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COURSE: ENG 214 (FLUID MECHANICS)

DEPT: MECHANICAL ENGINEERING

MATRIC: 16/ENG06/029

(1) Rate of pump delivery = $10 dm^3/min$
Pressure change = 12 bar = $12 \times 10^5 N/m^2$
speed of rotation = 1500 rev/min = $\frac{1500 rev}{1 min} \times \frac{1 min}{60 sec}$
nominal displacement = $10 cm^3/rev$
= 25 rev/sec

Torque input = 12.5 NM

(i) volumetric efficiency = $\frac{\text{Actual flow rate}}{\text{Ideal flow rate}} \times 100\%$

Actual flow rate = $10 dm^3/min$ = $\frac{10 dm^3}{1 min} \times \frac{1 m^3}{1000 dm^3} \times \frac{1 min}{60 sec}$
$= 1.667 \times 10^{-4} m^3/sec$

nominal displacement = $\frac{10 cm^3}{1 rev} \times \frac{1 m^3}{100^3 cm^3} = 1 \times 10^{-5} m^3/rev$

Ideal flow rate = nominal displacement × speed
$= 1 \times 10^{-5} \times 25$
$= 2.5 \times 10^{-4} m^3/sec$

volumetric efficiency = $\frac{1.667 \times 10^{-4}}{2.5 \times 10^{-4}} \times 100 = 66.68\%$

(ii) fluid power = Actual flow rate × pressure
$= 1.667 \times 10^{-4} \times 12 \times 10^5$
= 200.04 watts

(iii) shaft power = Torque output × angular speed
Torque input = 12.5 Nm
Angular speed = $\omega = \frac{2\pi N}{60} = 2 \times \pi \times \frac{1500}{60}$ (rps)

∴ shaft power = $12.5 \times 2 \times \pi \times 25 = 1963.5$ watts

(iii) Overall efficiency = $\frac{\text{fluid power}}{\text{Shaft power}} \times 100\%$

$= \frac{200.4}{1963.5} \times 100$

$= 10.21\%$

(2) Rate of delivery = $35 dm^3/min = 35/60 = 0.58 dm^3/sec$

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

Overall efficiency = 87%

Shaft power = ?

Rate of delivery = $0.58 \times \frac{1}{1000} = 5.83 \times 10^{-4} m^3/sec$

Fluid power = Actual flow rate × pressure change

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

$= 5833.33$ watts

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

$87 = \frac{5833.33}{S.P} \times 100$

$\frac{0.87}{5833.33} = \frac{1}{S.P}$

∴ Shaft power = 6704.977 watts.

(3) nominal displacement = $50 cm^3/rev = \frac{50 cm^3}{rev} \times \frac{1 m^3}{100^3 cm^3} = 5 \times 10^{-4} m^3/rev$

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

Shaft power = 15 KW = 15,000 W

Actual flow rate = $35 dm^3/min = \frac{35 dm^3}{1 min} \times \frac{1 min}{60 sec} \times \frac{1 m^3}{1000 dm^3}$

$= 5.833 \times 10^{-4} m^3/sec$

Speed of rotation = 850 rpm = 14.2 rps

Overall efficiency = ~~Actual~~ Fluid power / Shaft power × 100

Fluid power = Actual flow rate × pressure change

$= 5.833 \times 10^{-4} \times 100 \times 10^{5}$

$= 5833$ watts

Shaft power = Torque input × angular speed

$= 15KW = 15000W$

Overall efficiency $= \frac{5833}{15000} \times 100$

$= 388.9\%$ //

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

Ideal flow rate = nominal displacement × speed

$= 5 \times 10^{-4} \times 14.2$

$= 7.1 \times 10^{-3}\ m^3/sec$

Volumetric efficiency $= \frac{5.833 \times 10^{-4}}{7.1 \times 10^{-3}} \times 100$

$= 8.22\%$

(4) $z = 24,000cm = \frac{24,000}{100} = 240m$

Flow rate = 13 litres/sec

Since 1000 litres = $1m^3$

∴ 13 litres $= \frac{13 \times 1}{1000} = 0.013\ m^3/sec$

Velocity of jet = 66 m/sec

Jet issuing from nozzle is at atmospheric pressure and at datum level.

