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Mechatronics ; 18/ENG05/027

1) Real flowrate $= 10\,dm^3/min$ , $T = 12.5\,N/m$

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

Pressure $= 12\,bar = 12 \times 10^5\,N/m$

speed $= 1500\,rev/min = \frac{1500}{60} = 25\,rev/sec$

Norminal displacement $= 10\,\frac{cm^3}{rev} = 1 \times 10^{-5}\,m^3/rev$

Ideal flowrate $=$ Nominal displacement $\times$ speed

$= 1 \times 10^{-5}\,\frac{m^3}{\cancel{rev}} \times 25\,\cancel{rev}/sec$

$= 2.5 \times 10^{-4}\,m^3/sec.$

i) Volumetric efficiency $= \frac{\text{Real flowrate}}{\text{Ideal flowrate}} \times 100\%$

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

$= 66.8\%$ //

ii) Fluid power $= Q \cdot dP$

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

$= 200.4\,watts$ //

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

$\omega = 2\pi N = 2\pi \cdot 25 = 157.0796$

$\simeq 157.08$

Shaft power $= 12.5 \times 157.8$

$= 1963.5\,watts$ //

iv) Over all efficiency

$\frac{\text{fluid Power}}{\text{Shaft Power}} \times 100\% = \frac{200.4}{1963.5} \times 100 = 10.206 \simeq 10.21\%$ //

2) Pump delivery $= 35\,dm^3/min$

$\frac{35 \times 10^{-3}}{60} = 5.83 \times 10^{-4}$

$P = 100\,bar = 100 \times 10^5\,Nm^{-2}$

Overall efficiency $= 87\%$

Fluid power $= Q \cdot dp$

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

$= 5830$ watts //

Recall,

Overall efficiency $= \frac{\text{Fluid power}}{\text{Shaft power}} \times 100\%$

$\therefore$ Shaft power $= \frac{\text{fluid power} \times 100}{\text{overall efficiency}} = \frac{5830 \times 100}{87} =$

~~6.7~~ 6701.149 watts //

3) Nominal displacement of $50\,cm^3/rev = 50 \times 10^{-5}\,m^3/rev$.

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

Shaft power $= 15\,kw = 15000$ watts

Actual flowrate $= 35\,dm^3/min = \frac{35 \times 10^{-3}}{60}\,m^3$

$= 5.83 \times 10^{-4}\,m^3/s$

Speed $= 850$ rev/min $= \frac{850}{60} = 14.166 \approx 14.17$ rev/s

Ideal flowrate $=$ Nominal displacement $\times$ speed

$= 50 \times 10^{-6}\,cm^3/rev \times 14.17\,rev/s$

$= 7.085 \times 10^{-4}\,m^3/s$

i) Volumetric efficiency $= \frac{\text{Real flowrate}}{\text{Ideal flowrate}} \times 100\% = \frac{5.83 \times 10^{-4}}{7.085 \times 10^{-4}} \times 100\%$

$= 82.29\%$ //

ii) Fluid power $= Q \cdot dp$ ; $5.83 \times 10^{-4} \times 100 \times 10^5 = 5830$ watts

overall efficiency $= \frac{5830}{15000} \times 100 = 38.867\%$ //

4). $z = 2400cm = 24m$ ; Volumetric flowrate $Q = 13$ litres/sec $= 0.013\ m^3/sec$

velocity $= 66\ m/sec$

The general formula, $P = \rho g Q \left(\frac{P}{\rho g} + \frac{v^2}{2g} + z\right)$

$$P = QP + \frac{\rho Q v^2}{2} + \rho g Q z$$

Being in (Power of jet)

Pressure head $= 0$

$z = 0$ $\therefore$ $P = \frac{\rho Q v^2}{2}$

3, $Q = 0.013$, $\rho = 1000$, $v = 66m/s$

$P = \frac{1000 \times 0.013 \times (66)^2}{2}$ ; $P = 28314$ watts $= 28.314\ KW$

ii) Power supplied from reservoir

At atmospheric pressure, $P = 0$ & $v = 0$

$\therefore$ $P = \rho g Q z$

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

$= 30607.2$ watts $\simeq 30.607\ KW$

iii) Power loss in transmission,

Power of reservoir - Power of jet, $= (30607.2 - 28314)$

$= 2293.2$ watts $\simeq 2.2932\ KW$

Head loss in pipe line $= 2.2932\ KW$

$h = \frac{\text{Power lost in transmission}}{\rho g Q} = \frac{2293.2}{1000 \times 9.81 \times 0.013} = 17.98m$

