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18/ENG05/063
Mechatronics

(1)

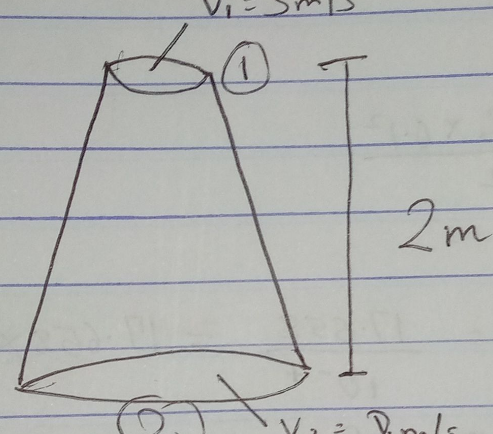
Head loss, $h = \dfrac{0.35\,(v_1 - v_2)^2}{2g}$

where $v_1 = 5\,m/s$, $v_2 = 2\,m/s$, $g = 9.8\,ms^{-2}$

$\therefore h = \dfrac{0.35(5-2)^2}{2 \times 9.8}$

$h = 0.161\,m$

But difference in pressure head in section 1 and 2 is



$h = \dfrac{P_1 - P_2}{w}$

Where

$w = \rho$ of water $\times g$

$P_1 =$ Pressure head at section (1) $= 2.5m$

$P_2 =$ Pressure head at section (2) $= ?$

$h = 0.161\,m$

$\therefore 0.161 = \dfrac{2.5 - P_2}{1000 \times 9.8}$

$-P_2 = \underline{1000 \times 9.8 \times 0.161} - 2.5$

$P_2 = -1,575.3\,m$

(3)

$$Q_{actual} = \frac{C_d \, A_1 A_2 \sqrt{2gh}}{\sqrt{A_1^2 - A_2^2}}$$

$d_1 = 20cm = \frac{20}{100} = 0.2m$

$A_1 = \frac{\pi d_1^2}{4} = \frac{3.142 \times 0.2^2}{4}$

$A_1 = 0.03142 \ m^2$

$d_2 = 10cm = 0.1m$

$A_2 = \frac{\pi d_2^2}{4} = \frac{3.142 \times 0.1^2}{4}$

$A_2 = 0.00786 \ m^2$

$P_{inlet} \ 17.658 N/cm^2 = \frac{17.658}{10^{-4}} = 17.658 \times 10^4$

$\frac{P_1}{\omega} = \frac{P_{inlet}}{\rho g} = \frac{17.658 \times 10^4}{10^3 \times 9.81}$

$\frac{P_1}{\omega} = 18$

Specific gravity of mercury = 13.6

$P_2 = P_{vacuum \ pressure}$

Vacuum pressure = 30 cm Hg $= -0.3 \times 13.6$

$\frac{P_2}{\omega} = -4.08m$

Recall, $h = \frac{P_1 - P_2}{\omega} = \frac{P_1}{\omega} - \frac{P_2}{\omega}$

$h = 18 + 4.08$

$h = 22.08$

$\therefore$ $Q_{actual} = \frac{0.98 \times 0.03142 \times 0.00786 \sqrt{2 \times 9.81 \times 22.08}}{\sqrt{(0.03142)^2 - (0.00786)^2}}$

$= \frac{5.037 \times 10^{-3}}{0.0304}$

$Q_{actual} = 0.166 \ m^3/sec$

(5)

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

Actual flow rate = Q = $5 dm^3/min$ = $\frac{0.05\ m^3/sec}{60}$

$5 dm^3/min = 8.33 \times 10^{-5}$

$= 8.33 \times 10^{-5}\ m^3/s$

$= 8.33 \times 10^{-4}\ m^3/sec$

Theoretical flow rate = Displacement / rev X driven speed

Driven speed = 1700 rev/min = $\frac{1700}{60}$ rev/sec

= 28.33 rev/sec

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

∴ Theoretical flow = $1 \times 10^{-5}\ \frac{m^3}{\cancel{rev}} \times 28.33\ \frac{\cancel{rev}}{sec}$

= $2.833 \times 10^{-4}\ m^3/sec$

∴ Volumetric efficiency = $\frac{8.33 \times 10^{-5}}{2.833 \times 10^{-4}} \times 100$

= 0.294×100

= 29.4 %

(ii) Fluid power = Torque x Speed

= 15×28.33

= 0.529 Nm rev/sec

(iii) Shaft power = $\frac{\text{Fluid power}}{\text{Volumetric efficiency}}$

= $\frac{0.529}{29.4}$ = 0.018

(iv) Overall efficiency = volumetric eff x mechanical eff

Mechanical eff = $\frac{\text{Theoretical Torque} \times 100}{\text{Actual Torque}}$

Theoretical torque = Pressure X displacement

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pressure = 15 bar = $1.5 \times 10^{6}\ Nm^{-2}$

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

Theoretical Torque = $1.5 \times 10^{6} \times 1 \times 10^{-5}$

= 1.5×10^{1}

= 15 Nm

∴ Mechanical effeciency = $\frac{\cancel{15}}{\cancel{15}} \times 100$

= $1 \times 100 = 100\%$

Overall efficiency = 29.4×100

= $2.9 \times 10^{-3}\%$

$d_0 = 15cm = 0.15m$

$A_0 = \frac{\pi d_0^2}{4} = \frac{3.142 \times 0.15^2}{4} = 0.0177\ m^2$

$d_1 = 30cm = 0.3m$

$A_1 = \frac{\pi d_1^2}{4} = \frac{3.142 \times 0.3^2}{4} = 0.0707\ m^2$

$y = 50cm\ Hg = 0.5mHg$

$h = y\left(\frac{S.g\ of\ mercury}{Sg\ of\ oil} - 1\right)$

$h = 0.5\left(\frac{13.6}{0.9} - 1\right)$

$h = 7.06$

$Q = \frac{Cd \cdot A_0 \cdot A_1 \sqrt{2gh}}{\sqrt{A_1^2 - A_0^2}}$

where $Cd = 0.64$

$Q = \frac{0.64 \times 0.0177 \times 0.0707 \sqrt{2 \times 9.81 \times 7.06}}{\sqrt{0.0707^2 - 0.0177}}$

$Q = \frac{0.0784}{0.068}$

$Q = 1.153\ m^3/sec$

(4)

Reading of manometer $y = 170\,mm = 0.17\,m$

$Sh_1 =$ Spg mercury $= 13.6$

S_l Spg sea water $= 1.026$

$$h = y\left[\frac{Sh_1}{S_l} - 1\right]$$

$$h = 0.17\left[\frac{13.6}{1.026} - 1\right]$$

$h = 2.08\,m$

$\therefore$ Speed of submarine $V = \sqrt{2gh}$

$$V = \sqrt{2 \times 9.81 \times 2.08}$$

$$V = 12.7\,m/s$$