OBI-OBUOHA ABIAMAMELA

MECHATRONICS ENGINEERING

18/ENG05/040

FLUID MECHANICS NUMBER1-10

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Question 1.

$Q = 10dm^3/min$

$= (10 \times 10^{-3})m^3 / 60 seconds$

$\therefore \frac{10 \times 10^{-3}}{60} m^3/s$

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

$\delta p = 12 bar = 12 \times 10^5 N/m^2$

Speed of rotation = 1500 rev/min

$= 1500 rev / 60 seconds$

$= \frac{1500}{60} rev/sec$

$= 25 rev/sec$

Nominal displacement = $10cm^3/rev$

$= (10 \times 10^{-6})m^3 / rev$

$= 1 \times 10^{-5} m^3/rev$

Torque input = 12.5Nm

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

NB: Ideal flow rate = speed of rotation × nominal disp

$$\left(\frac{rev}{sec}\right) \times \left(\frac{m^3}{rev}\right)$$

$$\Rightarrow m^3/sec \Rightarrow Q$$

∴ Ideal flow rate = $25 \frac{rev}{sec} \times 10^{-5} \frac{m^3}{rev}$

$= 25 \times 10^{-5}\ m^3/sec$

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

(I)

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

$= \underline{\underline{66.8\%}}$

(II) Fluid Power = $Q \times \delta P$

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

$= \underline{\underline{200.4\ Watts}}$

(III) Shaft Power = Torque input × angular speed

Angular speed = rad/sec

Using speed of rotation which is 25 rev/sec

$\Rightarrow \frac{25\ revs}{1\ sec} = \frac{25 \times 2 \times \pi}{1\ sec} = 50\pi\ rad/sec$

$= 157.08\ rad/sec$

∴ Shaft power = $12.5\ Nm \times 157.08 \frac{rad}{sec}$

$= \underline{\underline{1963.495\ Watts}}$

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

$= \frac{200.4}{1963.495} \times 100\%$

$= 10.206\%$

$\simeq 10\%$

QUESTION 2.

Question 2

Q. 2 $35\, dm^3 / min$

$= (35 \times 10^{-3})\, m^3 / 60$ seconds

$= \frac{35 \times 10^{-3}}{60}\, m^3/s$

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

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

Overall efficiency = 87%

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

fluid Power = $Q \times \delta P = (5.83 \times 10^{-4}) \times (100 \times 10^5)$

$\Rightarrow 5830$ watts

$\therefore \frac{5830}{x} \times 100 = 87$

$$\frac{87x}{87} = \frac{5830 \times 100}{87}$$

$$x = (5830 \times 100) / 87$$

$$x = 6701.149425$$

∴ Shaft power = 6701.1 Watts.

QUESTION 3.

Question 3.

Nominal displacement = $50 cm^3/rev$

δP = 100bar = $100 \times 10^5 N/m^2$

Shaft power = 15kW = 15000 Watts

Overall Efficiency = ?

Volumetric Efficiency = ?

Actual Flow Rate (Q) = $35 dm^3/min$

Speed of rotation = 850 rev/min

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

fluid power = Q × δP

Q = 35 dm³/min = $(35\times10^{-3})\,m^3$ / 60 seconds

$= \frac{35\times10^{-3}}{60}\ m^3/s$

$= 5.83\times10^{-4}\ m^3/s$

∴ fluid power = $(5.83\times10^{-4})\times(100\times10^{5})$

= 5830

Overall efficiency = $\frac{5830}{15000}\times100$

=> 38.9 %

Volumetric efficiency = $\frac{\text{Actual flow rate}}{\text{ideal flow rate}}\times100$

Ideal flow Rate = Nominal displacement × Speed of Rotation

Nominal displacement = 50 cm³/rev

$= (50\times10^{-6})\,m^3/rev$

Speed of Rotation = 850 rev/min

$= \frac{850}{60}$ rev/s

= 14.16 rev/s

∴ Ideal flow Rate = ~~$(5.83 \times 10^{-4}) \times ($~~

$$\Rightarrow (50 \times 10^{-6}) \times (14.16)$$

$$= 7.083 \times 10^{-4}\ m^3/s$$

Volumetric efficiency $= \dfrac{5.83 \times 10^{-4}}{7.083 \times 10^{-4}} \times 100$

$$= 82.31\ \%$$

QUESTION 4.

Question 4.

