LAWO DAMILOLA
MECHATRONICS
18/ENG05/058

FLUID MECHANICS ASSIGNMENT.

1) Rate of Pump delivery = $10 dm^3/min$
Pressure Change = 12 bar = $12 \times 10^5 N/m^2$
Speed of rotation = 1500 rev/min = $\frac{1500 \text{ rev}}{60 \text{ sec}}$ = 25 rev/sec
Nominal displacement = $10 cm^3/rev$
Torque Input = 12.5 NM

i) Volumetric efficiency = $\frac{\text{Actual flow rate}}{\text{Ideal flow rate}} \times 100\%$

Actual flow rate = $10 dm^3/min$ = $\frac{10 dm^3}{1 min} \times \frac{1 m^3}{1000 dm^3} \times \frac{1 min}{60 sec}$

$= 1.67 \times 10^{-4} m^3/sec$

nominal displacement = $\frac{10 cm^3}{1 rev} \times \frac{1 m^3}{100^3 cm^3}$ = $1 \times 10^{-5} m^3/rev$

Ideal flow rate = normal displacement × speed
$= 1 \times 10^{-5} \times 25$

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

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

$= 66.8\%$

ii) Fluid power = Actual flow rate × Pressure
$= 1.67 \times 10^{-4} \times 12 \times 10^5$
= 200 watts.

iii) Shaft power = Torque input × angular speed
Torque input = 12.5 Nm
Angular speed = $w = \frac{2\pi N}{60}$ = $\frac{2 \times \pi \times 1500}{60}$ rps

Shaft power = 12.5 × 2 × 3.142 × 25 = 1963.5 watts

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

$= \frac{200}{1963.5} \times 100$

$= 10.19\%$

2) Rate of delivery = $35 dm^3/min$ = $35/60$ = $0.58 dm^3/sec$.

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

Overall efficiency = 87%

Shaft power = ?

Rate of delivery = $\frac{0.58}{1000}$ = $5.83 \times 10^{-4} m^3/sec$

Fluid power = Actual flow rate × pressure change

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

$= 5833.33$ watts

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

$87 = \frac{5833.33}{S.P} \times 100$

$\frac{0.87}{5833.33} = \frac{1}{\text{Shaft power}}$

∴ Shaft power = 6704.977 watts

3) Nominal displacement = $50 cm^3/rev$ = $5 \times 10^{-4} m^3/rev$

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

Shaft power = 15 Kw = 15000 Watts

Actual flow rate = $35 dm^3/min$ = $5.833 \times 10^{-4} m^3/sec$

Speed of rotation = 850 rpm = 14.2 rps

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

Fluid power = Actual flow rate × Pressure change

$= 5.833 \times 10^{-4} \times 100 \times 10^5$

= 5833 watts

Shaft power = Torque input × angular speed

15000 Watts

Overall efficiency = $\frac{5833}{15000} \times 100$

= 388.9%

Volumetric efficiency = $\frac{\text{Actual flow rate}}{\text{Ideal flow rate}} \times 100$

Ideal flow rate = nominal displacement × speed

$= 5 \times 10^{-4} \times 14.2$

$= 7.1 \times 10^{-3}\ m^3/sec$

∴ Volumetric efficiency = $\frac{5.833 \times 10^{-4}}{7.1 \times 10^{-3}} \times 100$

= 8.22%

4) Z = 24,000 cm = 240 m

Flow rate = 13 litres = $1m^3$

Since 1000 litres = $1m^3$

13 litres = $\frac{13}{1000}$ = $0.013\ m^3/sec$

Velocity of a jet = 66 m/sec

Density = $1000\ kg/m^3$

Using equation $P\left(P + \rho g z + \frac{\rho v^2}{2}\right)Q$

Since $P = 0$ and $z = 0$

$$P = \frac{\rho Q v^2}{2} = \frac{1000 \times 0.013 \times 66^2}{2}$$

$P_{out} = 28314W = 28.314kW$

ii) At this point Density = 0 $v = 0$

$$P = \rho Q g z = 1000 \times 0.013 \times 9.8 \times 240$$
$$= 30576W$$
$$= 30.576kW$$

iii) Power loss in transmission $= (30.576 - 28.314)kW$
$$= 2.262kW$$

Head loss in pipeline;

$$h = \frac{\text{Power transmission loss}}{\rho g Q}$$
$$= \frac{2262}{1000 \times 9.81 \times 0.013}$$
$$= 17.73m$$

iv) Efficiency of the pipeline and nozzle $= \frac{\text{Power of jet}}{\text{Power of reservoir}} \times 100$

$$= \frac{28314}{30576} \times 100\%$$
$$= 92.6\%$$

5) Specific gravity of Oil = 0.89

$Z = 30,000cm = 300m$

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

Velocity of jet = 7m/sec

9) Section 1 diameter (D_1) = 300mm = 0.3m

Section 1 Area $(A_1) = \frac{\pi \times 0.3^2}{4} = 0.071 m^2$

Section 2 diameter (D_2) = 150mm = 0.15m

" 2 Area $(A_2) = \frac{\pi \times 0.15^2}{4} = 0.018 m^2$

Q = 40 liter/sec = $0.04 m^3/sec$; $Z_1 = 10m$, $Z_2 = 6m$, $P_1 = 400 kN/m^2 = 400 kPa$

