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Fluid Mechanics ENG 214
Mechanical Engineering

1.) ~~L = 20m~~ Real flow rate = $10 dm^3/min$ T = 12.8Nm
~~V_1 (smaller end) = 8m/s~~ $= \frac{10\times10^{-3}}{60} = 1.67\times10^{-4} m^3/s$
~~V_2~~

Pressure = 12bar = $12\times10^5 N/m$
Speed = 1800 rev = $\frac{1800 rev}{60 sec}$ = 28rev/sec

Normal displacement = $10cm^3/rev = 1\times10^{-5} m^3/rev$
Ideal flowrate = Normal displacement × speed = $1\times10^{-5} \cdot 28$
Ideal flowrate = $2.8\times10^{-4} m^3/sec$

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

$= \frac{1.67\times10^{-4}}{2.8\times10^{-4}} \times 100\%$

$= 66.8\%$

ii) Fluid Power = Q · dP
$= 1.67\times10^{-4} \times 12\times10^5$
= 200.4 watts

iii) Shaft Power = T·ω
~~ω~~ = 2πN = 2×π×n
ω = 2×π×28
= 187.0776 ≃ 187.08
Shaft Power = 12.8×187.08
= 1963.8 watts

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

$= \frac{200.4}{1963.8} \times 100\% = 10.206$

≃ 10.21%

= 7.853×10 //

2) Pump delivery = 38 dm^3/min

$= \frac{38 \times 10^{-3}}{60} = 5.83 \times 10^{-4}$

$P = 100 bar = 100 \times 10^5 N/m^{-2}$

Overall efficiency = 87%

Fluid Power = Q · dp

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

= 5830 watts

Overall efficiency = $\frac{\text{fluid Power} \times 100\%}{\text{Shaft Power}}$

∴ Shaft Power = $\frac{\text{fluid Power} \times 100\%}{\text{overall efficiency}}$

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

Shaft Power = 6701.49 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 = 18 kW = 18000 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 ≃ 14.17 rev/s

Ideal flowrate = Nominal displacement × speed

$= 50 \times 10^{-6} m^3/rev \cdot 14.17 rev/sec$

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

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%

Fluid Power = Q · dp

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

= 5830 watts

ii) Overall efficiency

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

= $\frac{5830 \text{ watts}}{18000 \text{ watts}}$ = 38.867% ≃ 38.9%

4.) Z = 2400 cm = 24 m

Volumetric flowrate, Q = 13 litres/sec
$= 0.013 m^3/sec$

Velocity = 66/sec

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

$P = Qp + \rho \frac{Qv^2}{2} + \rho g Q z$

i) Introducing Power of jet

Pressure head = 0

Z = 0

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

Q = 0.013, ρ = 1000, v = 66 m/s

$\therefore P = \frac{1000 \times 0.013 \times (66)^2}{2}$

P = 28314 watts

= 28.314 kW

(ii) Power supplied from reservoir

at A&B, P = 0 and U = 0

$\therefore P = \rho g Q Z$

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

$= 30607.2$ 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

$= 2.2932$ K watts

(iv) $h = \dfrac{\text{Power loss in transmission}}{\rho g Q}$

$h = \dfrac{2293.2}{1000 \times 9.81 \times 0.013}$

$h = \dfrac{2293.2}{127.53} = 17.98 m$

(v) Efficiency

$= \dfrac{\text{Power of jet}}{\text{Power of reservoir}} \times 100\%$

$= \dfrac{28314}{30607.2} \times 100$

$= 92.81\%$

5.) Specific quantity of oil = 0.89

$Z = 30{,}000 cm = 300 m$

$Q = 220 l/sec = 0.22 m^3/sec$

$U = 7 m/sec$

$Z = 0$, Pressure = 0

i.) $P = \dfrac{\rho Q U^2}{2}$

$S.g = 0.89$

$S.g = \dfrac{x}{1000}$

$\therefore x = 0.89 \times 1000$

$= 890$

$\rho = x = 890$

$P = \dfrac{890 \times 0.22 \times (7)^2}{2}$

$P = 4797.1$ 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

$\simeq 576.2394$ Kw

iii.) Power loss in transmission

= Power reservoir − power of jet

$= 576239.4 - 4797.1$

$= 571442.3$ watts

$= 571.4423$ Kw

$\simeq 571.4$ Kw

head used to overcome losses

$\dfrac{\text{Power loss in transmission}}{\rho g Q} = \dfrac{571442.3}{890 \times 9.81 \times 0.22}$

