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MATRIC NO: 17/ENG05/037

1a i) Three Conditions for Coutte flow:

- The velocity
- The flow rate
- The sher stress

ii) Four conditions to determine the nature of flow are;

* Mean flow velocity (V)
* The pipe Diameter (D)
* The Density (ρ)
* The fluid viscosity (μ).

iii) Difference btw Aerofoil and hydrofoils are

Aerofoil	Hydrofoil
* Used when the fluid is gas.	* used when the fluid is liquid.
* The foils (wings) are better than foils on a hydrofoil boat.	* The foils on a hydrofoil boat are smaller than the foils (wings) on an aeroplane
* Lift force is due to the angle of attack.	* Lift force is due to the pressure on the bottom of the foil.

1b iii) A liquid of 0.9 centipoise is filled between two horizontal plate of 10mm apart. If the upper plate moves at 1 m/s relative to the lower plate which is stationary and the pressure difference between the two sections 60m apart is 60kN/m², Compute;

i) Velocity distribution.
ii) Discharge per unit width.
iii) Shear stress per unit width.

Solution

Viscosity of the liquid $\mu = 0.9$; Centipoise $= 0.009$ poise $= 0.0009\, Ns/m^2$
Distance b/w the plates, $b = 10mm = 0.01m$
Velocity of the upper plate, $u = 1ms^{-1}$
Pressure difference b/w the sections 6m apart $10^3\, N/m^2/m^2$

i) $$u = \frac{u}{b} + \frac{1}{2\mu}\left(-\frac{\partial p}{\partial x}\right)(by - y^2)$$

$$= \frac{1}{0.01} + \frac{1}{2 \times 0.0009}(10^3)(0.01xy - y^2)$$

$$= y(100 + 5555.55 - 555555.55y)$$

$$\therefore u = y(5655.55 - 555555.55y)$$

ii) discharge per unit width

$$q = \int_0^b u\,dy$$

$$= \int_0^{0.01}(5655.55y - 555555.55y^2)\,dy$$

$$= \left[\frac{5655.55y^2}{2} - \frac{555555.55y^3}{3}\right]$$

$$= \left[\frac{5655.55 \times (0.01)^2}{2} - \frac{555555.55 \times (0.01)^3}{3}\right]$$

$$= 0.282777 - 0.185185$$

$$= 0.975\ m^3/s$$

iii) The shear stress at the upper plate.

Do " "

Sheer Stress $= \mu \times \left(\frac{\partial u}{\partial y}\right) = \mu \frac{\partial}{\partial y}\left(5655.55y - 555555.55y^2\right)$

$= 0.0009\left(5655.55 - 1111111.1y\right)$

$\therefore$ For the top plate; $y = 0.01m$

$T_0 = 0.0009\left(5655.55 - 1111111.1 \times 0.01\right)$

$= 4.91 N/m^2$

2. Laminar flow of a liquid whose viscosity is $0.9 Ns/m^2$ and density of ~~1260~~ $1260 kg/m^3$ occurs b/w a pair of parallel plates of extensive width inclined at an angle of $45°$ to the horizontal. The upper plate moved with a velocity of opposite to the fluid flow. Pressure guages mounted at two points 1m vertically apart on the upper ~~tube~~ plate records a pressure of $250 kN/m^2$ & $80 kN/m^2$ respectively. Determine a) Velocity & shear stress distribution b/w plates.

b) Max flow velocity

c) Shear stress on the upper plate.

Solution

$\mu = 0.9 Ns/m^3$; $\rho = 1260$; Specific gravity $= \frac{1260}{1000} = 1.26$

$b = 10mm = 0.01m$; $u = 1.5ms^{-1}$; $P_1 = 250 kN/m^2$; $P_2 = 80 kN/m^2$

a) velocity & shear stress distribution b/w the plate;

$h_1 - h_2 = \left(\frac{P_1}{w} + z_1\right) - \left(\frac{P_2}{w} + z_2\right)$

$= \left(\frac{250 \times 10^3}{1.26 \times 9810} + 1\right) - \left(\frac{80 \times 10^3}{1.26 \times 9810} + 0\right)$

$= 21.225 - 6.47$

$= 14.755 m$ in $\sqrt{2} m$ or $1.414 m$

$\frac{\partial h}{\partial x} = \frac{-14.755}{1.44} = -10.435$

$$\frac{\partial p}{\partial x} = \frac{w\partial h}{\partial x} = (1.26 \times 9810 \times (-10.435))$$

$$= -128983\ N/m^2 \text{ or } -128.983\ kN/m^2$$

$$\therefore u = \frac{u}{b} \cdot y = \frac{1}{2\mu} \cdot \left(\partial p/\partial x\right)(by - y^2)$$

$$= \frac{-1.5}{0.01} y - \frac{1}{2 \times 0.9} \times (-128.983 \times 10^3)(0.01y - y^2)$$

$$= -150y + 716.57y - 71657y^2$$

$$= 566.57y - (7.165 \times 10^{-4}) y^2$$

The shear stress distribution is given by;

$$\tau = \mu \cdot \frac{V}{b} - \frac{1}{2}\, \partial p/\partial x (b - 2y)$$

$$= 0.9 \times (-1.5/0.01) - \frac{1}{2} \times (-128983)(0.01 - 2y)$$

$$= -135 + 644.92 - 128983y$$

$$= 509.92 - 128983y$$

$$= 509.92 - 1.289 \times 10^5 y$$

b) Maximum flow velocity, V_{max};

for max velocity $\frac{du}{dy} = 0$

$$\frac{\partial}{\partial y}(566.57y - 71657y^2) = 0$$

$$566.57 - 143314y = 0$$

$$y = 566.57/143314 \qquad \therefore y = 3.95 \times 10^{-3} m$$

$$U_{max} = 566.57(3.95 \times 10^{-3}) - 7165 + (3.95 \times 10^{-3})^2$$

$$= 2.238 - 1.118 \Rightarrow 1.12\ ms^{-1}$$

c) The shear stress on the upper plate;

$$\tau_{0.01} = 509.92 - (128983 \times 0.01)$$

$$= -780\ N/m^2$$