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Question 1

A Pump delivers at the rate of 10dm³/min with a pressure change of 12bar. The speed of rotation is 1500 revolution/min while the norminal displacement is given as 10cm³/rev. If the torque Input is 12.5Nm compute
(i) volumetric efficiency (ii) fluid power (iii) shaft Power
(iv) Overall Efficiency

Solution

Parameters

$1000\,dm^3 \rightarrow 1m^3$

$60s \rightarrow 1min$

$Q_{act} = 10\,dm^3/min$ to $\frac{M^3}{s}$

$P = 12bar$

Speed = 1500rev/min

normmal displacement = $10\,cm^3/rev$

Torque = 12.5Nm

Therefore $Q = \frac{10dm^3}{Min} \times \frac{1m^3}{1000dm^3} \times \frac{1Min}{60s} = 1.67 \times 10^{-4}\, m^3/s$

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

$Speed = 1500\, rev/min \times \frac{1min}{60} = 25\, rev/s$

$Norminal\ displacement = \frac{10cm^3}{rev}$

$\frac{10cm^3}{rev} \times \frac{1m^3}{(100cm)^3} = 1 \times 10^{-5}\, m^3/rev$

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

Q_{ideal} = normind displacement × speed

$Q_{ideal} = 1 \times 10^{-5} \frac{m^3}{rev} \times 25 \frac{rev}{s} = 2.5 \times 10^{-4} \frac{m^3}{s}$

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

$$\text{Volumetric Efficiency} = 66.8\%$$

11) $$\text{Fluid Power} = \text{Actual flow rate} \times \text{Pressure}$$

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

$$= 200.4 \text{ watt}$$

14) $$\text{Shaft power} = \tau \times \text{angular speed}$$

$$\omega = \frac{\theta}{t} = \frac{rad}{s}$$

$$\text{Speed} = 25 \frac{rev}{s}$$

$$2\pi \, rad \longrightarrow 1 \, rev$$

$$\text{Speed} = 25 \frac{rev}{s} \times \frac{2\pi rad}{1 rev} = 50\pi \, rad/s$$

$$\text{Shaft power} = 12.5 Nm \times 50\pi \frac{rad}{s}$$

$$= 625\pi \text{ watt}$$

$$\text{Shaft power} = 1963.495 \text{ watt}$$

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

$$= \frac{200.4}{1963.495} \times 100\% = 10.2\%$$

Question 2

A Pump delivers $35 dm^3/min$ with a pressure change of 100bar. If the overall efficiency is 87%. Calculate the Shaft power

Solution

Parameter

$$Q_{act} = \frac{35 dm^3}{min} \qquad 1000 dm^3 \rightarrow 1 m^3 \qquad 60 s \rightarrow 1 min$$

$$Q_{act} = \frac{35 dm^3}{min} \times \frac{1 m^3}{1000 dm^3} \times \frac{1 min}{60 s}$$

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

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

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

$$Fluid\ Power = Q_{act} \times pressure$$

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

$$= 5830\ watt$$

$\therefore$

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

$$0.87 = \frac{5830}{Shaft\ Power}$$

$$Shaft\ Power = \frac{5830}{0.87} = 6701.149\ watts$$

Question 3

A Pump has a normminal displacement of $50 cm^3/rev$ and a Pressure rise of 100bar. If the shaft power is 15kw calculate the overall efficiency and volumetric efficiency.

$Q_{act} = 35 dm^3/min$ Speed of rotation = 850rpm

Solution

Parameters

$Q_{act} = 35 dm^3/min$, Speed = 850 rev/min

Normminal displacement = $50 cm^3/rev$ Pressure = 100 bar

Shaft power = 15kw

$1000 dm^3 \rightarrow 1 m^3$

$60 s \rightarrow 1 min$

$$Q_{act} = \frac{35 dm^3}{min} \times \frac{1 m^3}{1000 dm^3} \times \frac{1 min}{60 s}$$

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

$$Speed = \frac{850 rev}{min} \times \frac{1 min}{60 s} = 14.167 \frac{rev}{s}$$

$$\text{Norminal displacement} = \frac{50 cm^3}{rev} \times \frac{1 m^3}{(100)^3 cm^3} = 5 \times 10^{-5} m^3/rev$$

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

$$\text{Shaft power} = 15kw = 15 \times 10^3 \text{ watt}$$

i) $$\text{overall efficiency} = \frac{\text{fluid power}}{\text{Shaft Power}} \times 100\%$$

overall efficiency ∴ to find fand fluid power

$$\text{Fluid power} = Q_{act} \times Pressure$$

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

$$= 5830 \text{ watt}$$

$$\text{Overall efficiency} = \frac{5830}{15 \times 10^3} \times 100\% = 38.87\%$$