Efficiency $= \frac{\text{Power of jet}}{\text{Power of reservoir}} \times 100\% = \frac{28314}{30607.2} \times 100$

$= 92.51\%$

5) $S_g$ of oil $= 0.89$ ; $Q = 220 l/sec = 0.22 m^3/sec$.
$Z = 30{,}000 cm = 300 m$ $V = 7 m/sec$.

Subing; $Z = 0$, Pressure $= 0$

i) $P = \frac{\rho Q V^2}{2}$ ; $S_g = 0.89$

$x = 0.89 \times 1000$
$x = 890$
$\rho = x = 890$ ; $P = \frac{890 \times 0.22 \times (7)^2}{2}$
$P = 4797.1$ watts

ii) Power supplied from reservoir
$P = \rho g Q Z$ ; $P = 890 \times 9.81 \times 0.22 \times 300$.
$P = 576239.4$ watts $= 576.2394$ KW

iii) Power loss in transmission
= Power reservoir − Power of jet
$= (576.2394 - 4.7971)$ KW
$= 571442.3$ W
$= 571.442$ KW

Head used to overcome losses
$= \frac{571442.3}{890 \times 9.81 \times 0.22} = 297.51 m$

iv) efficiency $= \frac{\text{Power of jet}}{\text{Power of reservoir}} \times 100\%$

$= \frac{4797.1}{571442.3} \times 100\% = 0.83\%$

6)

7)

6) $P = \rho g Q z$

$z = \cancel{200m} + 20m = h$

$\rho = 1000$

$g = 9.81$

$Q = VA$

$d = 10cm = 10\times10^{-2}m^2$ ;

velocity of height at instant velocity is needed ; using equations of motion ;

$v = 0$

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

$u = \sqrt{v^2 + 2gh}$

$u = \sqrt{0^2 + 2\times9.81\times20}$

$u = \sqrt{392.4}$

$u = 19.809 \simeq 19.81 m/s$

$v = 19.81$

$\therefore Q = VA$

$19.81 \times 7.85\times10^{-3} = 0.15558 m^3/s \simeq 0.156 m^3/s$

$\therefore P = \rho g Q z$

$= 1000\times9.81\times0.156\times20$

$P = 30510.7677 W \simeq 305 kW$

7) $d_1 = 0.3m$ ; $A_1 = \frac{\pi d^2}{4} = \frac{\pi\times0.3^2}{4} = 0.07068m^3 \simeq 0.0707m^2$

$d_2 = 0.2m$

$A_2 = \frac{\pi d^2}{4} = \frac{\pi\times0.2^2}{4} = 0.031415m^2 \simeq 0.0314m^2$

$C_d = 0.96$ ; specific weight of gas $= 19.62 N/m^2$

$\int \frac{mg}{V} = \rho g$

$= \frac{19.62}{9.81} = \frac{\rho\times9.81}{9.81}$ , so, $\rho g = 19.62$

$\therefore \rho = 2 kg/m^2$

Calculating $Q_1 = A_1V_1$ , $Q_2 = A_2V_2$ , $Q_1 = Q_2$.

$\therefore V_1 = \frac{Q_1}{A_1}$ , $V_2 = \frac{Q_2}{A_2}$

$V_1 = \frac{Q}{0.0707}$ $V_2 = \frac{Q}{0.0314}$

For manometer

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

$$P_1 - P_2 = \rho_g g(z_2 - R_P) + \rho_w \cdot g R_P - \rho_g g z$$

$$P_1 - P_2 = 19.62(z_2 - z_1) + 587.423 \quad \text{---(i)}$$

for the venturimeter,

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

$$P_1 - P_2 = 19.62(z_2 - z_1) + 0.803 V_2^2 \quad \text{---(ii)}$$

& $z_2 - z_1 = 0.06 m$

equating $eq_n$ (i) & eqn (ii)

