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

$$= 0.97 \times 0.018 \times 4.54 \times 10^{-3} \times \sqrt{2 \times 9.81}$$

8. $A_2 = 4.54 \times 10^{-3} m^2$, $A_1 = 0.018 m^2$, $z_1 - z_2 = 0.914 m$

$C_d = 0.97$

a) When $P_1 = P_2$

Applying Bernoulli's Equation

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

But $Q = A_1 V_1 = A_2 V_2$

$$V_1 = \frac{4.54 \times 10^{-3} \times V_2}{0.018}$$

$$V_1 = 0.025 V_2$$

$$\therefore \frac{P_1}{\rho g} - \frac{P_2}{\rho g} + \frac{(0.025V_2)^2}{2 \times 9.81} = \frac{V_2^2}{2 \times 9.81} + z_1 - z_2$$

$$\frac{(0.025V_2)^2}{19.62} - \frac{V_2^2}{19.62} = -0.914$$

$$\frac{6.25 \times 10^{-4} V_2^2 - V_2^2}{19.62} = -0.914$$

$$6.25 \times 10^{-4} V_2^2 - V_2^2 = -17.93$$

$$V_2^2 - 6.25 \times 10^{-4} V_2^2 = 17.93$$

$$0.99 V_2^2 = 17.93$$

$$V_2^2 = 17.94$$

$$V_2 = 4.23 m/s$$

$\therefore$ $Q = A_2 V_2$

$Q = 4.54 \times 10^{-3} \times 4.23$

$Q = 0.019 m^3/se$

b) When $P_1 - P_2 = 15170 N/m^2$

$$h = \left[\frac{P_1 - P_2}{w}\right] + (z_1 - z_2)$$

$$= \left[\frac{15170}{800 \times 9.81}\right] - 0.914$$

$$= 1.93 - 0.914$$

$$h = 1.02 m$$

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

$$= \frac{0.97 \times 0.018 \times 4.54 \times 10^{-3} \times \sqrt{2 \times 9.81 \times 1.02}}{\sqrt{0.018^2 - (4.54 \times 10^{-3})^2}}$$

$$= \frac{7.93 \times 10^{-5} \times 4.47}{0.017}$$

$$= 0.021 m^3/sec$$

9. $A_1 = 0.070 m^2$, $A_2 = 0.177 m^2$, $Q = 0.04 m^3/sec$, $Z_1 = 10m$, $Z_2 = 6m$, $P_1 = 400 \times 10^3 N/m^2$, $P_2 = ?$

$$Q = A_1 V_1$$

$$V_1 = \frac{0.04}{0.070}$$

$$\Rightarrow V_1 = 0.57 m/s$$

$$Q = A_2 V_2$$

$$V_2 = \frac{0.04}{0.177}$$

$$\Rightarrow V_2 = 0.226 m/s$$

Applying Bernoulli's Equation;

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

$$10 + \frac{0.57^2}{2\times9.81} + \frac{400\times10^3}{1000\times9.81} = 6 + \frac{0.226^2}{2\times9.81} + \frac{P_2}{1000\times9.81}$$

$$50.79 = 6.002 + \frac{P_2}{9810}$$

$$P_2 = 44.788 \times 9810$$

$$P_2 = 439{,}370.28\ N/m^2$$

$$P_2 = 439.37\ kN/m^2$$

10. $y = 170mm = 0.17 m Hg$, $s.g_{Hg} = 13.6$, $s.g_{oil} = 1.026$

$$\Delta h = y\left(\frac{s.g_{Hg}}{s.g_{oil}} - 1\right)$$

$$= 0.17\left(\frac{13.6}{1.026} - 1\right)$$

$$= 0.17(12.26)$$

$$= 2.08 m$$

But $V = \sqrt{2g.\Delta h}$

$$= \sqrt{2\times9.81\times2.08}$$

$$V = 6.388 m/s$$