Overall efficiency = 38.87 %

ii) Volumetric efficiency $= \dfrac{\text{actual flow rate}}{\text{Ideal flow rate}} \times 100\%$

Q_{ideal} = nominal displacement × speed

$$Q_{ideal} = 5 \times 10^{-5} \times 14.167$$

$$= 7.0835 \times 10^{-4}\ m^3/s$$

Volumetric efficiency $= \dfrac{5.83 \times 10^{-4}}{7.0835 \times 10^{-4}} \times 100\%$

Volumetric efficiency $= 82.3\%$

Question 4

Water is drawn from a reservoir in which the water level is 24000 cm above the datum at the rate of 13 L/s the outlet of the pipe is at datum level and is fitted a nozzle to produce a high speed jet in order to drive a turbine of Pelton wheel type. if the velocity of jet is 66 m/s. Calculate

(i) Power of jet (ii) Power supplied from reservoir

(iii) Head used to overcome losses

(iv) Efficiency of the pipeline and nozzle in transmitting operation

Solution

$Z = 24000\,cm$, $Q_{act} = 13\,L/s$, velocity $= 66\,m/s$

$1000\,L \rightarrow 1\,m^3$

$100\,cm \rightarrow 1\,m$

$$Z = 24000\,cm \times \frac{1\,m}{100\,cm} = 240\,m$$

$$Q_{act} = \frac{13\,L}{s} \times \frac{1\,m^3}{1000\,L} = 0.013\,\frac{m^3}{s}$$

i) Power of Jet $[z = 0 \text{ and } P = 0]$

$$P = \rho \times g \times Q \times H$$

$$P = 1000 \times 9.81 \times 0.013 \times \left[\frac{0}{w} + \frac{66^2}{2 \times 9.81} + 0\right]$$

$$P = 127.53 \times 222.018$$

$$P = 28313.96 \text{ watt}$$

$$P \simeq 28314 \text{ watt} \quad \therefore P = 28.314\,kW$$

ii) Power Supplied from the reservoir $[P = 0 \text{ and } V = 0]$

$$P = \rho \times g \times Q \times H$$

$$P = 1000 \times 9.81 \times 0.013 \times \left[\frac{0}{w} + \frac{0^2}{2g} + 240\right]$$

$$P = 127.53 \times 240 = 30607.2 \text{ watt}$$

$$P = 30.6072\,kw$$

iii) Head used to overcome loss

Power loss = Power of reservoir − Power of Jet

Power loss = 30607.2 − 28314

= 2293.2 watt

$P = \rho \times g \times Q \times H$

$$H_L = \frac{P}{\rho \times g \times Q}$$

$$H_L = \frac{2293.2}{1000 \times 9.81 \times 0.013}$$

$H_L = 17.982\,m$

Head used to overcome loss = 17.982 m

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

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

= 92.51 %

Question 5;

Oil of specific gravity 0.89 is drawn from a reservoir in which the oil is 30,000 cm above the datum at the rate 220 L/s. If the velocity of jet is 7m/s

Calculate (i) Power of Jet (ii) Power supplied from reservoir

(iii) Head used to overcome losses

(iv) Efficiency of the Pipeline and nozzle in transmitting operation.

Solution

Parameters

S.G of oil = 0.89

$Z = 30{,}000\ cm$

$Q_{act} = 220\ L/s$, Velocity = 7 m/s

1000L → 1m³

100cm → 1m

$$Z = 30{,}000\ cm \times \frac{1m}{100\ cm} = 300m$$

$$Q_{act} = 220\frac{L}{s} \times \frac{1m^3}{1000} = 0.22\ m^3/s$$

$$S.G = \frac{\text{density of substance}}{\text{density of water}}$$

$$0.89 = \frac{\rho \text{ of oil}}{1000}$$

$$\rho_{oil} = 0.89 \times 1000 = 890\ kg/m^3$$

i) Power of Jet $[Z = 0,\ P = 0]$

$$P = \rho \times g \times Q \times H$$

$$P = 890 \times 9.81 \times 0.22 \times \left[\frac{0}{w} + \frac{7^2}{2 \times 9.81} + 0\right]$$

$$P = 1920.798 \times 2.497$$

$$P = 4797.1 \text{ watt}$$

ii) Power supplied from the reservoir [P = 0, V = 0]

$P = \rho \times g \times Q \times H$

$P = 890 \times 9.81 \times 0.22 \times \left[\frac{0}{w} + \frac{0^2}{2g} + 300\right]$

$P = 576239.4$ watt

iii) Head used to overcome losses

Power loss = 576239.4 − 4797.1 watt

= 571442.3 watt

$P = \rho \times g \times Q \times H$

$H = \frac{P}{\rho \times g \times Q} = \frac{571442.3}{890 \times 9.81 \times 0.22}$

