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DEPARTMENT: CHEMICAL ENGINEERING

FLUID MECHANICS ASSIGNMENT

1. **A pump delivers 10 dm^3 /min with a pressure rise of 12 bar. The speed of rotation is 1500 revolution / min and the nominal displacement is 10 cm^3 / rev. The Torque input is 12.5 N m. Calculate:**

i. **The volumetric efficiency.**

ii. **Fluid Power.**

iii. **The shaft power.**

iv. **The overall efficiency.**

SOLUTION

Idea flow rate = Nominal Displacement x Speed = 10 x 1500 = 15000 cm^3 /min = 15 dm^3 /min.

Volumetric efficiency = Actual Flow/Ideal Flow = 10/15 = 0.67 or 67%.

$Q = (10 \times 10^{-3}) /60\ m^3 /s = 16.7 \times 10^{-5} m^3 /s$

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

Fluid Power = $Q\ \Delta p = 16.7 \times 10^{-5} \times 12 \times 10^5 = 200.04$ Watts

Shaft Power = $2\pi NT/60 = 2\pi \times 1500 \times 12.5 /60 = 1963.5$ Nm

Overall Efficiency = F.P. /S.P. = 200.4/1963.5 = 0.0102 or 1.02%

2. **A pump Delivers 35 dm^3/ min with a pressure change of 100 bar. If the overall efficiency is 87 %. Calculate the shaft power.**

SOLUTION

$Q = (35 \times 10^{-3}) / 60\ m^3 /s = 58.33 \times 10^{-5}\ m^3/s$

$\Delta P = 100 \times 10^5$ N/m^2

Fluid Power = Q × ΔP = $58.33 \times 10^{-5} \times 100 \times 10^5$ = 5833 Watts

Overall Efficiency = Fluid Power / Shaft Power

Shaft Power = Fluid Power / Overall Efficiency

= 5833 / 0.87 = 6704.6 Nm

3. **A pump has a nominal displacement of 50 cm^3/rev and a pressure rise of 100 bar. If the shaft power is 15 Kilowatts. Calculate the overall Efficiency and Volumetric Efficiency. Taking Actual Flow rate = 35 dm^3/ min and speed of rotation = 850 r p m.**

SOLUTION

Idea flow rate = Nominal Displacement x Speed = 50 x 850 = 42500 cm^3 /min = 42.5 dm^3 /min.

Volumetric efficiency = Actual Flow/Ideal Flow = 35/42.5 = 0.82 or 82%.
Q = (35×10^{-3}) /60 m^3 /s = 58.33×10^{-5}m^3 /s

$\Delta p = 100 \times 10^5$ N/m^2

Fluid Power = Q Δp =$58.33 \times 10^{-5} \times 100 \times 10^5$ = 5833 Watts

Shaft Power = 15kW = 15000Nm

Overall Efficiency = F.P. /S.P. = 5833/15000 = 0.389 or 38.9%

4. **Water is drawn from a reservoir in which the water level is 2,4000 cm above the datum at the rate of 13 liters/sec. 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/sec. 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

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 Litres/sec. If the velocity of jet is 7m|sec. 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

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

SOLUTION

Known data:

h=20m, d=10cm=0.10m

$\rightarrow A=(\pi/4)d^2=0.7854(0.10m)^2=7.854\times10^{-3}m^2$

$V_f=0$

Unknowns:

$\dot{W}$=?

The speed of the water at the upper end of the stream is zero. Then, the initial speed of the water is defined by the following expression:

$V^2_f=v^2_i-2gh$

$V_i=\sqrt{V^2_f+2gh}$

$V_i=\sqrt{0^2+2(9.8m/s2)*(20m)}$ =19.80m/s

The flow rate is equal to the speed through the area.

Q = v*A = (19.80m/s)*(7.854×10−3m2) = 0.1555m3/s

The hydraulic power required to drive the water to a height h is defined by the following expression:

$\dot{W}=\rho gQh=(1000kg/m^3)*(9.8m/s^2)*(0.1555m^3/s)*(20m)=30478kgm^2/s^3=30\times10^3W$

The power required is:

$\dot{W}=30\times10^3W$.

