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17/ENG06/067
Mechanical

1.)(i) [redacted] Pressure gradient is constant
flow is steady
flow is uniform

(ii) [redacted] Diameter of the pipe
[redacted] Velocity of the flow
[redacted] Viscosity of fluid
density of the fluid passing through the pipe

(iii)

Hydrofoil	Aerofoil
• A wing attached to the hull of a ship that raises it out of the water travelling at speed and thus reduces drag	• Structure with curved surfaces designed to give the most favourable ratio of lift to drag in flight
• A lifting surface that operates in water	• A wing of an aircraft

(b) $\mu = 0.9$ centipoise $b = 10mm = 0.01m$, $y = ?$ $U = 1ms^{-1}$ $dx = 6mm$ $dp = 60kN/m^2$

(i) Velocity distribution

$$u = \frac{Uy}{b} - \left[\frac{1}{2\mu}\left(\frac{dp}{dx}\right)(by - y^2)\right]$$

$$= \frac{1 \times y}{0.01} - \left[\frac{1}{2\times(0.9\times10^{-3})} \cdot \left(\frac{-60\times10^3}{60}\right) \cdot (0.01y - y^2)\right]$$

$$= 100y - [-5560y + (5.56\times10^5 y^2)]$$

$$= 5660y + (5.56y^2 \times 10^5)$$

(ii) Flow rate, $q = \frac{Ub}{2} - \frac{b^3}{12\mu}\left(\frac{dp}{dx}\right)$

$$= \frac{1\times0.01}{2} - \left[\frac{(0.01)^2}{12(0.9\times10^{-3})} \cdot \left(\frac{60\times10^3}{60}\right)\right]$$

$$= 0.05 - [9.259\times10^{-5} \times -10^3] = 0.005 + 9.259\times10^{-2}$$

$$= 0.005 + 0.0926 = 0.0976 m^3/s$$

) Shear stress distribution, $= \frac{\mu U}{b} - \left[\frac{1}{2}\left(\frac{dp}{dx}\right)\cdot(b - 2y)\right]$

$$= \frac{0.9(10^{-3})}{0.01} - \left[\frac{1}{2}\left[-10^3\right]\cdot(0.01 - 2y)\right]$$

$$= 0.09 - [0.5\times -10^3 \times (0.01 - 2y)]$$

$$= 0.09 - [-5 + 10^3 y]$$

$$= 5.09 - 1000y \qquad y = 0.01$$

$$= -4.91$$

(2) $\mu = 0.9 Ns/m^2$, $\theta = 45°$, $\rho = 1260 kg/m^3$, $u = -1.5 ms^{-1}$, $b = 0.01 m$, $P_1 = 250 kNm^{-2}$, $P_2 = 80 kNm^{-2}$

Solution

$\frac{\delta p}{\delta x} = -128.95 \times 10^3 Nm^{-3}$

$P_1' = P_1 + \rho g h = 250 \times 10^3 + (1260 \times 9.81 \times 1)$

$= 2626 \times 10^3 Nm^{-2}$

$P_2' = P_2 + \rho g h = 80 \times 10^3 + (1260 \times 9.81 \times 0) = 80 \times 10^3 Nm^{-2}$

$\delta P = 262.6 \times 10^3 - 80 \times 10^3 = 182.6 \times 10^3 Nm^{-2}$

(i) Velocity distribution

$$U = \frac{U y}{b} - \left[\frac{1}{2\mu} \cdot \left(\frac{dp}{\delta x}\right) \cdot \left(by - y^2\right)\right]$$

$$= \frac{-1.5}{0.01} y - \left[\frac{1}{2(0.9)} \cdot (-128.95 \times 10^3)(0.01y - y^2)\right]$$

$$= -150y - [0.556 \cdot (-128.95 \times 10^3)(0.01y - y^2)]$$

$$u = 566.96y + (7.17 \times 10^4) y^2$$

(ii) shear stress distribution, $u = 566y + (7.17 \times 10^4) y^2$

$$\frac{\delta u}{dy} = 566 + 1.43 \times 10^5 y$$

$$\tau = \mu (du/dy) = 0.9(566 + 1.43 \times 10^5 y)$$

$$\tau = 509.4 + 1.287 \times 10^5 y$$

(iii) Max velocity

Umax occurs at $du/dy = 0$

$$0 = 566.4 + 1.43 \times 10^5 y$$

$$y = \frac{-566.4}{1.43 \times 10^5} = -3.958 \times 10^{-3} m$$

therefore

$$U_{max} = 566.96(y) + (7.17 \times 10^4)(y^2)$$

$$= -2.24 + 1.12$$

$= -1.12$ (in the opposite direction of the flow)

(iv) $\tau = 509.4 + 1.287 \times 10^5 (-3.958 \times 10^{-3})$

$= 509.4 + (-509.39)$

$= 0.01 Nm^{-2}$