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1. A pump delivers at the rate of 10 dm^3/min with a pressure change of 12 bar. The speed of rotation is 1500 rev/min while the nominal displacement is given as 10 cm^3/rev. If the torque input is 12.5 Nm. Compute
a. Volumetric efficiency
b. Fluid power
c. Shaft power
d. Overall efficiency.

Soln.

$Q_{actual} = 10 dm^3/min$

$\frac{10dm^3}{min} \times \frac{m^3}{1000dm^3} \times \frac{1min}{60sec}$

$= 1/6000 \, m^3 s^{-1}$

$\delta P = 12$ bar

$= 12 \times 10^5 Nm^{-2}$

Speed (S) = 1500 rev/min.

$\frac{1500 rev}{min} \times \frac{min}{60sec}$

$= 25 rev/sec$

Nominal Displacement $= 10cm^3/rev$

$\frac{10cm^3}{rev} \times \frac{m^3}{10^6 cm^3} = 10^{-5} m^3/rev$

Torque input (τ) = 12.5 Nm.

a. Volumetric effi. $= \frac{Q_a}{Q_i} \times 100$

Ideal flowrate (Q_i) = Nominal Displace. $\times$ Speed

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

$= 25 \times 10^{-5} m^3 sec^{-1}$

Vol. eff. $= \frac{1/6000}{25 \times 10^{-5}} \times 100$

$= 66.67\%$

b. Fluid Power $= Q_a \times \delta P$

$= 1/600 \times 12 \times 10^5$

$= 200W$

c. Shaft Power $= \tau \cdot \omega_c$

τ = torque, ω_c = angular speed

$\omega_c = 2\pi v$

$= 2\pi \times 25 = 50\pi \, rad/sec^{-1}$

$S.P = 12.5 \times 50\pi$

$= 625\pi = 1963.495W$

d. Overall eff. $= \frac{FP}{SP} \times 100$

$= \frac{200}{625\pi} \times 100$

$= 10.1859\%$

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

Soln

$Q = 35 dm^3/min$.

$= \frac{35 dm^3}{1min} \times \frac{1m^3}{10^3 dm^3} \times \frac{1min}{60sec}$

$= 7/12000 \cdot m^3 sec^{-1}$

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

$= 10^7 Nm^{-2}$.

Over. effic $= 87\%$.

Fluid Power $= Q_a \times \delta P$

$= \frac{7}{12000} \times 10^7$

$= \frac{17500}{3} W = 5833.3W$

$O.E = \frac{FP}{SP} \times 100$

$SP = \frac{FP \times 100}{O.E}$

$= \frac{\frac{17500}{3} \times 100}{87}$

$SP = 6704.98W$.

3. A pump has a nominal 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, Taking the actual flowrate $= 35 dm^3/min$ and speed of rotation $= 850$ rpm.

Soln.

$N.D = 50cm^3/rev$

$\frac{50cm^3}{1rev} \times \frac{1m^3}{10^6 cm^3}$

$= 50 \times 10^{-6} m^3 rev^{-1}$

$\delta P = 100bar = 10^7 Nm^{-2}$.

$S.P = 15KW = 15 \times 10^3 W$

$Q_a = \frac{35 dm^3}{1min} \times \frac{1m^3}{10^3 dm^3} \times \frac{1min}{60sec}$

$= 7/12000 \; m^3/sec$

$V(\text{speed}) = \frac{850rev}{1min} \times \frac{1min}{60sec}$

$= 85/6 \; rev/sec$.

Ideal $Q \, (Q_i) = ND \times V$

$= 50 \times 10^{-6} \times 85/6$

$= 17/24000 \cdot m^3 sec^{-1}$

Volumetric efficiency $=$

$\frac{Q_{actual}}{Q_{ideal}} \times 100$

$= 7/120$

$17/240$

$=$

Fluid Power $=$

$=$

Overall effic

$= \frac{1}{}$

$=$

4) Water is

in which

2,4000cm

at the rate

outlet of t

level and

produce a

to drive a

type. If th

to 66m/sec

a. Power of

b. Power

c. Head

d. Efficien

nozzle

$= \dfrac{7/12000}{17/24000} \times 100$

$= \dfrac{1400}{17} \simeq 82.35\%$

Fluid Power $= Q_a \times \delta P$

$= 7/12000 \times 10^7$

$= \dfrac{17500}{3} = 5833.3W$

Overall efficiency $= \dfrac{F.P}{S.P} \times 100$

$= \dfrac{17500/3}{15 \times 10^3} \times 100$

$= \dfrac{350}{9} \simeq 38.89\%$

4) Water is drawn from a reservoir in which the water level is 24,000cm above the datum line at the rate of 13 litres/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 the jet is 66m/sec. Calculate

a. Power of jet

b. Power supplied from reservoir

c. Head used to overcome losses

d. Efficiency of the pipeline and nozzle in transmitting operation.

