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Civil Engineering
18/ENG03/043
Fluid Mechanics

i) $Q = 10 dm^3/min$
$(10 \times 10^{-3}) m^3/60 s$

$\frac{10 \times 10^{-3}}{60} m^3/s = 1.61 \times 10^{-4} m^3/s$

12 bar : $12 \times 10^5 N/m^2$

speed of rotation $= \frac{1500 rev}{60 s}$

$= 25 rev/sec$

nominal displacement : $10 cm^3/rev$
$(10 \times 10^{-6}) m^3/rev = 1 \times 10^{-3} m^3/rev$

Torque input = 12.5 Nm
volumetric Efficiency = $\frac{\text{Actual flow rate}}{\text{ideal flowrate}} \times 100$

ideal flowrate $\frac{25 rev}{sec} \times 10^{-3} \frac{m^3}{rev}$

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

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

$= 66.8\%$

ii) fluid power $= Q \times \delta p$
$(1.67 \times 10^{-4})(12.10^{5})$
$= 200.4$ watts

iii) Shaft power = Torque input × angular speed

$\frac{25 \times 2 \times \pi}{1 sec} = 50\pi$ rad/sec which is
157.08 rad/sec

shaft power = 12.5Nm × 157.08 rad/sec

= 1963.495 watts

Question (2

2) · Q = 35dm³/min

$\frac{35 \times 10^{-3}}{60}$ m³/s

5.83 × 10^{-4} m³/s

δp = 100bar = 100 × 10^5 N/m²

overall efficiency = 87%

Note: Efficiency = $\frac{\text{fluid power}}{\text{shaft power}}$ × 100

fluid Power = Q × δp =

(5.83 × 10^{-4}) × (1000 × 10^5)

= 5830 watts

Question (3

(3: Normal displacement : 50cm³/rev, Pressure change = 100bar

shaft power = 18KW, flowrate Q = 35dm³/min

speed = 850rpm

Ideal flowrate = Normal displacement × speed

= 50cm³ (rev × 850 rpm)

= 42500 cm³/m ∴ 42.5dm³/min

volumetric efficiency = Actual flow / Ideal flow

35/42.5 = 0.8235

= 82.35%

ii) $Q = \frac{35 \times 10^{-3}}{60} m^3/sec = 50.3 \times 10^{-3} m^3/sec$

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

$\Delta p = 100 \times 10^3 N/m^2$

fluid power

$= \Delta p \times Q = 58.3 \times 10^{-3} m^3/sec \times 100 \times 10^3$

$= 5830$ watts

Overall Efficiency = $\frac{\text{fluid power}}{\text{shaft power}}$

$= \frac{5830}{15000} = 0.388$

38.86%

Question 4

4) $H = 240m$

$Q = 0.013 m^3/sec$

$V = 66 m/sec$

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

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

$\frac{1}{2} \times 1000 \times 0.013 \times 66^2$ watt

$= 28314$

28.314 kilowatts

b) Power supplied by Res = $\rho Q g h$

$= 1000 \times 0.013 \times 9.81 \times 240$ watts

$= 30607.2$

30607.2 watts

c) Head ~~req~~ required to overcome Loses

$H - v^2_{jet}/2g$

$240 - 66^2/2 \times 9.81$

$= 17.98 m$

* Efficiency of pipeline and nozzle

$$P_{re}/P_{res} \times 100$$

$$\frac{28.314}{30.6072} \times 100$$

$$= 92.51\%$$

(Question 5)

$Z = 300m \quad Q_1 = 220 l/s \quad = 220 \times 10^{-3} m^3/s$

$V_2 = 7m/s$. Power of jet $= \rho g Q H \quad \rho = 0.89 \times 1000$

$= 890 kg/m^3 \quad g = 9.81 m/s^2 \quad Q = (220 \times 10^{-3}) m^3/s$

$$H = 0 + \frac{0}{\rho g} + \frac{(7)^2}{2 \times 9.81}$$

$$H = 49/19.62 = 2.4975$$

$$\text{Power} = 890 \times 9.81 \times 220 \times 10^{-3} \times 2.477$$

$$= 4797.1 \text{ watts}$$

ii) Power supplied from reservoir

$$H = Z_1 + \frac{P}{\rho g} + \frac{V^2}{2g} = 300 + \frac{0}{\rho g} + \frac{0}{2g}$$

$$\text{Power} = 890 \times 9.81 \times 220 \times 10^{-3} \times 100 = 576239.4$$

