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MATRIC NO: 17/ENG06/047
MECHANICAL ENGINEERING

QUESTION 1a ANSWERS

- i. The three conditions for a Couette flow are:
 - a. Pressure gradient is constant
 - b. The flow is uniform
 - c. The flow is steady

- ii. Four (4) conditions that can be used to determine the nature of flow are given by Reynolds experiment as:
 - a. The diameter of the pipe(m)
 - b. The density of the fluid passing through the pipe(kg/m^3)
 - c. The viscosity of the fluid(Ns/m^2)
 - d. The velocity of the flow(m/s)

- iii. The differences between aerofoil and hydrofoils are enlisted below:

AEROFOIL	HYDROFOIL
1. The aerofoil is a lifting device mainly used in gaseous fluids (air in particular)	The hydrofoil is a lifting device mainly utilized in liquid fluids (water)
2. The aerofoil is mainly used for lifting of airplanes and jets.	The hydrofoil is mainly used to overcome drag and make machines move with a higher velocity in water.

QUESTION 1b SOLUTION

Given: $\mu = 0.9$ centipoise = 0.9×10^{-2} poise = 0.9×10^{-3} Ns/m²

$$U = 1 \text{ m/s}$$

$$b = 10 \text{ mm} = 0.01 \text{ m}$$

$$dp = 60 \text{ KN/m}^2$$

$$dx = 60 \text{ m}$$

therefore the pressure difference gradient is = $\frac{\partial p}{\partial x} = \frac{-60000}{60} = -1 \times 10^3 \text{ N/m}^3$

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

$$u = 100y + 5555.56y - 55555.56y^2$$

$$u = (5.65556 \times 10^3)y - (5.556 \times 10^5)y^2$$

ii. Discharge per unit width = $q = \frac{Ub}{2} - \frac{b^3}{12\mu} \left(\frac{\partial p}{\partial x} \right)$

$$q = 0.005 + 0.09259 = 0.09759 \text{ m}^3/\text{s}/\text{m}$$

iii. Shear stress at upper plate is @y=b,

$$\tau = \frac{\mu U}{b} - \frac{1}{2} \left(\frac{\partial p}{\partial x} \right) (b - 2y)$$

$$= \tau = \frac{\mu U}{b} - \frac{1}{2} \left(\frac{\partial p}{\partial x} \right) (-b)$$

$$\tau = 0.09 - 5 = -4.91 \text{ N/m}^2$$

QUESTION 2 SOLUTION

Given: $\mu = 0.9\text{Ns/m}^2$ $b = 10\text{mm} = 0.01\text{m}$

$\rho = 1260\text{kg/m}^3$ $P_1 = 250\text{KN/m}^2$

$U = -1.5\text{m/s}$ $P_2 = 80\text{KN/m}^2$

$$\frac{\partial p}{\partial x} = \frac{-(P_1 - P_2)}{\Delta x}$$

But $P_1 = P_1 + \rho g z$ (piezometric)

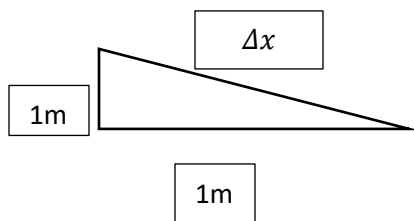
$$= 250000 + (1260) * (9.81) * (1)$$

$$= 262.36\text{KN/m}^2$$

And $P_2 = P_2 + \rho g z$ (piezometric)

$$= 80000 + (1260) * (9.81) * (0)$$

$$= 80\text{KN/m}^2$$



Because the two plates are aligned at an angle of 45 degrees, the above diagram can be used to calculate the change in x

By Pythagoras theorem,

$$\Delta x = \sqrt{1^2 + 1^2} = \sqrt{2} \text{ m}$$

Therefore,

$$\frac{\partial p}{\partial x} = \frac{-(P_1 - P_2)}{\Delta x} = \frac{-(262.36 - 80)}{\sqrt{2}} = -128.948\text{KN/m}^3$$

a. Velocity distribution = $u = \frac{U_y}{b} - \frac{1}{2\mu} \left(\frac{\partial p}{\partial x} \right) (by - y^2)$

$$u = -150y + 716.38y - 71637.8y^2$$

$$u = -(7.16378 \times 10^4)y^2 + 565.62y$$

ii. Shear distribution= $\tau = \frac{\mu U}{b} - \frac{1}{2} \left(\frac{\partial p}{\partial x} \right) (b - 2y)$

$$\tau = -135 + 644.74 - 128948y$$

$$\tau = 509.74 - (1.289 \times 10^5)y$$

b. Maximum flow velocity

At maximum flow velocity, $\frac{\partial u}{\partial y} = 0$

$$0 = -(1.4328 \times 10^5)y + 565.62$$

$$y = 3.9476 \times 10^{-3} \text{ m}$$

$$u_{\max} = -(7.16378 \times 10^4)(3.9476 \times 10^{-3})^2 + 565.62(3.9476 \times 10^{-3})$$

$$u_{\max} = 1.12 \text{ m/s}$$

c. Shear stress at upper plate is @y=b

Therefore, $\tau = 509.74 - (1.289 \times 10^5)y$

$$\tau = 509.74 - (1.289 \times 10^5)(0.01)$$

$$\tau = -779.26 \text{ N/m}^2$$