Soln

$z = 24,000cm$

$24,000cm \times \dfrac{1m}{100cm}$

$= 240m$

$Q = 13$ litres/sec

$\dfrac{13\text{ litres}}{sec} \times \dfrac{1m^3}{1000\text{ litres}}$

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

Velocity of jet $(v) = 66ms^{-1}$

Since the jet issuing from the nozzle will be at atmospheric pressure and datum level, hence.

$P = 0$, $z = 0$

$\rho(water) = 1000 Kg/m^3$

a. $P = \rho g Q \left(\dfrac{P}{\rho g} + \dfrac{v^2}{2g} + z \right)$

as $P = 0$ and $z = 0$

$P = \dfrac{\rho g Q v^2}{2g} = \dfrac{\rho Q v^2}{2}$

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

$= 28314 W$

b. As the reservoir operates at atmospheric pressure so

$P = 0$, $v = 0$, $z = 240m$

$P = \rho g Q z$

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

$= 30607.2 W$

c. Power loss in transmission =
Power of reservoir − Power of jet
$= (30607.2 - 28314)\,kW$
$= 2293.2\,kW$

Recall that
$P = \rho g Q H$; $H = \frac{P}{\rho g Q}$

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

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

$= 17.982\,m$

5. Oil of specific gravity 0.89 is drawn from a reservoir in which the oil is 30,000cm above the datum at the rate of 220 litres/sec. If the velocity of jet is 7m/sec, Calculate
a. Power of the jet
b. Power supplied from the reservoir
c. Head used to overcome losses
d. Efficiency of the pipeline and nozzle in transmitting operation.

ATTENTION! ATTENTION! ATTENTION!

No 4d. → Please below is 4d.

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

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

$= 92.507\%$

Soln To No 5

a. Jet is at atmospheric pressure. So
$P = 0$, $v = 7ms^{-1}$, $z = 0$.

$P = \frac{\rho g Q v^2}{2g} = \frac{\rho Q v^2}{2}$

But Recall that.
$Q = 220 \times 10^{-3}\,m^3/sec$.

$S.g_{oil} = \frac{\rho_{oil}}{\rho_{water}}$

$\rho_{oil} = S.g \times \rho_{water}$
$= 0.89 \times 1000 = 890\,kg/m^3$

$P = \frac{890 \times 220 \times 10^{-3} \times 7^2}{2}$

$= 4797.1\,kW$.

b. Power from reservoir.
$P = 0$, $v = 0$, $z = 300m$ (30,000cm)

$P = \rho g Q z$
$= 890 \times 9.81 \times 220 \times 10^{-3} \times 300$
$= 576239.4\,kW$

c. Loss in power head.
$= (576239.4 - 4797.1)\,kW$
$= 571442.3\,kW$

$h = \frac{P}{\rho g h} = \frac{571442.3}{890 \times 9.81 \times 220 \times 10^{-3}}$

$= 297.50\,m$

d. E...

$= \frac{4797.}{5762}$

=

6. A water f...
of water ...
the base of ...
diameter, ...
and the wat...

Soln.
$h = 20m$.
$d = 10cm^3$
$\rho = 1000kg$...
$A = \frac{\pi d^2}{4}$ ...

$\simeq$

$v_f = 0$ (
$v_f^2 = v$...
$v_i = $ ...

$Q = VA$
$= \pi$...

$kW = $ ...

$\therefore$ Efficiency = $\frac{\text{Power of jet}}{\text{Power of}}$

$= \frac{47971}{5762394} \times 100$

$= 0.83\%$

6. A water 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 height?

Soln

$h = 20m$.

$d = 10cm^3 = 0.10m$

$\rho = 1000 kgm^{-3}$

$A = \frac{\pi d^2}{4} = \frac{\pi \times 0.10^2}{4} = \frac{\pi}{400}$

$\simeq 7.85 \times 10^{-3} m^2$.