$$19.62(z_2 - z_1) + 587.423 = 19.62(z_2 - z_1) + 0.803 V_2^2$$

$$0.803 V_2^2 = 587.423$$

$$V_2 = \sqrt{\frac{587.423}{0.0803}}$$

$$V_2 = 27.0469 \simeq 27.047 \ m/s$$

$Q_{ideal} = A_2 V_2$

$\therefore$ $27.047 \times 0.0314$

$Q_{ideal} = 0.8492$

$\simeq 0.85 \ m^3/s$

$Q_{real} = C_d \times Q_{ideal}$

$= 0.96 \times 0.85$

$= 0.816 \ m^3/s$

8) Throat diameter $= 0.076m$ $(d_2)$

vertical diameter $= 0.152 m$ $(d_1)$

Relative density $= 0.8$

Throat being $= 0.914m$

$C_d = 0.91$

Bernoulli's eqn

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

Recall

$$Q_1 = V_1 A_1, \quad Q_2 = V_2 A_2$$

$$A_2 = \frac{\pi d^2}{4} = \frac{\pi \times 0.076^2}{4} = 4.64 \times 10^{-3} m^2$$

$$A_1 = \frac{\pi d^2}{4} = \frac{\pi \times 0.152^2}{4} = 0.0181 m^2$$

Then $P_1 - P_2 = 15170$

$$\left(\frac{P_1}{\rho g} + Z_1\right) - \left(\frac{P_2}{\rho g} + Z_2\right) = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

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

Recall, $Z_1 - Z_2 = 0.914$

$$\frac{P_1 - P_2}{\rho g} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g} - 0.914$$

Recall, $Q = VA$, $V = \frac{Q}{A}$, $\rho = 800$, $g = 9.81$,

$$\frac{15170}{800 \times 9.81} = \frac{\left(\left(\frac{Q}{A_2}\right)^2 - \left(\frac{Q}{A_1}\right)^2\right)}{2g} - 0.914$$

$$\frac{15170}{7848} = Q^2 \frac{\left(\left(\frac{1}{A_2}\right)^2 - \left(\frac{1}{A_1}\right)^2\right)}{2g} - 0.914$$

$$1.932 = \frac{Q^2(48516.36 - 3052.41)}{2g} - 0.914$$

$$(1.932 + 0.914)2g = Q^2(48516.36 - 3052.41)$$

$$\frac{55.3678}{45463.95} = \frac{Q^2 (45463.95)}{45463.95}$$

$$Q^2 = 1.24 \times 10^{-3}$$

$$Q = \sqrt{1.24 \times 10^{-3}}$$

$$Q = 0.0352 m^3/s$$

10.

9) $d_1 = 300mm = 0.3m$

$d_2 = 150mm = 0.15m$

$\therefore A_1 = 0.07069 m^2$

$A_2 = 0.977 m^2$

$Q = 40 lit/sec = 0.04 m^3/sec$

$z_1 = 16m, \; z_2 = 6m$

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

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

But $Q = A_1 V_1$

$V_1 = Q/A_1 = 0.04 / 0.07069$

$V_1 = 0.5658 \simeq 0.57 m/s$

Then $V_2 = \frac{Q}{A_2} = \frac{0.04}{0.0177}$, $V_2 = 2.2598 \simeq 2.26 m/s$

$$\frac{P_1}{\rho g} (z_1 - z_2) + \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) = \frac{P_2}{\rho g}$$

$$\frac{400kN}{9.81kN} + (10-6) + \left(\frac{0.572 - 2.26^2}{2\times 9.81}\right) = \frac{P_2}{9.81kN}$$

$$40.77 + 4 + (0.2438) = \frac{P_2}{9.81kN}$$

$$44.52 \times 9.81 = P_2$$

$$P_2 = 436.74kN.$$

10. Reading of manometer = 170mm
= 0.17m

Specific gravity of mercury = 13.6
" " seawater = 1.026

$y_f$ 0.17m

$$h = y_f\left(\frac{S_m}{S_f} - 1\right) = 0.17\left(\frac{13.6}{1.026} - 1\right)$$

$$= 2.0834m$$

recall $v = \sqrt{2gh}$

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

$$v = \sqrt{40.87}$$

$$V = 6.393\ m/s$$