$Z_1 = 24000\,cm \simeq 240\,m$

$Q = 13\,l/s = (13 \times 10^{-3})\,m^3/s$

$Z_2 = 0\,m$

$V_2 = 66\,m/s$

(I) Power of jet

Note power $= \rho g Q H$

Jet is at at atmospheric pressure

$\therefore P = 0$ and $Z = 0$

Density of water = 1000 kg/m³

Power = $\rho g Q H$

where H = Energy head

$$H = z_2 + \frac{P}{\rho g} + \frac{v^2}{2g}$$

$$\therefore H = 0 + \frac{0}{1000 \times 9.81} + \frac{(66)^2}{2 \times 9.81}$$

$$H = 0 + 0 + \frac{4356}{19.62}$$

$$H = 222.018 \text{ Joules}$$

$\therefore \rho g Q H$

$= 1000 \times 9.81 \times (13 \times 10^{-3}) \times 222.018$

$= 28314$ Watts

(II) Power supplied from reservoir

$P = \rho g Q H$

$\rho = 1000 \text{ kg/m}^3$, $g = 9.81$, $Q = 13 \times 10^{-3} \text{ m}^3/s$,

$$H = z_1 + \frac{P}{\rho g} + \frac{v^2}{2g}$$

where $z_1 = 240$ m

$v_1 = 0$ m/s

$P = 0$ (atmospheric pressure)

$$\Rightarrow 240 + \frac{0}{\rho g} + \frac{0^2}{2g} \Rightarrow 240 \text{ Joules}$$

∴ Power = $\rho g Q H$

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

$= 30607.2$ Joules/sec

$= 30607.2$ Watts

(iii) Head used to overcome losses

= Power loss / $\rho g Q$

Power loss = Power of reservoir − Power of Jet

$= 30607.2 - 28314$

$= 2293.2$ Watts

∴ Head = $2293.2 / (9.81 \times 1000 \times 13 \times 10^{-3})$

Head = 17.982 m

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

$= 28314 / 30607.2 \times 100$

$= 92.5076526\ \%$

Question 5.

$Z_1 = 30{,}000\ cm = 300 m$

$Q_1 = 220$ litres/s $= (220 \times 10^{-3})\ m^3/s$

$V_2 = 7 m/s$

Power of Jet $= \rho g Q H$

where $\rho = 0.89 \times 1000 = 890 kg/m^3$

$g = 9.81 m/s^2$

$Q = (220 \times 10^{-3})\ m^3/s$

$$H = Z_2 + \frac{P}{\rho g} + \frac{v^2}{2g}$$

$$H = 0 + \frac{0}{\rho g} + \frac{(7)^2}{2 \times 9.81}$$

$H = 49/19.62 = 2.497$ J

$\therefore$ Power $= 890 \times 9.81 \times 220 \times 10^{-3} \times 2.497$

$= 4797.1$ Watts

(ii) Power supplied from reservoir

$$H = Z_1 + \frac{P}{\rho g} + \frac{v^2}{2g} = 300 + \frac{0}{\rho g} + \frac{0}{2g}$$

$= 300$ J

∴ Power = $890 \times 9.81 \times 220 \times 10^{-3} \times 300$

$= 576239.4$

(iii) Head used to overcome the loss

$= \text{Power Loss} / \rho g Q$

$= (576239.4 - 4797.1) / 1000 \times 9.81 \times 220 \times 10^{-3}$

$= 571442.3 / 2158.2$

$\Rightarrow 264.7772681$

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

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

$= 0.83248386\ \%$

Question 6

$h = 20m$
$d = 10cm = (10\times10^{-2})m$
$A = \pi d^2/4 = \pi(10\times10^{-2})^2/4$

$$A = 7.85398\times10^{-3}\ m^2$$

According to $v^2 = u^2 + 2as$

Final velocity $v = 0$, u = unknown, $a = -9.81$, $s = 20m$

$\therefore 0^2 = u^2 + 2(-9.81)(20)$
$u^2 = 2(9.81)(20)$
$u^2 = 40\times9.81$
$u^2 = 392.4$
$u = 19.81\ m/s$

$Q = V.A. = 19.81\times7.85398\times10^{-3}$
$\Rightarrow 0.15558\ m^3/s$

$Q = \frac{V}{t} = 0.15558\ m^3/s$

multiply through by $\rho = \frac{\rho v}{t} = m/t$

$\therefore \frac{m}{t} = 0.15558\times1000\ kg/s$
$= 155.58\ kg/s$

Note:. amount of water (Kg) being ejected per second has been found.

∴ Energy required to take mass 155.58 kg every second through a height of 20m

is mgh

$= (155.58) \times 9.81 \times 20$

$= 30524.796\ J$

∴ 30524.796 J is needed every second

∴ 30524.796 J/s

∴ Power = 30524.796 Watts

QUESTION 7.

Question 7

Inlet diameter = 0.3m

Throat diameter = 0.2m

$C_d = 0.96$

S.w of gas = $19.62 N/m^3$

Pressure difference = 0.06m

$d_1 = 0.3m$

$A_1 = \pi d^2/4 = \pi(0.3)^2/4 = 0.0707 m^2$

$d_2 = 0.2m$

$A_2 = \pi d^2/4 = \pi(0.2)^2/4 = 0.0314 m^2$

N/B: $Q_{actual} = C_d A_1 . A_2 \sqrt{2gh} / \sqrt{A_1^2 - A_2^2}$

~~$\frac{P_1 - P_2}{w} = 0.06m = h$~~

$h = 0.06 \times \left(\frac{S_w}{S_g} - 1\right)$

Note $\rho_w = 1000 kg/m^3$

$\rho_g = 19.62 N/m^3 / 9.81 = 2 kg/m^3$

Note: No need to divide both by 1000 because it's a ratio.