$v_f = 0$ (momentarily at rest a maxi- heights)

$v_f^2 = v_i^2 - 2gh$.

$v_i = \sqrt{v_f^2 + 2gh}$

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

$= 19.80 ms^{-1}$

$Q = VA$

$= \pi/400 \times 19.80$.

$= 0.1556 m^3 sec^{-1}$

$W = \rho g Q z$

$= 1000 \times 9.81 \times 20 \times 0.1556$

$= 30524.8 W$

7. A venturimeter with an entrance diameter of 0.3m and throat diameter of 0.2m is used to measure the volume of gas flowing through a pipe. The discharge coefficient 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 entrance and the throat is measured as 0.06m on a water U-tube manometer.

Soln

$D_1 = 0.3m$

$D_2 = 0.2m$

$C_d = 0.96$

$\omega_g = 19.62 N/m^3$.

$Q = ?$

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

$h_g = \frac{h_w}{h_g} = \frac{\omega_g}{\omega_w}$.

$h_g = \frac{\omega_w}{\omega_g} \times h_w$.

$= \frac{9.81 \times 1000 N/m^3}{19.62 N/m^3} \times 0.06$

$= 30m$ of gas

$$Q = \frac{Cd \times \frac{\pi d_1^2}{4} \times \frac{\pi d_2^2}{4} \times \sqrt{2ghm}}{\sqrt{\left(\frac{\pi d_1^2}{4}\right)^2 - \left(\frac{\pi d_2^2}{4}\right)^2}}$$

$$= \frac{0.96 \times \frac{\pi^2}{16} \times 0.3^2 \times 0.2 \times \sqrt{2 \times 9.81 \times 30}}{\sqrt{\left(\frac{\pi \times 0.3^2}{4}\right)^2 - \left(\frac{\pi \times 0.2^2}{4}\right)^2}}$$

$= 0.816 m^3/s$

8. A venturimeter of throat diameter 0.076m is fitted into a 0.125m diameter vertical pipe in which liquid of relative density 0.8 flows downwards. Pressure guages are fitted to the inlet and to the throat section, the throat 0.914 below the inlet. Taking the coefficient of the meter as 0.97 find the discharge

a. when the pressure guage read the same.

B. when the inlet guage reads $15170 Nm^{-2}$ higher than the throat guage.

~~Data~~

$D_1 = 0.152m$

$D_2 = 0.076m$

$z_1 = 0.914m$

$z_2 = 0m$

$Cd = 0.97$

$$Q = \frac{Cd\, A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

For a vertical venturimeter

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

a. pressure guages read the same hence $P_1 = P_2$.

$$h = \left\{\frac{P_1 - P_2}{\omega} + \cancel{0.914}\, z_1 - z_2\right\}$$

$$R.D = \frac{\text{Specific } \cancel{\text{gravity}} \text{ weight of liquid}}{\text{Specific } \cancel{\text{gravity}} \text{ weight of water}}$$

$$0.8 = \frac{Sg_L}{9.81 \times 1000 N/m^2}.$$

$$\omega_L = 0.8 \times 9.81 \times 1000 N/m^2.$$

$$= 7848 N/m^2$$

$$h = \left\{\frac{0}{7848} + (0.914 - 0)\right\}.$$

$= 0.914 m$

$$Q = \frac{Cd \frac{\pi d_1^2}{4} \times \frac{\pi d_2^2}{4} \times \sqrt{2gh}}{\sqrt{\left(\frac{\pi d_1^2}{4}\right)^2 - \left(\frac{\pi d_2^2}{4}\right)^2}}.$$

$$= \frac{Cd \frac{\pi^2}{16} d_1^2 d_2^2 \sqrt{2gh}}{\sqrt{\left(\frac{\pi d_1^2}{4}\right)^2 - \left(\frac{\pi d_2^2}{4}\right)^2}}.$$

6. Pressure ... outlet ...

$h = \frac{P_1 - P_2}{\omega}$

$= \frac{15170}{7848}$

$= 2.$

$Q = Cd ...$

$= 0.97 \times \frac{\pi^2}{16}$ ...

$\sqrt{\left(\frac{\pi \times 0.15}{4}\right.}$ ...

$= 0.01$ ...

B. Pressure ... outlet $P_1 -$ ...

$h = \frac{P_1 -}{\omega}$

$= \frac{1517}{784}$ ...

$= 0$ ...

$Q = C_d$ ...

