LAW - ADUE EMMANUEL
19/ENG05/069
MECHATRONICS <200Lvl>

QUESTION ONE (1)

Actual flow rate $= 10\, dm^3/min$ - - Q
$= 0.01\, m^3/min = 1.67 \times 10^{-4}\, m^3/sec$

Speed $= 1500$ rev/min
$= \frac{1500}{60}$ rev/sec $= 25$ rps

Pressure $= 12$ bar - - P
$= 12 \times 10^5\, N/m^2$

Normal displacement $= 10\, cm^3/rev = \frac{10}{1000000}\, m^3/rev$
$= 1 \times 10^{-5}\, m^3/rev$

Ideal flow rate = normal displacement X speed
$= 1 \times 10^{-5} \times 25$
$= 2.5 \times 10^{-4}\, m^3/sec$

** Volumetric Efficiency $= \frac{\text{Actual flow rate}}{\text{Ideal flow rate}} \times 100\%$
$= \frac{1.67 \times 10^{-4}}{2.50 \times 10^{-4}} \times 100$
$= 66.8\%$

** P_F, Fluid power $= Q \times P$
$= 1.67 \times 10^{-4} \times 12 \times 10^5$
$= 200.4\, Nm/sec$

** Shaft power = $\tau \cdot \omega$

$$= 12.5 \times \left(2 \times \frac{22}{7} \times \text{speed}\right)$$

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

$$= 1964.25 \text{ Watts}$$ //

** Overall Efficiency ;

$$= \frac{\text{fluid power}}{\text{Shaft power}} \times 100$$

$$= \frac{200.4}{1964.25} \times 100 = 10.20\%$$ ///

QUESTION TWO (2)

Pressure change = 100 bar

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

Actual flow rate, Q = $35\ dm^3/min$

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

Fluid power = Q × P

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

= 5830 Watts

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

$= \frac{5830 \times 100}{87} = 6.701 \times 10^3$ Watts ///

QUESTION THREE (3)

Nominal displacement = $50 cm^3/rev$

$= \frac{50}{1000000}\ m^3/rev = 5 \times 10^{-5}\ m^3/rev$

Actual flow rate = $35\ dm^3/min$

$= \frac{35}{1000 \times 60}\ m^3/sec = 5.83 \times 10^{-4}\ m^3/sec$

Fluid power = Q × P

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

$= 5.83 \times 10^{-4} \times 100 \times 10^5 = 5830$ Watts

** Overall Efficiency = $\frac{5830}{15000} \times 100\%$

$= 38.87\%$

Ideal flow rate = nominal displacement x speed

= 850 rpm x 5 x10^{-5}

$= 5\times10^{-5} \times \frac{850}{60}$

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

** Volumetric Efficiency : $\frac{\text{Act flow rate}}{\text{Ideal flow rate}} \times 100\%$

$= \frac{5.83 \times 10^{-4}}{7.085 \times 10^{-4}} \times 100\%$

= 82.29 % ///

QUESTION FOUR

Z = 24000 cm

Z = 240 m

Volumetric flow rate = 13 l/sec

$= \frac{13}{1000}\ m^3/sec = 13 \times 10^{-3}\ m^3/sec$

Jet velocity = 66 m/s

Water density = 1000 kg/m^3

** Since p=0 and Z=0 ; < Jet power >

$P = (0 \times Q) + \frac{\rho Q \cdot V^2}{2} + \rho g Q(0)$

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

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

$P = 28314$ Watts /// --- Power of jet

** Power supplied from reservoir :

Since $p = 0$ and $v = 0$;

$$P = (0 \times Q) + \frac{\rho Q (0)^2}{2} + \rho g Q Z$$

$\Rightarrow P = \rho g Q z$

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

$= 30607.2$ Watts ///

** Power lost in transmission = Power of reservoir − Jet power ;

$= 30607.2 - 28314$

$= 2293.2$ Watts ///

** Headloss in pipeline, h : $\frac{\text{power lost in transmission}}{\rho g Q}$

$= \frac{2293.2}{1000 \times 9.81 \times 13 \times 10^{-3}}$

$= 17.982$ m

** Efficiency $= \frac{\text{Jet power}}{\text{Reservoir power}} \times 100\%$

$= \frac{28314}{30607.2} \times 100\%$

$= 92.5\%$

QUESTION FIVE

S_g of oil = 0.89

Z = 30, 300m = 300m

Q = 200 l/sec = 0.22 m^3/sec

V = 7 m/sec

Introducing z = 0, and p = 0;

