Chapter 5 : <u>Flow Past Immersed Bodies</u>

<u>Important terms</u> ⇒

- ★ **Drag :** The force in the direction of flow exerted by fluid on the solid is called drag.
- ★ **Wall drag :** Drag generated because of wall shear.
- ★ **Form drag :** Drag generated from pressure forces.
- ★ **Darcy's Law :** 1) Often used to describe flow of liquid through porous media.
  2) For a given system, the flow is proportional to the pressure drop and inversely proportional to the fluid viscosity.
- ★ **Free settling :** When a particle is at sufficient distance from container boundaries and other particles , it's fall is not affected by them and this condition is called free settling.
- ★ **Fluidization :** 1) Used to describe the condition of fully suspended particles.

  2) When the fluid velocity is steadily increased , the pressure drop and drag on the individual particles increases and eventually they start to move and become suspended in fluid.

  3) After fluidization, pressure difference remains constant, but bed height continues to increase with flow.
- ★ **Forces acting on a particle moving in fluid :**
  1) External force (gravitational / centrifugal)
  2) Drag in parallel direction of flow opposite to particle motion.

3) Buoyancy force

★ **Streamlining :** Form drag can be minimized by forcing separation toward the rear of the body. This is accomplished by streamlining. The usual method of streamlining is to so proportion the rear of the body that the increase in pressure in the boundary layer, which is the basic cause of separation, is sufficiently gradual to delay separation. Streamlining usually calls for a pointed rear, like that of an airfoil. A perfectly streamlined body would have no wake and little or no form drag.

★ **Void fraction :** It is defined as the ratio of void volume to total volume.

<u>Important formulas</u> ⇒

1. **Drag coefficient :** where , Ap is the projected area

$$C_D \equiv \frac{F_D/A_p}{\rho u_0^2/2g_c}$$

2. **Stoke's law :** when reynolds number is < 1

$$F_D = 3\pi \frac{\mu u_0 D_p}{g_c} \quad , \quad C_D = \frac{24}{N_{Re,p}}$$

3. **Sphericity :**

$$\Phi_s = (6/D_p)/(s_p/v_p)$$

4. ***Kozeny-Carman* equation :**
   (when Nre is < 1)

$$\frac{\Delta p}{L} = \frac{150\overline{V}_0\mu}{g_c\Phi_s^2 D_p^2}\frac{(1-\varepsilon)^2}{\varepsilon^3}$$

5. **Burke-Plummer equation :**

(when Nre > 1000)

$$\frac{\Delta p}{L} = \frac{1.75\rho \overline{V}_0^2}{g_c \Phi_s D_p} \frac{1-\varepsilon}{\varepsilon^3}$$

6. **Ergun equation :**

$$\frac{\Delta p}{L} = \frac{150\overline{V}_0 \mu}{g_c \Phi_s^2 D_p^2} \frac{(1-\varepsilon)^2}{\varepsilon^3} + \frac{1.75\rho \overline{V}_0^2}{g_c \Phi_s D_p} \frac{1-\varepsilon}{\varepsilon^3}$$

7. **Terminal velocity :**

$$u_t = \sqrt{\frac{2g(\rho_p - \rho)m}{A_p \rho_p C_D \rho}}$$

8. **Motion of spherical particles :**

$$u_t = \sqrt{\frac{4g(\rho_p - \rho)D_p}{3C_D \rho}}$$

9. **Stoke's law region :**

(when Nre is < 1)

$$u_t = \frac{g D_p^2(\rho_p - \rho)}{18\mu}$$

10. **Newton's law region :**

(when Nre is > 1000)

$$u_t = 1.75\sqrt{\frac{g D_p(\rho_p - \rho)}{\rho}}$$

11. CRITERION FOR SETTLING REGIME :

If K is < 2.6 ⇒ Stoke's law applies
If 68.9< K < 2360 ⇒ Newton's law applies

12. Minimum Fluidization Velocity :

- For Nre<1

$$\overline{V}_{OM} \approx \frac{g(\rho_p - \rho)}{150\mu} \frac{\varepsilon_M^3}{1 - \varepsilon_M} \Phi_s^2 D_p^2$$

- For Nre>1000

$$\overline{V}_{OM} \approx \left[\frac{\Phi_s D_p g(\rho_p - \rho)\varepsilon_M^3}{1.75\rho}\right]^{1/2}$$