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MECHATRONICS

1

Flow rate (Q) = 10dm³/min

Pressure change (ΔP) = 12bar

Speed (N) = 1500rpm

Normal displacement = 10cm³/rev

Torque Input (T) = 12.5N.m

i) Ideal flow rate = Normal displacement × speed

= 10cm³/rev × 1500rpm

= 15000cm³/min = 15dm³/min

Volumetric efficiency = Actual flow / Ideal flow

= 10/15 = 0.6667 or 66.67%

ii) $Q = \frac{10 \times 10^{-3}}{60} m^3/sec = 16.7 \times 10^{-5} m^3/sec$

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

Fluid power = ΔP × Q = $16.7 \times 10^{-05} m^3/sec \times 12 \times 10^5 N/m^2$ = 200 watts

Shaft power = $\frac{2\pi NT}{60} = \frac{2\pi \times 1500 \times 12.5}{60}$

= 1963.5 Watts

Overall efficiency = f.p/s.p = 200/1963.5

= 10.2%

iii)

Fluid Power can be either increased by the change in pressure or discharge

2

Flowrate, (Q) = 35dm³/min

Pressure change (ΔP) = 100bar

Overall efficiency = 87%

Shaft power = $\frac{2\pi NT}{60}$

$Q = \frac{35 \times 10^{-3}}{60} m^3/sec$

$= 58.3 \times 10^{-5} m^3/sec$

Fluid power ΔP × Q

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

$58.3 \times 10^{-3} \times 100 \times 10^5$

= 5830 watts

Overall efficiency = Fluid power / Shaft power

0.87 = 5830 / Shaft power

Shaft power = 5830 / 0.87 = 6701.14 Watts

3

Normal displacement = 50cm³/sec

Pressure change (ΔP) = 100bar

Shaft power = 15kilowatts = 15000

Overall efficiency = ?

Volumetric efficiency = ?

Flowrate (Q) = 35dm³/min

Speed (N) = 850rpm

Continuation of

No (3)

Ideal flow rate = Normal displacement × speed

$= 50 cm^3/rev \times 850 rev$

$= 42500 cm^3/min = 42.5 dm^3/min$

Volumetric efficiency = Actual flow / Ideal flow

$= 35/42.5 = 0.8235$ or 82.35%

$Q = \frac{35\times10^{-3}}{60} m^3/sec = 58.3\times10^{-5} m^3/sec$

$\delta P = 100\times10^5 N/m^2$

fluid power = $\delta P \times Q$

$= 58.3\times10^{-5} m^3/sec \times 100\times10^5$

$= 5830$ watts

Shaft power = 15000 watts

Overall efficiency = $\frac{\text{fluid power}}{\text{Shaft power}} = \frac{5830}{15000}$

$= 0.3886$

$= 38.86\%$

(4)

$H = 240m$

$Q = 0.013 m^3/s$

$v = 66 m/sec$

power of jet (P_{jet}) = $\frac{1}{2} m v^2_{jet}$

$= \frac{1}{2}\rho Q V^2_{jet}$

$= \frac{1}{2}\times1000\times0.013\times66^2$ watt

$= 28314$

~~= 28.314 watts~~ = 28.314 kilowatts

Power supplied by (P_{res}) = mgh

$= \rho Q g h$

$= 1000\times0.013\times9.81\times240$

$= 30607.2$

$= 30.6072$ kilo Watt

(c) Heat used to overcome losses

$(H_f) = H - \frac{V^2_{jet}}{2g}$

$= 240 - \frac{66^2}{2\times9.81}$

$= 17.98m$

(d) Efficiency of pipeline & nozzle = $\frac{P_{jet}}{P_{res}}\times100$

$= \frac{28.314}{30.6072}\times100 = 92.51\%$

$= 92.51\%$

(5)

$Z_1 = 30,000cm = 300m$

$Q_1 = 220$ litres/s $= (220\times10^{-3}) m^3/s$

$V = 7 m/s$

Power of Jet = $\rho g Q H$

where $\rho = 0.89\times1000 = 890 kg/m^3$

$g = 9.81 m/s^2$

$Q = (220\times10^{-3}) m^3/s$

$H = Z_2 + \frac{P}{\rho g} + \frac{V^2}{2g}$

$H = 0 + \frac{0}{\rho g} + \frac{(7)^2}{2\times9.81}$

$H = 49/19.62 = 2.497$ J

Power $= 890\times9.81\times220\times10^{-3}\times2.497$

$= 4797.1$ Watts.