** $P = \frac{\rho Q V^2}{2}$ — — — Jet power

Recall, S_g = 0.89

$S_g = \frac{x}{1000}$; x = 890

ρ = x = 890

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

P = 4797.1 watts

** Power supplied from reservoir ;

$P = \rho g Q z$

= 890 × 9.81 × 0.22 × 300

= 576239.4 Watts

≃ 576.24 Watts

** Power loss :

~~= (576.24 − 4.7971) kw~~

~~= 571.44 kilowatts~~

= (576239.4 − 4.7971) kilowatts

= 571.4423 kilowatts

= 571442.3 Watts ///

* * Head used to overcome losses:

$$= \frac{571442.3}{890 \times 9.81 \times 0.22}$$

$= 297.51m$ ///

QUESTION SIX

$P = \rho g Q z$

$z = 20m = h$

$\rho = 1000$, $g = 9.81$

$Q = VA$

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

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

The initial velocity is needed while $v = 0$;

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

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

$u = \sqrt{0^2 + 2 \times 9.81 \times 20}$, $u = \sqrt{392.4}$

$u = 19.81 ms^{-1}$

$Q = VA$

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

$= 0.15558 m^3/s = 0.156 m^3/s$

$\therefore P = \rho g Q z$

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

$= 30.5$ Kilowatts

QUESTION SEVEN

$d_1 = 0.3m$

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

$d_2 = 0.2m$, $A_2 = 0.0314 m^2$

$Cd = 0.96$

Sw of gas $= 19.62 \ N/m^2$

$\therefore \rho g = 19.62$

$\rho = \frac{19.62}{9.81} = 2 \ kg/m^2$

Recall, $Q = A_1 V_1 = A_2 V_2$

From the above equation ;

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

MANOMETER :

$P_1 + \rho_g g Z_1 = P_2 + \rho_g g (Z_2 - R_p) + \rho_w g R_p$

$P_1 - P_2 = 19.62 (Z_2 - Z_1) + 587.423$ — — A

VENTURIMETER :

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

$P_1 - P_2 = 19.62 (Z_2 - Z_1) + 0.803 V_2^2$ — — B

$\langle Z_2 - Z_1 = 0.06m \rangle$

Equating A and B :

$19.62 (Z_2 - Z_1) + 587.423 = 19.62 (Z_2 - Z_1) + 0.803 V_2^2$

$0.803 V_2^2 = 587.423$

$V_2^2 = \frac{587.423}{0.803}$

$V_2^2 = 731.535$

$V_2 = \sqrt{731.535}$

$V_2 \simeq 27.047 \, ms^{-1}$

$Q_{ideal} = A_2 V_2$

$= 27.047 \times 0.0314$

$= 0.8492 \, ms^{-1}$ ///

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

$= 0.96 \times 0.8492$

$= 0.815 \, ms^{-1}$ ///

QUESTION 8

Inlet diameter = 0.152m - - d_1

Throat diameter = 0.076m - - d_2

$Z_1 - Z_2 = 0.914m$

a) Discharge when pressure guages read the same :

$$\left(\frac{P_1}{w} - \frac{P_2}{w}\right) + \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) + (Z_1 - Z_2) = 0$$

$$\rightarrow 0 + \frac{V_1^2}{2g} - \frac{V_2^2}{2g} + 0.914 = 0 \quad - - - \text{eqn} (*)$$