$p = 0\ ;\ z = 0$

Density = $1000 kg/m^3$

from equation; $P = \left(p + \rho g z + \frac{\rho v^2}{2}\right) Q$

since

$p = 0;\ z = 0$

$P = 0 \cdot Q + \frac{\rho Q v^2}{2} + \rho g \cdot 0$

$P = \frac{\rho Q v^2}{2} = \frac{1000 \times 0.013 \times 66^2}{2}$

$P = 28314\ W = 28.314\ kW$

(ii) At this point; $p = 0$ while $v = 0$

$P = \left(pQ + \rho Q g z + \frac{\rho Q v^2}{2}\right)$

$P = \rho Q g z = 1000 \times 0.013 \times 9.8 \times 240$

$= 30576\ W$

$= 30.576\ kW$

(iii) Power loss in transmission $= 30.576 - 28.314$

$= 2.262\ kW = 2262\ W$

Head loss in pipeline;

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

$= \frac{2262}{1000 \times 9.81 \times 0.013} = 17.73\ m$

(iv) Efficiency of the pipeline and nozzle;

$\Rightarrow \frac{\text{Power of jet}}{\text{Power of reservoir}} \times 100 = \frac{28314}{30576} \times 100$

$\Rightarrow 92.6\ \%$

(5) specific gravity of oil = 0.89

$z = 30,000$ cm $= 300$ m

$Q = 220$ litres /sec

Since 1000 litres = $1 m^3$

220 litres = $\frac{220 \times 1}{1000} = 0.22 m^3/sec$

velocity of jet = 7 m/sec.

(i) Specific gravity = $\frac{\text{specific weight of liquid}}{\text{Specific weight of water}}$

$0.89 \times 9.81 =$ specific weight of liquid

$\Rightarrow 8.7309 \, KN/m^3 = 8730.9 \, N/m^3$

$\therefore$ density $(\rho) = \frac{8730.9}{9.81} = 890 \, kg/m^3$

Recall:

At the point of jet issuing from nozzle ; $P = 0$; $z = 0$

from equation ; $\left(PQ + \rho g z Q + \frac{\rho V^2 Q}{2}\right) =$ Power

$$P = \frac{\rho v^2 Q}{2} = \frac{890 \times 7^2 \times 0.22}{2}$$

$$= 4797.1 W = 4.7971 KW$$

(ii) Power supplied from reservoir ; $P = 0$; $V = 0$

Power $= \left(PQ + \rho z g Q + \frac{\rho v^2 Q}{2}\right)$

Power $= \rho z g Q = 890 \times 300 \times 9.81 \times 0.22$

$= 576239.4 \, W = 576.2394 \, KW$

(iii) Power loss in transmission $= 576239.4 - 4797.1$

$= 571442.3 \, W$

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

$\Rightarrow \dfrac{571442.3}{890 \times 9.81 \times 0.22}$

$= 297.50m$

(iv) efficiency = $\dfrac{\text{Power of jet}}{\text{Power of reservoir}} \times 100$

$= \dfrac{4797.1}{576239.4} \times 100$

$= 0.83\%$

(6) Power = pressure × flow rate

Pressure of water = $\rho g h$ = $1000 \times 9.81 \times 20$

$= 196200 \, N/m^2$

Area = $\pi \times (0.05)^2 = 7.854 \times 10^{-3} m^2$

volume = $7.854 \times 10^{-3} \times 20 = 0.1571 m^3$

Q = flow rate = $\dfrac{0.1571}{60} = 2.62 m^3/s$

~~power = 196200~~ power = 196200×2.62

$= 514044 W = 514.044 KW$

(7) Inlet diameter (D_1) = 0.3m $\Rightarrow \dfrac{\pi \times 0.3^2}{4} = 0.071 m^2$ = Inlet Area (A_1)