Continuation of Number (5)

(a) Power supplied from reservoir

$H = Z_1 + P/\rho g + V^2/2g =$

$300 + \frac{0}{\rho g} + \frac{0}{2g}$

$= 300J$

∴ Power $= 890 \times 9.81 \times 220 \times 10^{-3} \times 300$

$= 576239.4$

(ii) Head used to overcome the loss

$=$ Power loss $/ \rho g Q$

$= \frac{(576239.4 - 4797.1)}{1000 \times 9.81 \times 220 \times 10^{-3}}$

$= \frac{571442.3}{2158.2}$

⇒ 264.7772681

(iii) Efficiency $= \frac{\text{Power of Jet}}{\text{power of reservoir}} \times 100$

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

$= 0.8324838\%$

(6)

Power = $\frac{\text{workdone}}{\text{time}}$

workdone = $\frac{mgh}{time}$

V = Velocity of stream

ρ = density of water ($1000 kg/m^3$)

$m = \rho \times V$

$v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 20}$

$= 19.7989 m/s$

$P = \frac{\rho A t m' vgh}{t}$

Power $= \frac{1000kg}{m^3} \times \left(\frac{10 \times 10^{-2}}{2}\right)^2 \times 19.7989 m/s \times 9.8 m/s^2 \times 20m$

$= 1000 \times \pi \times 2.5 \times 10^{-3} \times 19.7989 \times 9.8 \times 20$

$= 30478.03W$

Power $= 30478.03 W$

(7)

Diameter $(D_1) = 0.3m$

$A_1 = \pi/4 \times 0.3^2$

$A_1 = 0.070685 m^2$

Throat diameter $(D_2) = 0.2m$

$A_2 = \pi/4 \times (0.2)^2$

$A_2 = 0.031416 m^2$, Coefficient of discharge = 0.96%

Specific weight of gas $(\gamma) = 19.62 N/m^3$

density of gas $(S_g) = \frac{19.62}{9.81}$

$S_g = 2kg/m^3$

P_1 220metric head difference $(h) = x\left(\frac{S_m}{S_g} - 1\right)$

$= 0.06 \times \left(\frac{1000}{2} - 1\right)$

$h = 29.94$

Volume flow rate $(Q) = \frac{C_d A_1 - A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$

$= \frac{0.96 \times 0.070685 \times 0.031416 \sqrt{2 \times 9.81 \times 29.94}}{\sqrt{(0.070685)^2 - (0.031416)^2}}$

$Q = 0.81599 m^3/s$

8

$A_1 = \frac{\pi}{4} D_1^2 = \frac{\pi}{4}(0.152)^2 = 0.018146 m^2$

$A_2 = \frac{\pi}{4} D_2^2 = \frac{\pi}{4}(0.0766)^2 = 4.5365 \times 10^{-3} m^2$

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

$= \frac{0.97 \times 0.018146 \times 4.5365 \times 10^{-3} \sqrt{2 \times 9.81 \times 0.24}}{\sqrt{(0.018146)^2 - (4.5365 \times 10^{-3})^2}}$

$Q = 0.04924 m^3/s$

ii) $h = \left(\frac{P_1 - P_2}{\rho g}\right) = \frac{15170}{0.8 \times 10^3 \times 9.81} = 1.933 m$

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

$Q = \frac{0.97 \times 0.018146 \times 4.5365 \times 10^{-3} \times \sqrt{2 \times 9.81 \times 1.933}}{\sqrt{(0.018146)^2 - (4.5365 \times 10^{-3})^2}}$

$Q = 0.02798 m^3/s$

9

$d = 300m = 0.3m$

$A_1 = \pi d^2/4 = \pi(0.3)^2/4 = 0.0707 m^2$

$d_2 = 150mm = 0.15m$

$A_2 = \pi d^2/4 = \pi(0.15)^2/4 = 0.0177 m^2$

$Q = 40 l/s$

$= (40 \times 10^{-3}) m^3/s$

$Z_1 = 10m$

$Z_2 = 6m$

$P_1 = ?$

$P_2 = 400 kN/m^2 = 400,000 N/m^2$

$Q = VA$

$V_1 A_1 = Q : (V_1)(0.0707) = (40 \times 10^{-3})$

$V_1 = \frac{(40 \times 10^{-3})}{0.0707}$

$V_1 = 0.5658 m/s$

$Q = V_2 A_2$

$V_2 (0.0177) = 40 \times 10^{-3}$

$V_2 = (40 \times 10^{-3}) / 0.0177$

$V_2 = 2.2599 m/s$

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

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

$10 + \frac{400000}{9.81 \times 1000} + \frac{(0.5656)^2}{2(9.81)} = 6 + \frac{P_2}{9.81 \times 1000} + \frac{(2.2599)^2}{2 \times 9.81}$

$50.79 = P_2/9.81 \times 1000 + 6.260303$

$\frac{P_2}{9.81 \times 1000} = 50.79 - 6.26$

$P_2 = (9.81 \times 1000)(44.53)$

$P_2 = 436.836 kN/m^2$

10

Calculate the head

$h = y\left(\frac{\rho_m}{\rho_f} - 1\right)$

$= 0.77\left[\frac{13.6}{1.026} - 1\right]$

$h = 2.0834$

ρ_m = density of mercury
ρ_f = density of fluid
y = manometric reading

Calculate the vel of submarine

$V = \sqrt{2gh}$

$= \sqrt{2 \times 9.81 \times 2.0834}$

$= 6.393 m/s$