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BIOMEDICAL ENGINEERING

18/ENG07/087

ENG 214 ASSIGNMENT

① Flowrate = 10 dm^3/min, Δ Pressure = 12 bar, Nominal displacement = 10 cm^3/
Speed = 1500 rev/min, Torque input = 12.5 N/m

Ideal flowrate = Nominal displacement × Speed = 10 × 1500 = 15000 cm^3/min
= 15 dm^3/min

i). Volumetric efficiency = $\frac{\text{Actual flow}}{\text{Ideal flow}} = \frac{10}{15} = 0.667 \simeq 66.7\%$

ii). $Q = \frac{10 \times 10^{-3}}{60} m^3/sec = 1.67 \times 10^{-2} m^3/sec$

$\Delta T = 12.5 \times 10^3 N/m^2$

Fluid Power = ΔT × Q = $1.67 \times 10^{-2} m^3/sec \times 12 \times 10^3$ = 200.4 Watt

iii). Shaft Power = $\frac{2\pi NT}{60} = \frac{2 \times \pi \times 1500 \times 12.5}{60} = 1963.5$ watt

iv). Overall efficiency → $\frac{FP}{SP} = \frac{200.4}{1963.5} = 0.102 \approx 10.2\%$

② Overall efficiency = 87% = $\frac{FP}{SP}$, $\frac{35 \times 10^{-3}}{60} = 5.83 \times 10^{-4}$,

$S.P = \frac{F.P}{87\%} \Rightarrow \frac{\Delta P \times Q}{87\%} = \frac{100 \times 10^5 \times 5.830 \times 10^{-3}}{0.87}$

= 6.7 watt

(3) Nominal displacement of $50 cm^3/rev = 50\times10^{-5} m^3/rev$

Pressure = 100 bar = $100\times10^5 N/m^2$, Shaft Power = 15kW = 15000 watts

Actual flow rate = $35 dm^3/min \Rightarrow \frac{35\times10^{-3}}{60} = 5.83\times10^{-4} m^3/s$

Speed = 850 rev/min = $\frac{850}{60}$ = 14.166 ≃ 14.17 rev/sec

Ideal flow rate = Nominal displacement × speed

$= 50\times10^{-6} m^3/rev \times 14.7$ rev/sec

$= 7.085\times10^{-4} m^3/sec$

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

$= \frac{5.83\times10^{-4}}{7.085\times10^{-4}} \times 100\% = 82.29\%$

Fluid Power = $Q.dp = 5.83\times10^{-4} \times 100 \times 10^5$

= 5830 watts

Overall efficiency = $\frac{\text{Fluid Power}}{\text{Shaft Power}} \times 100\% = \frac{5830}{15000} \simeq 0.389$

$\approx 38.9\%$

(4) Z = 2400cm = 24m

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

Velocity = 66m/sec, General formula, $P = \rho g Q\left(\frac{P}{\rho g} + \frac{V^2}{2g} + z\right)$

$P = Q p + \frac{\rho Q V^2}{2} + \rho g Q z$

i). Introducing Power of Jet,

Pressure head = 0

$z = 0$, $P = \frac{\rho Q V^2}{2}$, $Q = 0.013$, $\rho = 100$, $V = 66 m/s$

$\therefore P = \frac{100 \times 0.013 \times 66^2}{2}$ = 28 314 Watts = 28.314 kW ii). Power supplied from reservoir at atP, P=0, v=0

$\therefore P = \rho g Q z$

$P = 1000 \times 9.81 \times 0.013 \times 240 = 30607.2$ watts

≈ 30.607 kwatts

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

$= (30607.2 - 28314)$

$= 2293.2$ watts ≈ 2.2932 kW

Head loss in pipe line $= 2.2932$ kwatts

iv). $h = \dfrac{\text{Power loss in transmission}}{\rho g Q}$, $h = \dfrac{2293.2}{1000 \times 9.81 \times 0.013}$

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

v). Efficiency $= \dfrac{\text{Power of Jet}}{\text{Power of reservoir}} \times 100 \Rightarrow \dfrac{28314}{306072} \times 100 = 92.51\%$

(5) Specific gravity of oil = 0.89

$z = 30{,}000cm = 300m$, $Q = 220\ l/s = 0.22\ m^3/sec$, $v = 7m/s$

Introducing, z=0, Pressure = 0

(i) $P = \dfrac{\rho Q v^2}{2}$ (Power of jet), $S.g = 0.89$, $S.g = \dfrac{x}{1000}$

$x = 0.89 \times 1000 = 890$, $\rho = x = 890$,

$P = \dfrac{890 \times 0.22 \times 7^2}{2} = 4797.1$ watts

ii) Power supplied from reservoir

$P = \rho g Q z$

$P = 890 \times 9.81 \times 0.22 \times 300 = 576239.4$ watts

≈ 576.2394 kW

(ii). Power loss in transmission = Power of reservoir − Power of Jet
$= 576239.4 - 4797.1$
$= 571442.3$ watts
$= 571.4$ kW

head used to overcome losses = $\frac{\text{Power loss in transmission}}{\rho g Q}$

$= \frac{571442.3}{950 \times 9.81 \times 0.22} = 297.51$ m

(iv). Efficiency = $\frac{\text{Power of Jet}}{\text{Power of reservoir}} \times 100\%$

(5) $P = \rho g Q z$, $z = 20$ m $= h$, $Q = VA$, $d = 10$ cm $= 0.1$ m, $\rho = 1000$, $g = 9.81$