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/m^3, 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

$\rho_g g = 19.62\ N/m^3$

$C_d = 0.96$

$d_1 = 0.3m$

$d_2 = 0.2m$

Calculate; Q,

$$u_1 = Q/0.0707\ ,\quad u_2 = Q/0.0314$$

For the manometer;

$$P_1 + \rho_g gz = P_2 + \rho_g g*(z_2 - R_p) + \rho_w gR_p$$

$$P_1 - P_2 = 19.62*(z_2 - z_1) + 587.423$$

For the Venturimeter;

$$\frac{P_1}{\rho_g g z} + \frac{u_1^2}{2g} + z_1 = \frac{p_2}{\rho_g g} + \frac{u_2^2}{2g} + z_2$$

$P_1 - P_2 = 19.62*(z_2 - z_1) + 0.803u_2^2$

Combining (1) and (2);

$0.803u_2^2 = 587.423$

$u_{2ideal} = 27.047$ m / s

$Q_{ideal} = 27.047 \times \pi*(\frac{0.2}{2})^2 = 0.85$ m^3 / s

$Q = C_d * Q_{ideal} = 0.96 \times 0.85 = 0.816$ m^3 / s

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/m^2 higher than the throat gauge.

SOLUTION

$d_1 = 0.152$m, $d_2 = 0.076$m, $A_1 = 0.01814$m , $A_2 = 0.00454$m , $\rho = 800$kg / m^3

C

$_d = 0.97$

Apply Bernoulli;

$$\frac{P_1}{\rho_g g z} + \frac{u_1^2}{2g} + z_1 = \frac{p_2}{\rho_g g} + \frac{u_2^2}{2g} + z_2$$

a. $P_1 = P_2$

$$\frac{u_1^2}{2g} + z_1 = \frac{u_2^2}{2g} + z_2$$

By continuity;

$Q = u_1 A_1 = u_2 A_2$

$u_2 = u_1 \frac{A_1}{A_2} = u_1 4$

$\frac{u_1^2}{2g} + 0.914 = \frac{16u_1^2}{2g}$

$u_1 = \sqrt{\frac{0.914 \times 2 \times 9.81}{15}} = 1.0934$ m / s

$Q = C_d A_1 u_1$

$Q = 0.96 \times 0.01814 \times 1.0934 = 0.019\ m^3 / s$

b. $P_1 - P_2 = 15170$

$\frac{P_1 - P_2}{\rho g} = \frac{u_2^2 - u_1^2}{2g} - 0.914$

$\frac{P_1 - P_2}{\rho g} = \frac{Q^2(220.43^2 - 55.11^2)}{2g} - 0.914$

$55.8577 = Q^2 *(220.43^2 - 55.11^2)$

$Q = 0.035\ m^3 / s.$

9. The water is flowing through a tapering pipe having diameter 300mm and 150mm at section 1 & 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 400kN/m².

SOLUTION

At section 1;

D_1=300mm=0.3m, Area a_1= π/4*0.32 =0.0707m², Pressure p_1=400kN/m², Height of upper end above the datum, z_1=10m

At section 2;

D_2=150mm=0.15m, Area A_2= (π/4)*0.152 =0.01767m², Height of lower end above the datum, z_2=6m

Rate of flow (that is discharge) Q=40lit/sec=40/1000 (1litre = 1 m^3 /sec) =0.04m^3 /sec

Intensity of pressure at section 2, p_2

As the flow is continuous,

$$Q = A_1V_1 = A_2V_2 \text{ (Continuity equation)}$$

Therefore, $V_1 = Q/A_1$ = 0.04/0.0707 = 0.566m/sec and $V_2 = Q/A_2$ = 0.04/0.01767 = 2.264m/sec

Apply Bernoulli's equation at sections 1 & 2, We get, $p_1/w+v_1{}^2/2g+z_1=p_2/w+v_2{}^2/2g+z_2$

and $p_2/w = p_1/w + (v_1{}^2 - v_2{}^2/2g) + z_1-z_2$ = (400/9.81) + 1/ (2*9.81)*(0.5662 -2.2642)+(10-6) = 40.77- 0.245+4 (as w =ρ*g = 1000 x 9.81 N/m^3) = 44.525m = 9.81 kN/m^3

P_2 = 44.525 * w = 44.525 * 9.81 = 436.8 kN/m^2

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 submarine and along its axis is connected to the 2 limbs of U-tube containing mercury. The difference in mercury level is found to be 170mm. Find the speed of the submarine knowing that the specific gravity of mercury is 13.6 and that of sea water is 1.026 with respect of fresh water.

SOLUTION

$$V = c\sqrt{2}gr(\frac{spgr_m}{s} - 1)$$

$$X = \frac{170}{1000} = 0.17m$$

$$spgr_m = 13.6$$

$$Spgr_s = 1.026$$

$$C = 1$$

$$V = 1 * \sqrt{2} \times 9.81 \times 6.17 \times (\frac{13.6}{1.026} - 1)$$

$V = 6.4\ m / s$