DALYCE WIAFA
FLUID MECHANICS
16/ENG01/008
CHEMICAL ENGINEERING

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1) Rate of pump delivery = 10 dm^3/min
Pressure of Charge = 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 N/m

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

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

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 Input × angular speed
Torque Input = 12.5 Nm
Angular Speed = $w = \frac{2\pi N}{60} = \frac{2 \times \pi \times 1500}{60}$ (rps)

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

iii) Overall efficiency = $\frac{\text{Fluid Power}}{\text{Shaft Power}} \times 100\%$

$= \frac{200.4 \times 100}{1963.5} = 10.21\%$

$P = 28314 \text{ W} = 28.314 \text{ kW}$

(ii) At this point; P = 0 while V = 0

$P = (PQ + \rho Q g z + \frac{\rho Q V^2}{2})$

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

$= 30576 \text{W}$

$= 30.576 \text{ kW}$

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

$= 2.262 \text{kW} = 2262$

Head loss in pipeline;

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

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

(iv) Efficiency of the pipeline and nozzle;

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

$= 92.6\%$

(5) Specific gravity of oil = 0.89

= 30,000 cm = 300 m.

Q = 220 litres/sec

Since 1000 litres = 1m3

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

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

$0.89 \times 9.81 = \text{Specific weight of liquid}$

$= 8.7309 \text{ kN/m}^3 = 8730.9 \text{ N/m}^3$

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

Since $h = 0$

$\therefore Q = 0$

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

$h = \frac{15170}{7818}$

$w = \rho g$

$w = 800 \times 9.81 = 7.8481 kN/m^3$

$h = 1.933m + 0.914m$

$\therefore h = 2.847m$

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

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

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

(9) Section 1 diameter $= 300mm = 0.3m$ (D_1)

Section 1 area $= \frac{\pi \times 0.3^2}{4} = 0.071m^2$ (A_1)

Section 2 diameter $= 150mm = 0.15m$ (D_2)

Section 2 area $= \frac{\pi \times 0.15^2}{4} = 0.018m^2$ (A_2)

$Q = 40$ litres/sec

$Z_1 = 10m$; $Z_2 = 6m$

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

$= 400 kPa$

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

$V_2 = \frac{Q}{A_2} = \frac{0.04}{0.018}$ $2.22 m/s$

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/m²

(5) axis = 12m below sea-level

$y = 170mm = 0.17m$ of mercury

S.P gravity of Hg = 13.6

S.P gravity of water = 1.026

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

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

$$h = 2.08m$$

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

$= 6.39$ m/s

Power = 196200 × 2.62
= 514044W = 514.044 kW

(7) Inlet diameter (d_1) = 0.3m = $\frac{\pi \times 0.3^2}{4}$ = 0.071m² Inlet area

Throat diameter (d_2) = 0.2m = $\frac{\pi \times 0.2^2}{4}$ = 0.031 m² = Throat area

$C_D = 0.96$; h = 0.06m ;
Sp. gr of water = 1
Specific weight of gas = 19.62N/m³
Sp. gr of gas = $\frac{19.62 \div 1000}{9.81}$ = 0.002

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

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

Q = 0.0359 m³/s
Volume flowing = 0.0359m³

(8) Throat diameter (D_2) = 0.076m
Throat area (A_2) = $\frac{\pi \times (0.076)^2}{4}$ = 4.54×10^{-3} m²

Relative density = 0.8
Pipe diameter = 0.152m = D_2
Pipe area (A_1) = 0.0181m²
Difference between inlet and throat = 0.914m
Cd = 0.97

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

(a) when $P_1 - P_2$
∴ h = 0.

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

Recall

At the point of jet issuing from nozzle ; $P=0$, $z=0$
From equation, $\left(PQ + \rho gzQ + \frac{\rho v^2}{2}Q\right) = \text{Power}$

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

$$= 4797.1 w = 4.797 \, kw$$

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

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

$$\text{Power} = \rho zgQ = 890 \times 300 \times 9.81 \times 0.22$$

$$= 576239.4 w = 576.2394 \, kw$$

(iii) Power loss in transmission $= 576239.4 - 4797.1$
$= 571442.3 w$

$$\text{Head used} = \frac{\text{Power Loss In transmission}}{\rho gQ}$$

$$= \frac{571442.3}{890 \times 9.81 \times 0.22}$$

$$= 297.50 m$$

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

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

$$= 0.83\%$$

(5) Power = Pressure X flow rate

Pressure of water $= \rho gh = 1000 \times 9.81 \times 20$
$= 196200 \, N/m^2$

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

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

$$Q = \text{Flow rate} = \frac{0.1571}{60} = 2.62 \, m^3/s$$

shaft power = Torque Input X angular speed
$= 15 \text{ Kw} = 15000 \text{ W}$

overall efficiency $= \frac{5833 \times 100}{15000}$
$= 388.9\%$

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

Ideal flow rate = Nominal displacement X Speed
$= 5 \times 10^{-4} \times 14.2$
$= 7.1 \times 10^{-3} \text{ m}^3/\text{sec}$

Volumetric efficiency $= \frac{5.833 \times 10^{-4}}{7.1 \times 10^{-3}} \times 100$
$= 8.22\%$

(4) $Z = 24{,}000 \text{cm} = \frac{24000}{100} = 240 \text{m}$

Flow rate = 13 litres/sec
Since 1000 litres = 1m^3
$\therefore 13$ litres $= \frac{13 \times 1}{1000} = 0.013 \text{ m}^3/\text{sec}$

Velocity of jet = 66m/sec
Jet issuing from nozzle at atmospheric pressure and at datum level
$P = 0 ; Z = 0$
Density = 1000kg/m^3
From equation ; $P\left(P + Pg + \frac{Pv^2}{2}\right)Q$
Since
$P = 0, Z = 0$
$P = 0 \cdot Q + P\frac{Qv^2}{2} + Pg \cdot 0$

$P = \frac{PQv^2}{2} = \frac{1000 \times 0.013 \times 66^2}{2}$

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 = 13,000 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 = $\frac{\text{Fluid power}}{\text{Shaft power}} \times 100$

Fluid Power = Actual flow rate × Pressure Change
= $5.833 \times 10^{-4} \times 100 \times 10^5$
= 5833 watts