## Chapter 8: The Motion of Fluids

Stress and Strain in Fluids

$$\tau = C\frac{du}{dy}.$$

Newtonian Fluids

$$\mu = \frac{\tau}{-\frac{du}{dy}} = \text{constant, i.e.} \neq f\left(\frac{du}{dy}\right)$$

Non-Newtonian Fluids

$$\mu_{app} = \frac{\tau}{-du/dy} = f\left(\frac{du}{dy}\right)$$

Power-Law Fluids --> for these fluids, shear stress is proportional to shear rate raised to a power n.

$$\tau = -K\left|\frac{du}{dy}\right|^n = -K\left|\frac{du}{dy}\right|^{n-1}\frac{du}{dy}$$

<u>Bingham Plastic Fluids</u>

$$\tau = \tau_o - \mu_o\left(\frac{du}{dy}\right) \text{ for } \tau \geq \tau_o$$

and du/dy = 0 for $\tau < \tau_o$

<u>8.2 Potential Flow</u>

Bernoulli's Equation

$$P + \frac{1}{2}\rho u^2 + \rho hg = \text{constant, or}$$

Flow of Viscous (Real) Fluids

**Reynolds Number**

$$R_e = \frac{D\bar{u}\,\rho}{\mu}$$, Where,

D = pipe diameter, m
$\bar{u}$ = average velocity, m/s
ρ= density, kg/m$^3$
μ= viscosity, Pa.s or kg/m.s

Laminar flow in pipes when Re < 2,100
Turbulent flow in pipes when Re > 4,000

**Laminar Flow in Pipes; The Hagen Poiseulle Eqn.**

$$-\left[\frac{\Delta P}{L} + \rho g\,\frac{h_2 - h_1}{L}\right] = \frac{8\mu Q}{\pi r_w^4} = \frac{128\mu Q}{\pi D^4}$$

Other useful equations

$$or, \quad \frac{u}{u_{\max}} = \left[1 - \left(\frac{r}{r_w}\right)^2\right]$$

$$\bar{u} = \frac{u_{\max}}{2}$$

$$\frac{\tau_w}{r_w} = \frac{\tau}{r} = \text{constant}$$

**Turbulent Flow in Pipes**

$$\frac{\bar{u}}{u_{\max}} = \left[1 - \frac{r}{r_w}\right]^{1/7}$$

The friction factor

$$f = \frac{2\tau_w}{\rho \bar{u}^2}$$

$$-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{2 f \bar{u}^2 \rho}{D}$$

**Use of Friction Factor Chart**

- Calculate Re
- Determine the pipe roughness
- Read the value of f at appropriate Re and pipe roughness
- Use: $-\left[\frac{\Delta P}{L} + \rho g \frac{\Delta h}{L}\right] = \frac{2 f \bar{u}^2 \rho}{D}$ to calculate pressure drop.

## Chapter 9: The Structure and Transport Properties of Solids

**Heat Conduction in Solids**

$$\kappa = \frac{Q / A}{-(dT / dx)}$$

$$Q = -\kappa A \frac{dT}{dx} = -\kappa A \frac{\Delta T}{\Delta x}$$

Composite (Layered) Walls

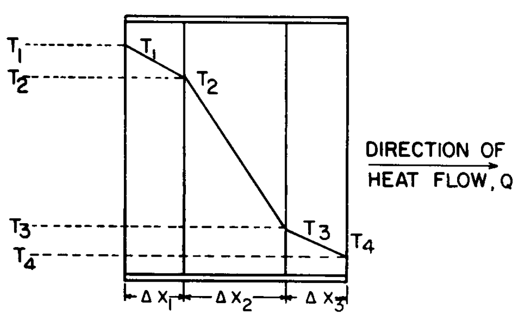


**Figure 9-6 Temperature Profile for a Composite Wall**

$$Q = \frac{A(T_1 - T_4)}{\left[\frac{\Delta x_1}{\kappa_1} + \frac{\Delta x_2}{\kappa_2} + \frac{\Delta x_3}{\kappa_3}\right]}$$

For Cylindrical systems

a. Single walls,

$$Q = \frac{2\pi\kappa L(T_1 - T_2)}{\ln\left(\frac{r_2}{r_1}\right)}$$

b. For composit Walls

$$Q = \frac{-2\pi L\Delta T}{\frac{\ln(r_2/r_1)}{\kappa_1} + \frac{\ln(r_3/r_2)}{\kappa_2} + \frac{\ln(r_4/r_3)}{\kappa_3} + \ldots\ldots.}$$

## CHAPTER 10

## STRESS-STRAIN RELATIONSHIP FOR SOLIDS

Young's Modulus for Linear Deformation

$$\sigma_y = E\varepsilon_y$$

$$\sigma_y = \frac{F_y}{A} \quad \text{and} \quad \varepsilon_y = \frac{\Delta y}{y_o}$$

***Poisson's Ratio*** (denoted by ν)

$$\nu = \frac{-\varepsilon_x}{\varepsilon_y}$$

For a three-dimensional body, stressed in all three directions,

$$\varepsilon_x = \frac{\sigma_x}{E} - \frac{\nu}{E}\left(\sigma_y + \sigma_z\right)$$

$$\varepsilon_y = \frac{\sigma_y}{E} - \frac{\nu}{E}\left(\sigma_x + \sigma_z\right)$$

$$\varepsilon_z = \frac{\sigma_z}{E} - \frac{\nu}{E}\left(\sigma_y + \sigma_x\right)$$

The bulk Modulus for Volume Change

$$\frac{\Delta V}{V} = \frac{-3(1-2\nu)P}{E} \equiv -\frac{P}{K}$$

Where, $K = \dfrac{E}{3(1-2\nu)}$ is called the bulk modulus of elasticity. It is a function of E and ν.

The bulk modulus is used when the normal stress is same in all directions.