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18/ENG07/010

PETROLEUM ENGINEERING

ENG 214 - FLUID MECHANICS

Question 1

1. Actual rate = 10dm^3/min

10dm = 1m

10dm^3 = x

Volumetric flowrate

$= x = \frac{10}{1000}$

Actual flow rate = 0.01m^3/min

= 60sec = 1min

$= \frac{0.01}{60}$

$q = 1.67 \times 10^{-4} m^3/sec$

Speed (N) = 1500rev/min

$= \frac{1500}{60} = 25 rev/sec$

∴ 25rps

Pressure (P) = 12bar

1bar = $1 \times 10^5 N/m^2$

12bar = x

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

∴ $\partial P = 12 \times 10^5 N/m^2$

Nominal displacement = 10cm^3/rev

100cm = 1m

$100^3 cm^3 = 1m^3$

$10 cm^3 = x$

$x = \frac{10}{1000000}$

$x = 1 \times 10^{-5} m^3/rev$

Ideal flowrate = nominal × speed

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

$= 2.5 \times 10^{-4} m^3/sec$

(i) Volumetric Efficiency

$= \frac{\text{Actual flowrate}}{\text{Ideal flowrate}} \times 100\%$

$= \frac{1.67 \times 10^{-4}}{2.5 \times 10^{-4}} \times 100\%$

= 66.8%

(ii) $P_f = Q \cdot \partial P$

$= 1.67 \times 10^{-4} \times 12 \times 10^5$

= 200.4 Nm/sec

(iii) Shaft Power = T. w

T = 12.5Nm

$w = \frac{2\pi N}{60}$ for rpm

$w = \frac{2 \times 22 \times 25}{7} = 157.14 rad/sec$

Shaft power = 12.5 × 157.14

= 1964.25watts

(iv) Overall Efficiency

$= \frac{\text{fluid Power}}{\text{Shaft power}} \times 100\%$

$= \frac{200.4}{1963} \times 100\% = 10.2\%$

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Question 2

2. $\partial P = 100 \text{ bar}$

$1 \text{ bar} = 10^5 N/m^2$

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

Actual flowrate, $Q = 35 dm^3/min$

$= \frac{35}{1000 \times 60} m^3/sec$

$= 5.83 \times 10^{-4} m^3/sec$

$P_f = Q \cdot \delta p$

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

$= 5830$ watts

(2) Overall Efficiency

$= \frac{\text{fluid Power}}{\text{Shaft power}} \times 100\%$

Shaft Power $= \frac{\text{Fluid Power}}{\text{overall Efficiency}} \times 100\%$

$= \frac{5830 \times 100}{87}$

Shaft Power $= 6701.15$ watts

$\therefore 6.701 \times 10^3$ watts

Question 3

3. Nominal Displacement $= 50 cm^3/rev$

$\eta = \frac{50}{1000000}$

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

Actual flow rate $= 35 dm^3/min$

$= \frac{35}{1000 \times 60}$

$= 5.63 \times 10^{-4} m^3/sec$

$\delta p = 100 \text{ bar}$

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

$P_f = Q \cdot \delta p$

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

$=$ ~~5830W~~ $5830 W$

(i) Overall Efficiency $= \frac{\text{fluid Power}}{\text{Shaft Power}} \times 100\%$

$= \frac{5830 \times 100}{15000}$

Overall Efficiency $\mathcal{E} = 38.87\%$

(ii) Ideal flowrate = nominal displacement × Speed

$N = 850 \text{ rpm}$

$= \frac{850}{60}$

$= 14.17 \text{ rps}$

Ideal flowrate $= 5 \times 10^{-5} \times 14.17$

$= 4.085 \times 10^{-4} m^3/sec$

(iv) Volumetric Efficiency

$= \frac{\text{Actual flowrate}}{\text{Ideal flowrate}} \times 100\%$

$= \frac{5.83 \times 10^{-4}}{7.085 \times 10^{-4}} \times 100\%$

Volumetric Efficiency

$= 82.3\%$

Question 4

$Z = 2400\,cm$

$100\,cm = 1\,m$

$Z = \frac{2400}{100}$

$Z = 24\,m$

Volumetric flowrate

$Q = 13\,litre/sec$

$1000\,litres = 1\,m^3$

$Q = \frac{13}{1000}$

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

Velocity of Jet $= 66\,m/sec$

(i) $P = \frac{\rho Q v^2}{2}$

$= \frac{1000 \times 13 \times 10^{-3} \times (66)^2}{2}$

$= 283.14$ watts

$P = 28.314$ kilowatts

(ii) Power supplied from a Reservoir

$P = \rho g Q z$

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

$= 30607.2$ watts

$P = 30.6072$ kilowatts

(iii) Power loss in transmission

= Power of Reservoir − Power of Jet

$= 30607.2 - 28314$

$= 2293.2$ watts

(iv) Head loss in pipeline;

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

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

$h = 17.982\,m$

(v) Efficiency $= \frac{\text{Power of Jet}}{\text{Power of Reservoir}} \times 100\%$

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

$\eta = 92.5\%$

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Question 5

5. i) Power of Jet $= P = \frac{\rho Q \cdot v^2}{2}$

$= \frac{1000 \times 220 \times 10^{-3} \times (7)^2}{2}$

$= 5.39$ watts

$P = 5.39$ kilowatts

ii) Power supplied from a Reservoir

$P = \rho g Q z$

$= 1000 \times 9.81 \times 22 \times 10^{-4} \times 300$

$= 647.46$ watts

$\therefore P = 64.746$ kilowatts

iii) Power loss in Transmission

= Power of Reservoir − Power of Jet

$= 64.746 - 5.39$

$= 59.356$ watts

iv) Head loss in pipeline

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

$h = \frac{59.356}{1000 \times 9.81 \times 0.22}$

$h = 12.8102$ m

v) Efficiency $= \frac{\text{Power of Jet}}{\text{Power of Reservoir}} \times 100\%$

$= \frac{5.39}{64.746} \times 100\%$

$\mathcal{E} = 83.2\%$

Question 9

① Diameter, $D_1 = 300$ mm
$= 0.3$ m

Area, $A_1 = \frac{\pi}{4} \times 0.3^2 = 0.0707 m^2$

Pressure $P_1 = 400 kN/m^2$

$Z_1 = 10$ m

② Diameter $D_2 = 150$ mm
$= 0.15$ m

Area, $A_2 = \frac{\pi}{4} \times 0.15^2$
$= 0.01767 m^2$

$Z_2 = 6$ m

$Q = 40$ litres/sec $= \frac{40 \times 10^3}{10^6}$
$= 0.04 m^3/s$

$Q = A_1V_1 = A_2V_2$

$V_1 = \frac{Q}{A_1} = \frac{0.04}{0.0707}$
$= 0.566$ m/s

$V_2 = \frac{Q}{A_2} = \frac{0.04}{0.01767} = 2.264$ m/s

$\frac{P_2}{w} = \frac{P_1}{w} + \left[\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right] + (Z_1 - Z_2)$

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

$= 40.77 - 0.245 + 4$

$= 44.525$ m

$P_2 = 44.525 \times w$

$= 44.525 \times 9.81$

$\therefore P_2 = 436.8 kN/m^2$