FLUID MECHANICS I – MODULE 1

PROPERTIES OF FLUIDS

Fluid mechanics deals with the study of fluids (liquids and gases) at rest and in motion. A fluid is defined as a substance that deforms continuously when subjected to a shear stress, however small that stress may be. Unlike solids, which resist deformation, fluids flow under applied shear. Fluid mechanics can be divided into: - Fluid Statics (fluids at rest) - Fluid Kinematics (motion without considering forces) - Fluid Dynamics (motion considering forces and energy)

BASIC PROPERTIES OF FLUIDS

Density (ρ): Mass per unit volume, $\rho = m/V$ (kg/m^3). For water at 4°C, $\rho = 1000\ kg/m^3$.
Specific Weight (γ): Weight per unit volume, $\gamma = \rho g$ (N/m^3).
Specific Gravity (S): Ratio of density of fluid to density of water, $S = \rho/\rho w$.
Viscosity (μ): Internal resistance to flow. It relates shear stress τ and velocity gradient du/dy as $\tau = \mu(du/dy)$.
Kinematic Viscosity (ν): $\nu = \mu/\rho$ (m^2/s).
Compressibility (β): Fractional change in volume per unit pressure change, $\beta = -(1/V)(dV/dp)$.
Bulk Modulus (K): Reciprocal of compressibility, $K = 1/\beta = -V(dp/dV)$.
Vapour Pressure (pv): Pressure exerted by vapour molecules above a liquid surface at equilibrium.
Surface Tension (σ): Force per unit length acting on liquid surface. For water at 20°C, $\sigma = 0.0728$ N/m.

NEWTON’S LAW OF VISCOSITY

Consider two fluid layers separated by a distance dy and moving with velocity difference du. The shear stress τ required to maintain motion is proportional to du/dy: $\tau = \mu(du/dy)$. Fluids following this relation are Newtonian (e.g., water, air), while non-linear fluids are Non-Newtonian (e.g., paints, blood).

CAPILLARITY

When a small-diameter tube is dipped in a liquid, the liquid level rises or falls due to surface tension. The capillary rise is given by: $h = (4\sigma\cos\theta)/(\rho g d)$, where θ is contact angle and d is tube diameter. Water rises ($\theta < 90°$), mercury falls ($\theta > 90°$).

COHESION AND ADHESION

Cohesion is the attraction between like molecules (water-water), while adhesion is attraction between unlike molecules (water-glass). Capillary rise results from the balance of these two effects.

COMPRESSIBLE AND INCOMPRESSIBLE FLUIDS

Liquids are nearly incompressible, while gases are compressible. For compressible fluids, pV^n = constant, where n is the polytropic index (n = 1 for isothermal, $n = \gamma$ for adiabatic).

NEWTONIAN AND NON-NEWTONIAN FLUIDS

Newtonian fluids show a linear relation between τ and du/dy, while non-Newtonian fluids show non-linear behavior.
Types:
- Pseudoplastic (shear-thinning)
- Dilatant (shear-thickening)

- Bingham plastic (requires yield stress before flow)

CONTINUUM HYPOTHESIS

Fluids are treated as continuous media where properties like density and velocity are defined at every point. This assumption is valid when the mean free path of molecules is much smaller than the characteristic dimension of flow.

MEASUREMENT OF VISCOSITY

Capillary-Tube Method: Based on Poiseuille’s law: Q = (πr■Δp)/(8μL). By measuring Q and Δp, μ can be found.
Falling-Sphere Method: Based on Stokes’ law. When a sphere falls at terminal velocity Vt through a fluid:
$\mu = (2r^2g(\rho s - \rho))/(9Vt)$.

IMPORTANT UNITS

Density: kg/m^3 | 1 g/cm^3 = 1000 kg/m^3
Viscosity: Pa·s | 1 Poise = 0.1 Pa·s
Surface Tension: N/m | 1 dyn/cm = 0.001 N/m
Pressure: N/m^2 (Pa) | 1 atm = 101325 Pa

EXAM POINTS

- Explain Newton’s law of viscosity with a diagram.
- Derive expression for capillary rise.
- Define surface tension and its significance.
- Differentiate between Newtonian and Non-Newtonian fluids.
- Explain the measurement of viscosity by capillary and falling sphere methods.