$P_2 = ?$, $V_1 = \frac{Q}{A_1} = \frac{0.04}{0.071} = 0.563 m/s$

$V_2 = \frac{Q}{A_2} = \frac{0.04}{0.018} = 2.27 m/s$

Using bernoulli's equation: $\frac{P_1}{w} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + Z_2$

$= \frac{400}{9.81} + \frac{0.563^2}{2 \times 9.81} + 10 = \frac{P_2}{9.81} + \frac{2.27^2}{2 \times 9.81} + 6$

$\frac{P_2}{9.81} = 44.53$

$P_2 = 9.81 \times 44.53$

$= 436.82 kN/m^2$

10) Hvis = 12m below sea level, y = 170mm = 0.17m of mercury ; Sp. gravity of Hg = 13.6

Sp. gravity of water = 1.026

$h = y\left(\frac{S_M}{S_0} - 1\right)$

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

$h = 2.08m$

∴ Velocity of Submarine = $\sqrt{2gh}$

$= \sqrt{2 \times 9.81 \times 2.08}$

$= 6.39 m/s.$

8) Throat diameter $= 0.076m$

Throat Area $= \frac{\pi \times (0.076)^2}{4}$

$= 4.54 \times 10^{-3} m^2$

Relative density $= 0.8$; Pipe diameter $= 0.152m$

Pipe Area $= 0.0181m^2$

Difference between Inlet and throat $= 0.914m$

$Cd = 0.97$

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

a) When $P_1 = P_2$ $\therefore h = 0$

$$\text{Discharge } (Q) = cd \times \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$$

and since $h = 0$ $\therefore Q = 0$

b) When $P_1 - P_2 = 15170$.

Density of liquid $= 0.8 \times 1000 = 800 kg/m^3$

~~$h = 15170$~~ $w = \rho g = 800 \times 9.81 = 7848 N/m^3$

$$h = \frac{15170}{7848}$$

$h = 1.933m + 0.914m$

$\therefore h = 2.847m$

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

$$Q = \frac{0.97 \times 0.0181 \times 4.54 \times 10^{-3}}{\sqrt{(0.0181)^2 - (4.54 \times 10^{-3})^2}} \times \sqrt{2 \times 9.81 \times 2.847}$$

$Q = 0.034 m^3/sec$

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

$= \frac{4797.1}{576239.4} \times 100$

$= 0.83\%$

6) Power = Pressure × flowrate

Pressure of water = $\rho g h$ = $1000 \times 9.81 \times 20$

= $196200 \, N/m^2$

Area = $\pi (0.05)^2 = 7.854 \times 10^{-3} \, N/m^2$

Volume = $7.854 \times 10^{-3} \times 20 = 0.1571 \, m^3$

Q = flow rate = $\frac{0.1571}{60}$ = $2.62 \, m^3/sec$

Power = 196200×2.62

= 514044W = 514.044Kw

7) Inlet diameter (D_1) = 0.3m ⇒ $\frac{\pi \times 0.3^2}{4} = 0.071 \, m^2$

Throat diameter (D_2) = 0.2m ⇒ $\frac{\pi \times 0.2^2}{4} = 0.031 \, m^2$

$C_D = 0.96$, $h = 0.06m$, specific gravity of water = 1

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

Specific gravity of gas = $\frac{19.62 \div 1000}{9.81} = 0.002$

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

$$Q = 0.96 \times \frac{0.071 \times 0.031}{\sqrt{(0.071)^2 - (0.031)^2}} \times \sqrt{2 \times 9.81 \times 0.06}$$

$Q = 0.0359 \, m^3/s$

Volume flowing = $0.0359 \, m^3$

i) Specific gravity = $\frac{\text{Specific weight of liquid}}{\text{Specific weight of water}}$

S.P of liquid = 0.89 × 9.81

= ~~8.7309 kN/m³~~ = 8730.9 N/m³

∴ density (ρ) = $\frac{8730.9}{9.81}$ = 890 kg/m³

$P = 0$

Power = $\left(PQ + \rho g z Q + \frac{\rho V^2 Q}{2}\right)$

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

= 4797.1 W = 4.7971 kW

ii) Power applied from reservoir

Power = $\left(PQ + \rho z g Q + \frac{\rho V^2 Q}{2}\right)$

Power = $\rho z g Q$

= 890 × 300 × 9.81 × 0.22

= 576239.4 Watt or 576.2394 kW

iii) Power loss in transmission = (576239.4 − 4797.1) W

= 571442.3 Watt

Head loss = $\frac{\text{Power loss in transmission}}{\rho g Q}$

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

= 297.5 m