$= 297.51 m$

iv.) Efficiency $= \dfrac{\text{Power of jet}}{\text{Power of reservoir}} \times 100\%$

6.) $P = \rho g Q Z$ $Q = UA$

$Z = 20 m = h$ $d = 10 cm = 10 \times 10^{-2} m$

$\rho = 1000$

$g = 9.81$

$A = \dfrac{\pi d^2}{4} = \dfrac{\pi \times (10 \times 10^{-2})^2}{4} = 7.85 \times 10^{-3} m^2$

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Using equation of motion velocity of height at initial velocity

$u = 0$

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

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

$u = \sqrt{0^2 + 2 \times 9.81 \times 20}$

$u = \sqrt{392.4}$

$u = 19.809 \approx 19.81 \, m/s$

∴ Velocity of height at initial velocity $= 19.8 \, m/s$

$Q = uA$

$= 19.81 \times 7.85 \times 10^{-3}$

$= 0.18858 \, m^3/sec$

$\approx 0.186 \, m^3/sec$

$P = \rho g Q z$

$= 1000 \times 9.81 \times 0.186 \times 20$

$P = 30810.767$ watts

$P \approx 30.810 \, kW$

7) $d_1 = 0.2m$

$A_1 = \frac{\pi d^2}{4} = \frac{\pi \times (0.3)^2}{4} = 0.07068 m^2$

$A_1 \approx 0.0707 m^2$

$A_2 = 0.2m$

$A_2 = \frac{\pi d^2}{4} = \frac{\pi \times (0.2)^2}{4} = 0.031415 m^2$

$= 0.0314 m^2$

$Cd = 0.96$

Specific weight of gas $= 19.62 \, N/m^2$

$S = \frac{mg}{v} = \rho g$

$= \frac{19.62}{9.81} = \frac{\rho \times 9.81}{9.81}$

$\therefore \rho_g = 19.62$

$P = 2 \, kg/m^2$

$Q_1 = A_1 u_1, \quad Q_2 = A_2 u_2$

$u_1 = \frac{Q}{A_1} \qquad u_2 = \frac{Q}{A_2}$

$u_1 = \frac{Q}{0.0707} \qquad u_2 = \frac{Q}{0.0314}$

From the manometer,

$P_1 + \rho_g g z_1 = P_2 + \rho_g g(z_2 - h_p) + P_w \rho_p$

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

$= P_1 - P_2 = 19.62 \, (z_2 - z_1) + 887.423$ — ①

For the venturimeter,

$\frac{P_1}{\rho_1 g} + \frac{u_1^2}{2g} + z_1 = \frac{P_2}{\rho_2 g} + \frac{u_2^2}{2g} + z_2$

