OTTIH NNAMBI PATRICK
18/ENG06/064
MECHANICAL ENGINEERING
ENG 214 (FLUID MECHANICS II)

(1) Given data

Flow rate (Q) = 10 dm³/min

Pressure change (ΔP) = 12 bar

Speed (N) = 1500 r.p.m, Normal Displacement = 10 cm³/rev; Torque input (T) = 12.5 N-m

Soln

flow rate = Normal displacement × speed

= 10 cm³/rev × 1500 rpm

= 15000 cm³/min = 15 dm³/min

i) Volumetric efficiency = $\frac{\text{Actual flow}}{\text{Ideal flow}}$

= 10/15 = 0.6667

ii) $Q = \frac{10 \times 10^{-3}}{60}$ m³/sec = 16.7×10^{-05} m³/s

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

Fluid Power = ΔP × Q = 16.7×10^{-3} m³/s × 12×10^5

= 200 Watts

Contd ①

iii) Shaft power $= \frac{2\pi N T}{60} = \frac{2\pi \times 1500 \times 12.6}{60}$

$= 1963.5$ watts

iv) Overall efficiency $= F.P/S.P$

$= 200$

② Q_A = Volume flow rate from pump

$= 35\ dm^3/min = 5.83 \times 10^{-4} m^3/s$

Pressure change $= \Delta p = 100$ bar

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

Overall efficiency :-

$\eta = \rho g Q H / P$

P = Shaft power

$\rho g H = \Delta P$

$P = \frac{5.83 \times 10^{-4} \times 100 \times 10^5}{0.87}$

P = Shaft Power = 6704.98 watts

P = 6.705 kW

(3) Given Nominal displacement of pump

$= 50\ cm^3/rev$

Speed = 850 rev/min

Q° = theoretical discharge

= Nominal displac × Speed of rotatio

$= 50 \times 850 = 42500\ cm^3/min$

$= 42.5\ dm^3/min$

Volumetric efficiency = $\frac{Q_{act}}{Q_{th}} = \frac{35\ dm^3/min}{42.5\ dm^3/min} \times 100$

$= 82.35\%$

Overall efficiency is given as:

$= \rho g Q H / P_{shaft}$

$\rho g H = \Delta P = 100\ bar = 100 \times 10^5\ N/m^2$

$Q_{actual} = 35\ dm^3/min = 35 \times 10^{-3}/60$

$= 5.83 \times 10^{-4}\ m^3 s^{-1}$

$P_{shaft} = 15\ kW = 15 \times 10^3$ watts

$= \frac{100 \times 10^5 \times 5.83 \times 10^{-4} \times 100}{15 \times 10^3}$

$\therefore \%_o = 38.88\%$

(b)

Power = $\frac{\text{Work done}}{\text{time}}$

u = velocity, ρ = density of water
(1000 kg $m^{-1}s^{-1}$)

$m = \rho \times v$

$v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 20}$

$= 19.7959 \ ms^{-1}$

$P = \frac{\rho \pi r^2 v g h}{t}$

Power $= 1000 \times \left(\frac{10 \times 10^{-2}}{2}\right) \times 19.79 \times 9.8 \times 20$

$= 1000 \times \pi \times 2.5 \times 10^{-3} \times 19.7959 \times 9.8 \times 20$

$= 30478.03 W$

(B) $A_1 = \frac{\pi}{4}(0.152)^2 = 0.01814 m^2$

$A_2 = \pi/4 (0.076)^2 = 0.00454 m$

$Cd = 0.97$

→ Applying Bernoulli's equation:

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

$\rho = 0.8 \times 1000 = 800 kg m^{-3}$

(i) $P_1 = P_2$, $\frac{V_1^2}{2g} + Z_1 = \frac{V^2}{2g} + Z_2$

By continuity,

$Q = V_1 A_1 = V_2 A_2$;

$V_2 = V_1 \cdot (A_1/A_2) = V_1 (4)$

$V_1 = \sqrt{\frac{0.914 \times 2 \times 9.81}{15}} = 1.093 ms^{-1}$

$Q = Cd A_1 V_1 = 0.97 \times (0.01814) \times (1.934)$

$Q = 0.0192 m^3 s^{-1}$

(ii) $P_1 - P_2 = 15170$

$= P_1 - P_2 / \rho g = \frac{V_2^2 - V_1^2}{2g} - 0.914$

$\frac{15170}{800 \times 9.81} = \frac{Q^2 (220.91^2 - 55.11^2)}{2 \times 9.8} - 0.914$

$\therefore Q = 0.035 m^3 s^{-1}$

(4) i) Power of Jet = $1/2\, \rho v^2 Q$

$= 1/2 \times 1000/9.81 \times 66^2 \times 0.13$

$= 28862 \times 9.81 = 283140W$

$= 283.14kW$

(ii) At the reservoir, pressure is atmospheric and velocity of surface is = 0, $\phi = 0$, $v = 0$

