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17/ENG006/059

Mechanical Engineering

Fluid Mechanics Assignment 3

1. Given $\mu = 0.9 \text{Ns/m}^2$, $\rho = 1260 \text{kg/m}^3$, $L = 65 \text{m}$, $D = 10 \text{mm} = 0.01 \text{m}$

$q = 180 \text{lt/min} = 0.003 \text{m}^3/\text{s}$

a) from continuity equation

$$q = A \cdot u$$

$$\text{where } A = \frac{\pi D^2}{4} = \frac{\pi \times (0.01)^2}{4} = 7.855 \times 10^{-5} \text{m}^2$$

$$\therefore u = \frac{q}{A} = \frac{0.003}{7.855 \times 10^{-5}} = 38.19 \text{m/s}$$

$$\therefore Re = \frac{\rho u D}{\mu} = \frac{1260 \times 38.19 \times 0.01}{0.9} = 534.66$$

Because $Re < 2000$, the flow is laminar

$$\text{b) } \Delta P = \frac{32 \mu u L}{D^2} = \frac{32 \times 0.9 \times 38.19 \times 65}{(0.01)^2} = \frac{71191.68}{0.0001} = 7.15 \times 10^8 \text{N/m}^2$$

2. Given $\mu = 800 \text{cp} = 0.8 \text{Ns/m}^2$, $G = 0.85$, $\rho = 850 \text{kg/m}^3$

$\Delta p = 2000 \times 10^3 \text{N/m}^2$, $D = 65 \text{mm} = 0.065 \text{m}$, $L = 95 \text{m}$

$$\text{a) } A = \frac{\pi D^2}{4} = \frac{\pi \times (0.065)^2}{4} = 3.319 \times 10^{-3} \text{m}^2$$

$$\frac{dp}{dx} = \frac{-2000 \times 10^3}{95} = -21.05 \times 10^3$$

Rate of flow, $Q = A \cdot u$

$$\text{where } u = \frac{-1}{8\mu} \frac{dp}{dx} R^2$$

$$= \left(\frac{-1}{8 \times 0.8} \right) (-21.05 \times 10^3) (0.0325)^2 = 3.474 \text{m/s}$$

$$\therefore Q = 3.474 \times 3.319 \times 10^{-3} = 0.0115 \text{m}^3/\text{s}$$

b. Center line velocity = U_{max}

$$\text{But, } U_{max} = 2 \times u$$

$$= 2 \times 3.474 = 6.948 \text{ m/s}$$

c. Total frictional drag, f_D

$$f_D = T_0 \pi DL$$

$$\text{where } T_0 = \frac{-\delta p}{\delta x} = \frac{21.05 \times 10^3 \times 0.0325}{2}$$

$$T_0 = 342.0625 \text{ N/m}^2$$

$$\therefore f_D = 342.0625 \times \pi \times 0.065 \times 95 = 6636.645 \text{ N} \approx 6.637 \text{ kN}$$

d. Power required to maintain the flow

$$P = f_D \times U$$

$$P = 6636.645 \times 3.474$$

$$= 23055.7 \text{ Watts}$$

$$= 23 \text{ kW}$$

e. Velocity gradient at the pipe wall

$$T_0 = \mu \frac{\delta u}{\delta y} \text{ @ } y=0$$

$$\therefore \frac{\delta u}{\delta y} = \frac{T_0}{\mu} = \frac{342.0625}{0.8} = 427.584 \text{ s}^{-1}$$

f. Velocity and shear stress 60mm from wall

$$u = \frac{-1}{4\mu} \frac{\delta p}{\delta x} (R^2 - r^2)$$

$$\text{but } y = R - r \text{ and } y = 60 \text{ mm} = 0.06 \text{ m}$$

$$\therefore 0.06 = 0.065 - r$$

$$r = 0.005$$

$$\therefore u = \frac{-1}{(4 \times 0.8)} (-21.05 \times 10^3) (0.065^2 - 0.005^2)$$

$$\text{or } u = 27.628 \text{ m/s}$$

The shear stress can be found as;

$$\frac{\tau}{r} = \frac{T_0}{R}$$

$$\therefore \tau = \frac{r \times T_0}{R} = \frac{0.005 \times 342.0625}{0.065}$$

$$= 26.3558 \text{ N/m}^2 //$$