$H = 297.5m$

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

= ~~28314~~ ~~$\frac{4797.1}{571442.3} \times 100\%$~~

Efficiency $= \frac{4797.1}{576239.4} \times 100\% = 0.832\%$

$= 0.832\%$

Question 6

A fountain sends a stream of water 20m up into the air. If the base of the stream is 10cm in diameter, what power is required to send the water to this hight

Solution

Parameters

$Z = 20m$

$d = 10cm = 0.1m$

$P = ??$

$P = \rho \times g \times Q \times H$

$Q = AV$

$A = \frac{\pi d^2}{4} = \frac{\pi \times 0.1^2}{4} = 7.85 \times 10^{-3} m^2$

$v^2 = u^2 + 2gs$

~~$v^2 = u^2 + 2gs$~~ $\therefore v^2 = u^2 - 2gs$

$V = 0$ at max height

$0^2 = u^2 - 2gs$

$u^2 = 2gs \therefore u = \sqrt{2gs}$

$u = \sqrt{2 \times 9.81 \times 20}$

Velocity $= 19.81 m/s$

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

$Q = 0.156 m^3/s$

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

power $= 30607.2$ watt

Question 7; A venturimeter with an entrance diameter of 0.3m and a throat diameter of 0.2m is used to measure the volume of gas flowing through a pipe. The discharge coefficient of the meter is 0.96. Assuming the specific weight of the gas to be constant at 19.62 N/m³, calculate the volume flowing when the pressure difference between the entrance and the throat is measured as 0.06m on a water U-tube manometer.

Solution

Parameters

$d_1 = 0.3m$, $d_2 = 0.2m$, $C_d = 0.96$

S.W of gas = 19.62 N/m3

Pressure difference = 0.06m on a water U-tube manometer

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

Specific weight = density × acceleration due to gravity

$$19.62 = \rho_{gas} \times 9.81$$

$$\rho_{gas} = \frac{19.62}{9.81} = 2 \, kg/m^3$$

$$S.G \text{ of gas} = \frac{2}{1000} = 2 \times 10^{-3}$$

$$S.G \text{ of water} = \frac{1000}{1000} = 1$$

$$H_{gas} = \left(\frac{S.G_{H_2O}}{S.G_{gas}} - 1\right) \times y$$

$$H_{gas} = \left(\frac{1}{2 \times 10^{-3}} - 1\right) \times 0.06$$

$$H_{gas} = 499 \times 0.06$$

$$H_{gas} = 29.94 \text{ m of gas}$$

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

$$A_1 = \frac{\pi d_1^2}{4} = \frac{\pi \times 0.3^2}{4} = 0.0707 m^2$$

$$A_2 = \frac{\pi d_2^2}{4} = \frac{\pi \times 0.2^2}{4} = 0.0314 m^2$$

$$Q_{act} = 0.96 \times \frac{0.0707 \times 0.0314}{\sqrt{0.0707^2 - 0.0314^2}} \times \sqrt{2 \times 9.81 \times 29.94}$$

$$Q_{act} = 0.96 \times 0.8494$$

$$Q_{act} = 0.815 m^3/s$$

Question 8

A Venturimeter of throat diameter 0.076m is fitted in a 0.152m diameter vertical pipe in which liquid of relative density 0.8 flows downwards. Pressure gauges are fitted to the inlet and to the throat sections. The throat being 0.914m below the inlet; Taking the coefficient of the meter as 0.97 Find the discharge

a) when the pressure gauges read the same

b) when the inlet gauge reads 15170 N/m² higher than the throat gauge.

Solution

Parameters

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

relative density of liquid = 0.8

height difference between the two inlet = 0.914m

$C_d = 0.97$

a) when pressure gauge reads the same

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

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

Where $P_1 = P_2$

$h = (z_1 - z_2) = 0.914m$

$$A_1 = \frac{\pi d_1^2}{4} = \frac{\pi \times 0.152^2}{4}$$

Qact = ~~0.9~~

$A_1 = 0.0181m^2$

$$A_2 = \frac{\pi d_2^2}{4} = \frac{\pi \times 0.076^2}{4} = 4.536 \times 10^{-3} m^2$$

$$Q_{act} = 0.97 \times \frac{0.0181 \times 4.536 \times 10^{-3}}{\sqrt{0.0181^2 - (4.536 \times 10^{-3})^2}} \times \sqrt{2 \times 9.81 \times 0.914}$$