$P = \rho Q g z = \gamma Q z$

$= 1000 \times 0.13 \times 240$

$= 31200 kgms^{-1}$

$31200 \times 9.81 = 306072W$

$= 306.1 kW$

(iii) If H_1 = Total head at the reservoir

H_2 = total head at jet

h = head loss in transmission

$a - b = c$, power lost in transmission

$= \gamma Q h = 2338 kgms^{-1}$

Head loss in pipe $\Rightarrow h = \text{Power loss}/\gamma Q$

$h = 2338/1000 \times 0.13$

$= 17.98m$

$Q = 94.65 ft/day$

10.) $x = 170mm = 0.17m$

Sp. gr of Mercury = 13.6

Sp gr of Sea water = 1.026

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

$$= 2.0834 m$$

$$V = \sqrt{2gh}$$

$$= \sqrt{2 \times 9.81 \times 2.0834} = 6.393 ms^{-1}$$

$$= \frac{6.393 \times 60 \times 60}{1000} km/hr = 23.01 km/hr$$

$0.22 m^3 s^{-1}$

(5) $\rho = 890 \, kg/m^3$, $H = 300 \, m$, $Q = 220 \, L/s =$
$v = 7 \, ms^{-1}$

(1) Power of Jet $P = \frac{1}{2} \rho Q v^2 = \frac{1}{2} \times 890 \times 0.22 \times 7^2$
$P = 4797.1 \, W = 4.797 \, kW$.

(2) Power from reservoir $(P) = WQH$
$= 890 \times 9.81 \times 0.22 \times 300$
$= 576.239 \, kW$

(3) Power Supplied from reservoir $= \gamma QH$
$= 890 \times 0.22 \times 300 =$
$58740 \, kg \, m s^{-1}$

$\frac{1}{2} \rho v^2 Q = \frac{1}{2} \times 890/9.81 \times 7^2 \times 0.22$
$= 4.89 \, kg m s^{-1}$

Power lost in transmission $= \gamma Q h$
$= 58740 - 489$
$= 58251 \, kg m s^{-1}$

$h = 58251 / 890 \times 0.22 = 297.50 m$ //

(4) $\eta = \dfrac{\text{power of Jet}}{\text{Power supplied}} = \dfrac{489}{58740}$
$= 0.0083 = 0.8324\%$

(7) $\rho_g g = 19.62\ N m^{-2}$

$C_d = 0.96$

$d_1 = 0.3m,\ d_2 = 0.2m$

calculate Q:

$V_1 = Q/0.0707 \quad V_2 = Q/0.0314$

for the manometer,

$P + \rho_g g x = P_2 + \rho_a g (Z_2 - Rt) + \rho_w g Rf$

$P_1 - P_2 = 19.62(Z_2 - Z_1) + 587.423$ —(1)

for the manometer

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

$P_1 - P_2 = 19.62(Z_2 - Z_1) + 0.803 V_2^2$ —(2)

$0.803 V_2^2 = 587.423$

$V_2 = 27.047\ ms^{-1}$ (ideal)

$Q_{ideal} = 27.047 \times \pi \times \left(\frac{0.2}{2}\right)^2 = 0.85\ m^3 s^{-1}$

$Q = C_d Q_{ideal} = 0.96 \times 0.85$

$= 0.816\ m^3 s^{-1}$

(9) Solution (at section 1):

Diameter, $D_1 = 300mm = 0.3m$

Area, $A_1 = \pi/4 \times 0.3^2 = 0.0707 m^2$

Pressure, $P_1 = 400 kN/m^2$

Height of upper end above the datum

$Z_1 = 10m$

(at section 2):

Diameter, $D_2 = 150mm = 0.15m$

Area, $A_2 = \pi/4 \times 0.15^2$

$= 0.01767 m^2$

Height of lower end above the datum, $Z_2 = 6m$

$Q = 40 L/s = 40 \times 10^3 / 10^6$

$= 0.04 m^3 s^{-1}$

$V_1 = Q/A_1 = 0.04/0.0707 = 0.566 ms^{-1}$

& $V_2 = Q/A_2 = 0.04/0.1767 = 2.264 ms^{-1}$

Bernoulli's equation at sect 1 & sect 2

$P_1/w + V_1^2/2g + Z_1 = P_2/w + V_2^2/2g + Z_2$

&, $P_2/w = P_1/w + (V_1^2/2g - V_2^2/2g) + (Z_1 - Z_2)$

$= 400/9.81 + 1/(2 \times 9.81) (0.566^2 - 2.264^2) + (10-6)$

$= 40.77 - 0.245 + 4 = 44.525 m$

$P_2 = 44.525 \times w = 44.525 \times 9.81$

$= 436.8 kN/m^2$