576239.4 watts

iii) Heat used to overcome power loss Power loss / $\rho g Q$

$$\frac{576239.4 - 4797.1}{100 \times 9.81 \times 220 \times 10^{-3}}$$

$= 2640.7772081$

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

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

$= 0.8324838\%$

Question 6

Power = $\frac{\text{work done}}{\text{time}}$ and workdone = $\frac{mgh}{s}$

v = velocity of stream , ρ = density of water (1000kg/m³)

$m = \rho \times v$

$v = \sqrt{2gh}$, $\sqrt{2 \times 9.8 \times 20}$ = 19.7959 m/s

Power = 1000 $\frac{kg}{m^3}$ × $\left(\frac{40 \times 10^{-2}}{2}\right)$ × 19.7959 m/s × 9.8 m/s × 20 m

P = 30478.03 watts

Question 7

Diameter = 0.3m

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

$A_1 = 0.070685 m^2$

Diameter D_2 = 0.2m

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

$A_2 = 0.03146 m^2$

Cd = 0.96

Specific weight of gas (1) = 19.62 N/m³

Density of gas (ρg) = 19.62/9.81

= 2 kg/m³

Piezometric head difference (h) = $0.06 \times \left(\frac{Sm}{Sg} - 1\right)$

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

h = 29.94m

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

$= \frac{0.96 \times 0.010685 \times 0.031416 \times \sqrt{2 \times 9.81 \times 29.94}}{\sqrt{(0.070685)^2 - (0.031416)^2}}$

$Q = 0.81599 m^3/s$

Question 8)

8) $A_1 = \pi/4 \, D_1^2 = \pi/4 \, (0.152)^2 = 0.018146 m^2$

$A_2 = \pi/4 \, D_2^2 = \pi/4 \, (0.076)^2 = 4.5365 \times 10^{-3} m^2$

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

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

$Q = 0.01924 m^3/s$

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

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

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

$Q = 0.02798 m^3/s$

Question 9

$D_1 = 0.3m$ $A_1 = \frac{\pi d^2}{4} = \frac{\pi(0.03)^2}{4} = 0.0707 m$

$D_2 = 0.15m$ $A_2 = \frac{\pi d^2}{4}$ $\frac{\pi(0.15)^2}{4} = 0.0177 m$

Q = 40L/s $(40\times10^{-3}) m^3/s$

$Z_1 = 10m$ $Z_2 = 6m$ $P_1 = ?$ P_2 4000,000 N/m^2.

Q = VA

$V_1 A_1 = Q$ $Q = V_2 A_2$

$V_1 = (40\times10^{-3}) / 0.0707$ $V_2 = (40\times10^{-3}) / 0.0177$

$V_1 = 0.5655 m/s$ $V_2 = 2.2599 m/s$

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

$$10 + \frac{400,000}{9.81\times1000} + \frac{(0.5655)^2}{2(9.81)} = 6 + \frac{P_2}{9.81\times1000} + \frac{(2.2399)^2}{2\times9.81}$$

$P_2 / 9.81\times1000 = 50.79 - 6.26$

$P_2 = (9.81\times1000)(44.53)$

~~$P_2 = 436,536.326 N/m^2$~~

$P_2 = 436836 N/m^2$

Question 10

10) ρ_m = density of mercury ρ_f = density of flowing fluid

y → manometric reading

$$h = y\left[\frac{\rho_m}{\rho_1} - 1\right]$$

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

h = 2.0134

Calculate velocity of submarine

$V = \sqrt{2gh}$

$V = \sqrt{2\times9.81\times2.0834}$

V = 6.393 m/sec