$Q_{act} = 0.019 m^3/s$

b) When the inlet gauge reads 15170 N/m² higher than the throat gauge

$$h = \left(\frac{P_1 - P_2}{w}\right) + (Z_1 - Z_2)$$

$P_1 = 15170 + P_2$

$P_1 - P_2 = 15170$

~~h = 15170~~

$S \cdot G = 0.8$

$$0.8 = \frac{\rho_L}{1000}$$

$\rho_L = 800 \ kg/m^3$

Specific weight $= 800 \times 9.81 = 7848 \ N/m^3$

$$\therefore h = \left(\frac{15170}{7848}\right) + 0.914$$

$h = 2.85 m$

$$Q_{act} = \frac{0.97 \times 0.0181 \times 4.536 \times 10^{-3} \times \sqrt{2 \times 9.81 \times 2.85}}{\sqrt{0.0181^2 - (4.536 \times 10^{-3})^2}}$$

$Q_{act} = 0.03399 \ m^3/s$

Question 9; The water is flowing through a tapering pipe having diameter 300mm and 150mm at section 1 and 2 respectively. The discharge through the pipe is 40Lit/sec. The section 1 is 10m above datum and Section 2 is 6m above datum. Find the intensity of pressure at Section 2, if that at section 1 is 400 kN/m²

Solution

Parameters-

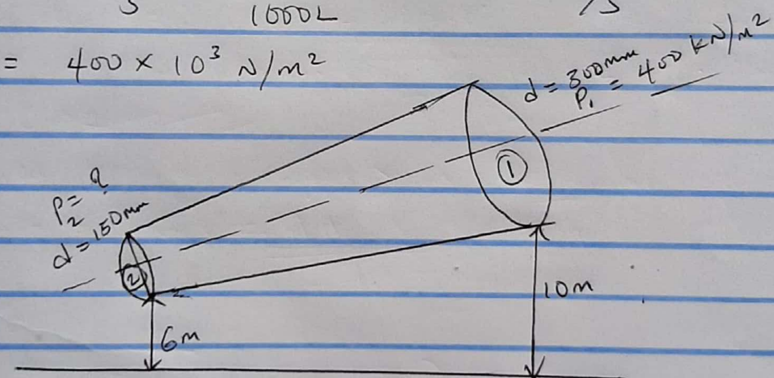
$d_1 = 300mm$, $d_2 = 150mm$, $Q = 40 L/s$

$Z_1 = 10m$ & $Z_2 = 6m$ $P_1 = 400kN/m^2$

$d_1 = 300mm = 0.3m$, $d_2 = 0.15m$

$$Q_2 = \frac{40L}{s} \times \frac{1m^3}{1000L} = 0.04 m^3/s$$

$P_1 = 400 \times 10^3 N/m^2$



$$A_1 = \frac{\pi d_1^2}{4} = \frac{\pi \times 0.3^2}{4} = 0.0707m^2$$

$$A_2 = \frac{\pi d_2^2}{4} = \frac{\pi \times 0.15^2}{4} = 0.0177m^2$$

$Q = A \times V$ = ~~Q_1 = 0.0707~~

$0.04 = 0.0177 \times V_2$

$$V_2 = \frac{0.04}{0.0177} = 2.2599 m/s \approx 2.26 m/s$$

$A_1 V_1 = A_2 V_2$

$$V_1 = \frac{A_2 V_2}{A_1} = \frac{0.04}{0.0707} = 0.57 m/s$$

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

$$\frac{400 \times 10^3}{1000 \times 9.81} + \frac{0.57^2}{2 \times 9.81} + 10 = \frac{P_2}{1000 \times 9.81} + \frac{2.26^2}{2 \times 9.81} + 6$$

$$50.791 = \frac{P_2}{9810} + 6.26$$

$$\frac{P_2}{9810} = 44.531$$

$$P_2 = 44.531 \times 9810$$

$$P_2 = 436849.11 \, Pa$$

$$P_2 = 436.85 \, KPa$$

Question 10; A submarine moves horizontally in sea and has its axis 15m below the surface of water. A pitot-tube properly placed just in front of the sub-marine and along its axis is connected to the two limbs of a U-tube containing mercury. The difference of mercury level is found to be 170mm. Find the speed of the sub-marine knowing the specific gravity of mercury is 13.6 and that of sea water is 1.026 with respect to fresh water.

Solution

$$V = \sqrt{2g\Delta h}$$

difference in mercury level = 170mm of mercury

= 0.17m of mercury

To find difference in mercury level in terms of sea water

$$\therefore h = \left(\frac{\text{Specific gravity of Mercury}}{\text{specific gravity of Sea water}} - 1\right) \times 0.17$$

$$h = \left(\frac{13.6}{1.026} - 1\right) \times 0.17 = 2.083\text{m of sea water}$$

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

$$V = \sqrt{40.86846}$$

$$V = 6.393\text{ m/s}$$

$\therefore$ Speed of submarine = 6.393 m/s