~~6. Pressure difference inlet and outlet $(= 15170\ N/m^2)$ $P_1 - P_2$~~

~~$h = \frac{P_1 - P_2}{w} + z_1 - z_2$~~

~~$= \frac{15170}{7848} + (0.914 - 0)$~~

~~$= 2.847\ m$~~

~~$Q = C_d \frac{\pi d_1^2}{4} \times \frac{\pi d_2^2}{4} \times \sqrt{2gh}$~~

ERROR

$$= \frac{0.97 \times \frac{\pi^2}{16} \times 0.152^2 \times 0.076^2 \times \sqrt{2 \times 9.81 \times 0.914}}{\sqrt{\left(\frac{\pi \times 0.1522}{4}\right)^2 - \left(\frac{\pi \times 0.076^2}{4}\right)^2}}$$

$= 0.0192\ m^3/s$

5. Pressure difference b/w inlet and outlet $P_1 - P_2 = 15170\ Nm^{-2}$.

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

$$= \frac{15170}{7848} + (0.914 - 0)$$

$= 2.847\ m$.

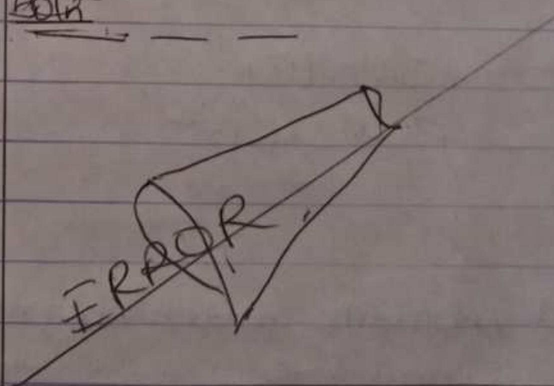
$$Q = \frac{C_d \frac{\pi^2}{16} d_1^2 d_2^2 \sqrt{2gh}}{\sqrt{\left(\frac{\pi d_1^2}{4}\right)^2 - \left(\frac{\pi d_2^2}{4}\right)^2}}$$

$$= \frac{0.97 \times \frac{\pi^2}{16} \times 0.152^2 \times 0.076^2 \times \sqrt{2 \times 9.81 \times 2.847}}{\sqrt{\left(\frac{\pi \times 0.152^2}{4}\right)^2 - \left(\frac{\pi \times 0.076^2}{4}\right)^2}}$$

$= 0.0339\ m^3/s$

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 40 litre/sec. The section 1 is 10m above the datum and section 2 is 6m above the datum. Find the intensity of the pressure at section 2 if that at section 1 is 400 kN/m².

Soln



$$Q = \frac{40\ \text{litre}}{\text{sec}} \times \frac{1\ m^3}{1000\ \text{litre}}$$

$= 0.04\ m^3 sec^{-1}$

$z_1 = 10m$ $z_2 = 6m$

$P_1 = 400 KN/m^2$ $P_2 = ?$

Recall that

$Q = A_1V_1 = A_2V_2$

$V_1 = \frac{Q}{A_1}$; $V_2 \frac{Q}{A_2}$.

$= \frac{0.04}{\frac{\pi(300\times10^{-3})^2}{4}}$; $\frac{0.04}{\frac{\pi(150\times10^{-3})^2}{4}}$

$V_1 = 0.566ms^{-1}$; $V_2 = 2.26ms$

According to Bernoulli's eqn.

$\frac{P_1}{w} + z_1 + \frac{v_1^2}{2g} = \frac{P_2}{w} + z_2 + \frac{v_2^2}{2g}$.

$P_2 = \left\{\frac{P_1}{w} + (z_1 - z_2) + \left(\frac{v_1^2 - v_2^2}{2g}\right)\right\} w$

$= \left\{\frac{400 KN/m^2}{9.81} + (10-6) + \left(\frac{0.566^2 - 2.26^2}{2(9.81)}\right)\right\}$

$\times 9.81 KN/m^3$.

$P_2 = 44.52 \times 9.81$

$= 436.83 KN/m^2$

10. A submarine moves horizontally in sea, and has it 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 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 to that of freshwater.

Soln

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

where

v = velocity Δh = diff in pressure head

y = manometric reading

$S_{Hg} = 13.6$

$S_w = 1.026$

$y = 170mm = 0.17m$

$h = y\left(\frac{S_{Hg}}{S_w} - 1\right)$

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

$= 2.08 m$

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

$= 6.39ms^{-1}$.