Throat diameter (D_2) = 0.2m $\Rightarrow \dfrac{\pi \times 0.2^2}{4} = 0.031 m^2$ = Throat Area (A_2)

$C_D = 0.96$; $h = 0.06m$; ~~Sp. gr of mercury = 13.6~~ ~~Sp. gr of gas~~

Sp. gr of water = 1

~~Sp. gr of gas = 19.62~~

Specific weight of gas = $19.62 \, N/m^3$

Sp. gr of gas = $\dfrac{19.62 \div 1000}{9.81} = 0.002$

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

$$Q = 0.96 \times \frac{0.071 \times 0.031}{\sqrt{(0.071)^2 - (0.031)^2}} \times \sqrt{2 \times 9.81 \times 0.06}$$

$Q = 0.0359 \, m^3/s$

Volume flowing $= 0.0359 \, m^3$

(8) Throat diameter (D_2) $= 0.076m$

Throat area (A_2) $= \frac{\pi \times (0.076)^2}{4} = 4.54 \times 10^{-3} \, m^2$

Relative density $= 0.8$

Pipe diameter $= 0.152m = D_2$

Pipe Area (A_1) $= 0.0181 \, m^2$

Difference between inlet and throat $= 0.914m$

$C_d = 0.97$

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

(a) when $P_1 = P_2$

$\therefore$ ~~$h = (z_1 - z_2)$~~ $\therefore h = 0$

Discharge (Q) $= C_d \times \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$

Since $h = 0$

$\therefore Q = 0$

(b) when $P_1 - P_2 = 15170$; $0.8 \times 1000 = 800 \, kg/m^3$ = density of liquid

$h = \frac{15170}{7848}$

$w = \rho g$

$w = 800 \times 9.81 = 7.848 \, kN/m^3$

$h =$ ~~1.933~~. $1.933m + 0.914m$

$\therefore h = 2.847m$

$\therefore$ Discharge (Q) $= C_d \times \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \times \sqrt{2gh}$

$$Q = \frac{0.97 \times 0.0181 \times 4.54 \times 10^{-3}}{\sqrt{(0.0181)^2 - (4.54 \times 10^{-3})^2}} \times \sqrt{2 \times 9.81 \times 2.847}$$

$Q = 0.034 \, m^3/seconds$ //

(9) section 1 diameter = 300 mm = 0.3 m (D_1)

section 1 Area = $\frac{\pi \times 0.3^2}{4} = 0.071\,m^2$ (A_1)

section 2 diameter = 150 mm = 0.15 m (D_2)

section 2 Area = $\frac{\pi \times 0.15^2}{4} = 0.018\,m^2$ (A_2)

Q = 40 litres/sec = 0.04 m^3/sec

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

$P_1 = 400 kN/m^2$ $\quad P_2 = ?$

= 400 kPa

$$V_1 = \frac{Q}{A_1} = \frac{0.04}{0.071} = 0.563 m/s$$

$$V_2 = \frac{Q}{A_2} = \frac{0.04}{0.018} = 2.27 m/s$$

from bernoulli's equation: $\frac{P_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + z_2$

$$\frac{400}{9.81} + \frac{0.563^2}{2 \times 9.81} + 10 = \frac{P_2}{9.81} + \frac{2.27^2}{2 \times 9.81} + 6$$

$$\frac{P_2}{9.81} = 44.53$$

∴ Intensity of pressure at section 2 ⇒ 9.81 × 44.53

$P_2 = 436.82 kN/m^2$

(10) axis = 12m below sea-level.

y = 170 mm = 0.17 m of mercury

Sp. gravity of Hg = 13.6

Sp. gravity of water = 1.026

$$h = y\left(\frac{S_{hl}}{S_l} - 1\right)$$

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

h = 2.08 m

$\therefore$ Velocity of submarine $(v) = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 2.08}$

$= 6.39\ m/s$