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Assignment 3

Question 1

Glycerine of viscosity 0.9 Ns/m² and density 1280 Kg/m³ is pumped along a horizontal pipe 65m long and 10mm diameter at a flow rate of 180 Lit/min. (a) Determine the nature of flow (b) Compute the pressure loss due to frictional effect

Solution

Viscosity, $\mu = 0.9 \, Ns/m^2$

Density $= 1280 \, Kg/m^3$

Specific gravity $= 1.28$

Diameter $= 10mm = 0.01m$

Length $= 65m$

Area of the pipe $= A = \frac{\pi D^2}{4} = \frac{\pi (0.01)^2}{4}$

$A = 7.854 \times 10^{-5} m^2$

$A \approx 7.9 \times 10^{-5} m^2$

(a) Rate of flow, $Q = A\bar{u}$

where $\bar{u} = -\frac{1}{8\mu} \frac{\partial P}{\partial x} R^2$

$Q = A\bar{u}$

$180 = (7.9 \times 10^{-5}) \times \bar{u}$

$\bar{u} = \frac{180}{7.9 \times 10^{-5}} = 2278481.013 \, m/s$

$Re = \frac{\rho u D}{\mu} = \frac{1280 \times 2278481.013 \times 0.01}{0.9}$

$Re = 31898734.18$

$Re > 2000$

Hence, the flow is 'TURBULENT'.

(b) Pressure loss due to frictional effect, ΔP -

$$\Delta P = \frac{32 \mu \bar{u} L}{D^2}$$

$$= \frac{32(0.9)(2278481.0.3)(65)}{(0.01)^2}$$

$$\Delta P = 4.3 \times 10^{13} \ KN/m^2$$

Question 2

Given the following specifications

Viscosity = 800cp

Specific gravity = 0.85

Pipe diameter = 65mm

Pressure drop = 2000KN/m²

Length of the pipe = 95m

- Determine (a) Rate of flow of oil (b) Centre line Velocity (c) Total frictional drag over the entire length of the pipe (d) Power required to maintain the flow (e) Velocity gradient at the pipe wall. (f) Velocity and shear stress at 60mm from the wall.

Solution

Viscosity, μ = 800 Centipoise = $\frac{800}{1000}$ = 0.8 $N s/m^2$

Specific Gravity = 0.85

Density, ρ = 0.85×10^3 kg/m³

Pressure Drop, ΔP = 2000KN/m²

Length of the pipe, L = 95 metres

Pipe Diameter, D = 65mm = 0.065m

(a) Rate of flow, Q = $A\bar{u}$

Area, $A = \frac{\pi D^2}{4} = \frac{\pi (0.065)^2}{4} = 3.32 \times 10^{-3}$

Area $= 0.00332$

find $\bar{u}$

$$\Delta P = \frac{32 \mu \bar{u} L}{D^2} =$$

$$2000 = \frac{32 \times 0.8 \bar{u} \times 95}{0.065^2} = \frac{2432\bar{u}}{4.225 \times 10^{-3}}$$

$$2432\bar{u} = 2000 \times 4.225 \times 10^{-3}$$

$$\bar{u} = \frac{8.45}{2432} = \cancel{3.47 \times 10^{-3}}$$

$$\bar{u} = 3.495065789 \times 10^{-3} \text{ m/s}$$

$$\bar{u} \approx 3.5 \times 10^{-3} \text{ m/s}$$

$$Q = 0.00332 \times (3.5)$$

$$Q = 0.01162 \text{ m}^3/\text{s}$$

Nature of flow

$$Re = \frac{\rho u D}{\mu} = \frac{0.85 \times 10^3 \times 3.47 \times 0.065}{0.8}$$

$$Re = 239.646875$$

$Re \approx 239.65$, Since $Re < 2000$.

Hence, The Flow is 'LAMINAR'

(b) Centre line velocity, U_{max}

$$U_{max} = 2\bar{u}$$

$$= 2 \times (3.5)$$

$$U_{max} = 7 \text{ m/s}$$

(c) Total frictional drag, F_D

$$F_D = \tau \pi D L$$

$$\frac{\partial p}{\partial x} = \frac{2000 \times 10^3}{95}, \quad r = \frac{D}{2} = 0.0325$$

$$\tau_0 = -\frac{\partial P}{\partial x}\frac{r}{2} = \frac{2000\times10^3 \times 0.0325}{95\times2}$$

$\tau_0 = 342.11\, N/m^2$

$F_D = 342.11 \times 3.142 \times 0.065 \times 95$

$F_D = 6636.706372$

$= 6636.7N$

$F_D \approx 6.637\, KN$

(d) Power to maintain the flow, $P = F_D \times \bar{U}$

$= 6636.7 \times 3.5$

$= 23228.45$ Watt

$P = 23.5\, KW$

(e) Velocity gradient at pipe wall

$$\tau_0 = \mu \frac{\partial u}{\partial y} \quad @\ y = 0$$

$$\frac{\partial u}{\partial y} = \frac{\tau_0}{\mu} = \frac{342.11}{0.8} = 427.63875\, s^{-1}$$

(f) Velocity at 60mm from the wall:

$y = 60mm = 0.06m$

	$y = R - r$
	$0.06 = 0.0325 - r$
$u = \frac{-1}{4\mu}\frac{\partial p}{\partial x}(R^2 - r^2)$	$-r = 0.0275$
	$r = -0.0275$

$$u = \frac{-1}{4(0.8)}\left(\frac{-2000\times10^3}{95}\right)\left(0.06^2 - (-0.0275)^2\right)$$

$u = 18.70888158$

$u \approx 18.7\, m/s$

(g) Shear Stress:

$$\frac{\tau_{mm}}{r} = \frac{\tau_o}{R}$$

$$\frac{\tau_{mm}}{0.0275} = \frac{342.11}{0.0325}$$

$342.11 \times 0.0275 = 0.0325\,\tau_{mm}$

$9.408025 = 0.0325\,\tau_{mm}$

$\tau_{mm} = 289.4776923$

$\tau_{mm} \approx 289.5\,N/m^2$