$P_1 - P_2 = 19.62(z_2 - z_1) + 0.803u^2$ — ⓐ

$z_2 - z_1 = 0.06m$

Put equation ⓐ and ①

$19.62(z_2 - z_1) + 887.423 =$

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

$0.803u_2^2 = 887.423$

$u_2^2 = \frac{887.423}{0.803}$

$u_2^2 = 731.535$

$V_2 = \sqrt{731.535}$

$V_2 = 27.0469$

$\approx 27.047 \, m/s$

$Q_{ideal} = A_2 u_2$

$= 27.047 \times 0.0314$

$= 0.8492$

$\approx 0.85 \, m^3/s$

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

$= 0.96 \times 0.85 = 0.816 \, m^3/s$

8) Throat diameter = 0.076

Vertical diameter = 0.182m

Relative density = 0.8

throat being = 0.914 m

$Cd = 0.91$

Bernoulli's equations

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

$Q = V_1 A_1$, $Q = V_2 A_2$

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

$$A_2 = 4.64 \times 10^{-3} m^2$$

$$A = \frac{\pi d^2}{4} = \frac{\pi \times 0.152^2}{4}$$

$$A_1 = 0.0181 m^2$$

$V_1 A_1 = V_2 A_2$

$$V_1 = \frac{V_2 A_2}{A_1} = \frac{V_2 \times 4.54 \times 10^{-3}}{0.0181}$$

$V_1 = 0.251 V_2$

for $P_1 = P_2$, $\rho = 800$

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

$$Z_1 - Z_2 + \frac{V_1^2}{2g} = \frac{V_2^2}{2g}, \quad Z_1 - Z_2$$

$= 0.914$

$$0.914 = \frac{V_2^2 - 0.251 V_2^2}{19.62}$$

$V_2^2 - 0.063 V_2 = 17.93$

$0.937 V_2^2 = 17.93$

$$V_2^2 = \frac{17.93}{0.937}$$

$V_2^2 = 19.136$

$V_2 = \sqrt{19.136}$

$V_2 = 4.37$

$\therefore Q_{ideal} = A_2 V_2 = 4.37 \times 4.64 \times 10^{-3}$

$= 0.02027$

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

$= 0.96 \times 0.02027$

$= 0.0195 m^3/s$

11) $P_1 - P_2 = 18170$

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

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

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 $Q = VA$, $V = \frac{Q}{A}$

$\rho = 800$, $g = 9.81$

$$\frac{18170}{800 \times 9.81} = \left(\frac{Q}{A_2}\right)^2 - \left(\frac{Q}{A_1}\right)^2 - 0.914$$

$$\frac{18170}{7848} = Q^2 \frac{\left((1/A_2)^2 - (1/A_1)^2\right)}{2g} - 0.914$$

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$1.932 = Q^2 \frac{(48816.36 - 3082.41)}{2g}$

$= 0.914$

$1.932 + 0.914 \, 2g = Q^2 \, 48816.36 - 3082.41$

$\frac{56.3678}{48463.98} = \frac{Q^2 \, 48463.95}{48463.95}$

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

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

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

9.) $d_1 = 300m = 0.3m$

$d_2 = 150m = 0.15m$

$\therefore A_1 = 0.07069 m^2$

$A_2 = 0.0177 m^2$

$Q = 40 \, ltr/sec = 0.04 m^3/sec$

$Z_1 = 10m, \; Z_2 = 6m$

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

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

But, $Q = A_1 V_1$

$\therefore V_1 = \frac{Q}{A_1} = \frac{0.04}{0.07089}$

$V_1 = 0.5658 m/s$

$\simeq 0.57 m/s$

$Q = A_2 V_2$

$V_2 = \frac{Q}{A_2} = \frac{0.04}{0.0177}$

$V_2 = 2.2598 m/s$

$\simeq 2.26 m/s$

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

$\frac{400kN}{9.81kN} + (10 - 6) + \frac{(0.57^2 - 2.26^2)}{2 \times 9.81}$

$= \frac{P_2}{9.81kN}$

$\therefore 40.77 + 4 + (-0.2434) = \frac{P_2}{9.81kN}$

$44.52 \times 9.81 = P_2$

$\therefore P_2 = 436.74 kN$ //

10) Reading of manometer

$= 170mm$

$= 0.17 m$

S.g of mercury $= 13.6$

S.g of seawater $= 1.026$

$y = 0.17 m$

$h = y\left(\frac{S_{gm}}{S_{gsw}} - 1\right)$

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

$h = 0.17 \times 12.255$

$h = 2.0834 m$

Recall $V = \sqrt{2gh}$

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

$V = \sqrt{40.87}$

$V = 6.393 m/s$ //