→ From continuity equation : $A_1V_1 = A_2V_2$

$$V_1 = \frac{A_2V_2}{A_1}$$

$$V_1 = \frac{\frac{\pi}{4} \times 0.076^2 \times V_2}{\pi/4 \times 0.152^2}$$

$$V_1 = 0.25V_2$$

Substitute " $V_1 = 0.25V_2$ " into eqn (*) ;

$$\rightarrow \frac{(0.25V_2)^2}{2g} - \frac{V_2^2}{2g} + 0.914 = 0$$

$$\rightarrow \left(0.0625 \times \frac{V_2^2}{2g}\right) - \frac{V_2^2}{2g} + 0.914 = 0$$

$$\rightarrow \left(\frac{0.0625}{2 \times 9.81} \times V_2^2\right) - \left(\frac{V_2^2}{2 \times 9.81}\right) + 0.914 = 0$$

$$\rightarrow 0.00319 V_2^2 - \frac{V_2^2}{19.62} + 0.914 = 0$$

$$\rightarrow V_2^2\left(0.00319 - \frac{1}{19.62}\right) + 0.914 = 0$$

$\rightarrow V_2^2 (-0.0478) + 0.914 = 0$

~~$\rightarrow V_2^2 = \frac{-0.914}{-0.0191} = 47.85$~~

~~$V_2 = \sqrt{47.85} = 6.92 \; ms^{-1}$~~

~~Discharge, $Q = A_2 V_2$~~

~~$Q = \frac{3.142 \times 0.076^2}{4} \times 6.92$~~

~~$Q = 0.031 \; m^3 s^{-1}$~~ ///

$\rightarrow V_2^2 = \frac{-0.914}{-0.0478} = 19.12$

$V_2 = \sqrt{19.12}$

$= 4.37 \; ms^{-1}$

Discharge, $Q = A_2 V_2$

$= \frac{3.142 \times 0.076^2}{4} \times 4.37$

$= 0.0198 \; ms^{-1}$ ///

QUESTION 9

Diameter at S1, d_1 = 300mm = 0.3m

Diameter at S2, d_2 = 150 mm = 0.15m

$Z_1 = 10$, $Z_2 = 6$

P_1 = 400 kN/m² = 40×10^5 N/m²

From continuity equation, $Q = A_1V_1$

[Q = 40lit/sec = 0.04 m³/sec]

$$0.04 = \frac{\pi \times d_1^2}{4} V_1 = \frac{3.142 \times 0.3^2}{4} V_1 = 0.071 V_1$$

$0.04 = 0.071 V_1$

$$V_1 = \frac{0.04}{0.071} = 0.56 m^3$$

Recall, $A_1V_1 = A_2V_2$

$$0.071 \times 0.56 = \frac{3.142 \times 0.15^2}{4} V_2$$

$0.04 = 0.0177 V_2$; $V_2 = \frac{0.04}{0.0177}$

$V_2 = 2.26 m^3$

From bernoulli's equation;

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

$$\frac{40 \times 10^5}{1000 \times 9.81} + \frac{0.56^2}{2 \times 9.81} + 10 = \frac{P_2}{1000 \times 9.81} + \frac{2.26^2}{2 \times 9.81} + 6$$

$$\frac{(40 \times 10^5) - P_2}{1000 \times 9.81} + \left(\frac{0.56^2 - 2.26^2}{2 \times 9.81}\right) + 4 = 0$$

$$\Rightarrow 407.75 - \frac{P_2}{9810} + \left(-0.244\right) + 4 = 0$$

$\rightarrow P_2 = 9810(407.75 - 0.244 + 4)$

$\rightarrow P_2 = 4.04 \times 10^6$ N/m²

QUESTION 10

Velocity of the submarine, $V = \sqrt{2gH}$

$$H = y\left(\frac{\text{SG of mercury} - \text{SG of water}}{\text{SG of water}}\right)$$

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

$= 0.17 \times 12.26$

$= 2.0842\,m$

$$V = \sqrt{2 \times 9.81 \times 2.0842}$$

$= 6.39\,ms^{-1}$

$\therefore$ the speed of the sub-marine $= 6.39\,ms^{-1}$ ///