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

Using equation of motion, Velocity of height of initial velocity

$V = 0$, $V^2 = U^2 - 2gh$, $U = \sqrt{V^2 + 2gh}$, $U = \sqrt{0^2 + 2 \times 9.81 \times 20}$

$U = \sqrt{392.4} = 19.809 \approx 19.81$ m/s

Velocity of height of initial velocity = 19.81 m/s

$Q = UA = 19.81 \times 7.85 \times 10^{-3} = 0.15558$ m^3/sec

≈ 0.156 m^3/s

$P = \rho g Q z = 1000 \times 9.81 \times 0.156 \times 20 = 30510.767$ watts

$Q_{ideal} = A_2 V_2 = 27.047 \times 0.0314 = 0.8492\ m^3/s$

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

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

(8) Throat diameter = 0.076m, Vertical diameter = 0.152m

Relative density = 0.8, Throat leng 0.914m, $C_d = 0.91$

Bernoullis equation,

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

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

$$A_2 = \frac{\pi d^2}{4} = \frac{\pi \times 0.76^2}{4} = 4.64 \times 10^{-3}\ m^2$$

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

$V_1 A_1 = V_2 A_2$

$$V_1 = \frac{V_2 A_2}{A_1} = \frac{V_2 \times 4.54 \times 10^{-3}}{0.0181},\quad V_1 = 0.251 V_2$$

For $P_1 = P_2$, $P = 800$

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

$$Z_1 - Z_2 + \frac{V_1^2}{2g} = \frac{V_2^2}{2g},\quad Z_1 - Z_2 = 0.914$$

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

$V_2^2 - 0.063 V_2 = 17.93$

$0.937 V_2^2 = 17.93$

$$V_2^2 = \frac{17.93}{0.937} \Rightarrow V_2 = \sqrt{19.136} = 4.37$$

(7) $d_1 = 0.3m$, $A_1 = \frac{\pi d^2}{4} = \frac{\pi \times (0.3)^2}{4} = 0.07068m^2$,

$d_2 = 0.2m$, $A_2 = \frac{\pi d^2}{4} = \pi \frac{\times 0.2^2}{4} = 0.031415m^2$

$Cd = 0.96$

Specific weight of gas $= 19.62 N/m^3$

$$\gamma = \frac{mg}{V} = \rho g = \frac{19.62}{9.81} = \frac{\rho \times 9.81}{9.81}$$

$\therefore \rho g = 19.62$, $\rho = 2 \, kg/m^3$

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

$V_1 = \frac{Q}{A_1}$ $\quad V_2 = \frac{Q}{A_2}$

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

for the manometer,

$P_1 + \rho_g g z_1 = P_2 + \rho_g g (z_2 - R_p) + \rho_{aw} R_p$

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

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

for the venturimeter,

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

$P_1 - P_2 = 19.62(z_2 - z_1) + 0.803V_2^2$ --- (ii)

$z_2 - z_1 = 0.06m$

equating (ii) and (i)

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

$\therefore 0.803V_2^2 = 587.423$

$V_2^2 = \frac{587.423}{0.803}$, $V_2^2 = 731.535$, $V_2 = \sqrt{731.535}$

$V_2 = 27.047 \, m/s$

$Q_{ideal} = A_2 U_2 = 4.37 \times 4.64 \times 10^{-3} = 0.02027$

$Q_{real} = C_d \times Q_{ideal} = 0.96 \times 0.02027 = 0.0195 m^3/s$

(ii) $P_1 - P_2 = 15170$

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

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

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 $Q = UA$, $V = Q/A$, $\rho = 800$, $g = 9.81$

$$\frac{15170}{800 \times 9.81} = \frac{\left(\frac{Q}{A_2}\right)^2 - \left(\frac{Q_1}{A_1}\right)^2}{2g} - 0.914$$

$$\frac{15170}{7848} = \frac{Q^2 (48517.36 - 3052.41)}{2g} - 0.914$$

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

$$\frac{56.3678}{45463.95} = Q^2 \frac{45463.95}{45463.95}$$

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

$Q = \sqrt{1.24 \times 10^{-3}} = 0.0352 m^3/s$

(5) $d_1 = 300mm = 0.3m$, $d_2 = 150mm = 0.15m$

$\therefore A_1 = 0.07069 m^2$, $A_2 = 0.0177 m^2$

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

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

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

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

$Q = A_1 V_1$

$$V_1 = \frac{Q}{A_1} = \frac{0.04}{0.07059}$$

$V_1 = 0.5658 m/s \simeq 0.57 m/s$

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

$\therefore V_2 = 2.2598 m/s \approx 2.26 m/s$

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

$$400 kN/9.81 kN + (10-6) + \left(\frac{0.57^2 - 2.26^2}{2 \times 9.81}\right) = \frac{P_2}{9.81}$$

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

$44.52 \times 9.81 = P_2$

$P_2 = 436.74 kN$

(10) Reading of manometer = 170mm = 0.17m

S.g = mercury = 13.6

S.g of seawater = 1.026

$y = 0.17m$

$h = y\left(\frac{S_{tal}}{S_1} - 1\right) \Rightarrow 0.17\left(\frac{13.6}{1.026} - 1\right)$

$h = 0.17 \times 12.255$

$h = 2.0834m$

Recall, $V = \sqrt{2gh}$

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

$V = \sqrt{40.87} = 6.393m/s$