$$h = 0.06\left(\frac{1000}{2} - 1\right)$$

$$= 0.06 \times (500 - 1)$$

$$= 0.06 \times 499$$

$$= 29.94\,m$$

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

$$Q = \frac{0.96 \times 0.0707 \times 0.0314 \times \sqrt{2 \times 9.81 \times 29.94}}{\sqrt{(0.0707)^2 - (0.0314)^2}}$$

$$Q = \frac{0.05165}{\sqrt{4.01253 \times 10^{-3}}}$$

$$Q = \frac{0.05165}{0.0633}$$

$$Q = 0.8153821121$$

$$\simeq 0.815\ m^3/s$$

QUESTION 8.

Question 8.

$d_1 = 0.152m$
$d_2 = 0.076m$

$S_L = 0.8$

~~h~~ $y = 0.914m = h$

$C_d = 0.97$

$A_1 = \pi d^2 / 4 = \pi (0.152)^2 / 4 = 0.01815 m^2$

$A_2 = \pi d^2 / 4 = \pi (0.076)^2 / 4 = 4.536 \times 10^{-3} m^2$

$h = 0.914m$

$Q = C_d \cdot A_1 \cdot A_2 \sqrt{2gh} / \sqrt{A_1^2 - A_2^2}$

$$Q = \frac{0.97 \times 0.01815 \times 4.536 \times 10^{-3} \times \sqrt{2 \times 9.81 \times 0.914}}{\sqrt{(0.01815)^2 - (4.53 \times 10^{-3})^2}}$$

$= 3.38177 \times 10^{-4} / 0.017576$

$\Rightarrow 0.01924 \ m^3/s$

(II) When inlet guage reads 15170 N/m² higher

$$h = \frac{P_1}{w} - \frac{P_2}{w} = \frac{P_1 - P_2}{w} = \frac{15170\ N/m^2}{800 \times 9.81}$$

$$= 15170 / 7848 = 1.933\ m$$

$$\therefore Q = Cd \cdot A_1 \times A_2 \times \sqrt{2gh} \Big/ \sqrt{A_1^2 - A_2^2}$$

$$Q = 0.97 \times 0.01815 \times 4.536 \times 10^{-3} \times \sqrt{2 \times 9.81 \times 1.933} \Big/ \sqrt{(0.01815)^2 - (4.536 \times 10^{-3})^2}$$

$$Q = 0.02798\ m^3/s$$

QUESTION 9.

Question 9.

$d_1 = 300mm$

$= 0.3m$

$A_1 = \pi d^2 / 4 = \pi (0.3)^2 / 4 = 0.0707 \, m^2$

$d_2 = 150mm$

$= 0.15m$

$A_2 = \pi d^2 / 4 = \pi (0.15)^2 / 4 = 0.0177 \, m^2$

$Q = 40 L/s$

$= (40 \times 10^{-3}) m^3/s$

$Z_1 = 10m$

$Z_2 = 6m$

$P_1 = ?$

$P_2 = 400 kN/m^2 = 400{,}000 N/m^2$

$Q = VA$

$V_1 A_1 = Q \therefore (V_1)(0.0707) = (40 \times 10^{-3})$

$V_1 = (40 \times 10^{-3}) / 0.0707$

$V_1 = 0.5658 m/s$

$Q = V_2 A_2$

$V_2 (0.0177) = 40 \times 10^{-3}$

$V_2 = (40 \times 10^{-3}) / 0.0177$

$V_2 = 2.2599 \, m/s$

$$Z_1 + \frac{P_1}{w} + \frac{v^2}{2g} = Z_2 + \frac{P_2}{w} + \frac{v_2^2}{2g}$$

$$\Rightarrow Z_1 + \frac{P_1}{\rho g} + \frac{v_1^2}{2g} = Z_2 + \frac{P_2}{\rho g} + \frac{v_2^2}{2g}$$

$$10 + \frac{400000}{9.81 \times 1000} + \frac{(0.5658)^2}{2(9.81)} = 6 + \frac{P_2}{9.81 \times 1000} + \frac{(2.2599)^2}{2 \times 9.81}$$

$$50.79 = \frac{P_2}{9.81 \times 1000} + 6.260303$$

$$\frac{P_2}{9.81 \times 1000} = 50.79 - 6.26$$

$P_2 = (9.81 \times 1000)(44.53)$

$P_2 = 436836.326 \, N/m^2$

$P_2 = 436.836 \, KN/m^2$

Question 10.

Difference in mercury level = 170 mm

$\therefore$ 170 mm = 0.17 m

S_m = 13.6

S_s = 1.026

$V = \sqrt{2gh}$

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

$h = 12.255 \times 0.17$

$h = 2.083$ m.

$\therefore V = \sqrt{2 \times 9.81 \times 2.083}$

$V = \sqrt{40.877}$

$V = 6.39$ m/s.