CHAPTER - 10

MECHANICAL PROPERTIES OF FLUIDS

SYNOPSIS:

- **Property of a fluid** :
  (1) It can flow.
  (2) It **does not** have any resistance to change its shape.
  (3) The shape of a fluid is governed by the **shape of its container**.

- **Liquids** are incompressible and has a free surface of its own.

- **Gases** are compressible and it expands to occupy all the space available to it.

- **F** is the normal force exerted by a fluid on an area.

- The **average pressure P_{av}** :The ratio of the force to area

$$P_{av} = \frac{F}{A}$$

- The unit of the pressure is the **pascal.** It is the same as Nm^{-2} . Other common units of pressure are:

  1 atm = 1.01 × 10^5Pa

  1 bar = 10^5 Pa

  1 torr = 133Pa = 0.133KPa

  1 mm of Hg = 1 torr = 133Pa

- **Pascal's law:** 'Pressure in a fluid at rest is same at all points which are at the same height. A change in pressure applied to an enclosed fluid is transmitted undiminished to every point of the fluid and the walls of the containing vessel'.

- The **pressure in a fluid** varies with depth h according to the expression $P = P_a + \rho gh$ where P is the density of the fluid assumed uniform.

- The volume of an **incompressible** any point every second in a pipe of non uniform crossection is the same in the steady flow. **vA = constant**. The equation is due to mass conservation in incompressible fluid flow.

- **Bernoulli's principle** : As we move along a streamline, the sum of the pressure(**P**), the kinetic energy per unit volume($\rho\mathbf{v^2/2}$) and the potential energy per unit volume ($\rho\mathbf{gy}$) remains a constant $\mathbf{P + \rho v^2/2 + \rho gy = constant}$.
  The equation is basically the conservation of energy applied to non viscuss fluid motion in steady state.

- **Shear strain** in a fluid **does not** require **shear stress**, when a shear stress is applied to a fluid, the motion is generated which causes a shear strain growing with time.

- The **ratio** of the **shear stress** to the time rate of **shearing strain** is known as **coefficient of viscosity,η.**
  where symbols have their usual meaning.

- **Tokes' law:** 'The viscous drag force **F** on a sphere of radius a moving with velocity **v** through a fluid of viscosity is
  $\mathbf{F = -6\pi\eta av'}$.

- **Reynolds number** : The onset of turbulence in a fluid is determined by a dimensionless parameter : $\mathbf{R_e = \rho vd/\eta}$
  Where d is a typical geometrical length associated with the fluid flow and the other symbols have their usual meaning.

- **Capillarity:** The phenomenon of rise or fall of a liquid in a capillary.

- **Pressure on the surface:** Force acting on a surface per unit area in a direction perpendicular to it.

- **Density of the object:** The ratio of the mass to the volume of an object.

- **Surface tension:** Force per unit length or surface energy per unit area, acting in the plane of interface between the liquid and the bounding surface.

- **Specific gravity:** Two substances and more are done with water and the magnitude of relative density of a substance gives us the idea of heaviness of the substance.

- **Relative density or specific density:** The ratio of density of a substance, to the density of water at 277 K.

- **Buoyant force**: The upward force exerted by any fluid on an object.

- **Archimedes's Principle:** 'When a body is partially or completely immersed in a liquid, the buoyant force acting on it is equal to the weight of the displaced liquid and it acts in an upward direction at the centre of gravity of the displaced liquid'.

- **Steady flow:** The velocity of the fluid at each point remains constant with time.

- **Velocity gradient:** The difference in velocity between two layers of liquid per unit perpendicular distance, in the direction perpendicular to the direction of flow.

- **Unsteady flow:** The velocity of the fluid at a given point keeps on changing with time.
  For example, the motion of water during ebb and tide.

- **Turbulent flow:** The velocity of the fluid changes erratically from point to point as well as from time to time.
  For example waterfalls, breaking of the sea waves are examples of turbulent flow.

- **Irrotational flow:** The element of a fluid at each point has no net angular velocity about that point.

- **Rotational flow:** The element of a fluid at each point has net angular velocity about that point.

- **Incompressible flow:** The density of a fluid remains constant with time.

- **Compressible flow:** The density changes with position and time.

- **Non-viscous flow:** The flow of a fluid having small co-efficient of viscosity.

- **Viscous flow:** The flow of a fluid which has large co-efficient of viscosity**.**

- **Streamlines:** The path of motion of a fluid particle in one direction.

- **Surface tension:** The surface of a liquid has a tendency to contract like stretched elastic membrane and as a result tension prevails in the surface.

- **Cohesive force:** The intermolecular attractive force between the molecules of the same matter.

- **Adhesive force**: The attractive force between the molecules of different matter.

- **Reynolds number:** The type of a flow through tube which depends on four factors:
  (1) The co-efficient of viscosity (η) of the fluid.
  (2) The density (ρ) of the fluid.
  (3) Average velocity (ν) of the fluid.
  (4) The diameter (D) of the tube.

- Reynolds number $N_R = \frac{\rho \nu D}{\eta}$

  The magnitude of N_R depends on the types of the flow, N_R is dimensionless.
  Experiments show that,
  if N_R < 2000, the flow is streamline,
  if N_R < 3000, the flow is turbulent,
  if 2000 < N_R < 3000 the flow is unstable and may change from streamline flow to turbulent flow.

- If η = 0, (i.e. d is non-viscous), N_R will be infinite. Hence the flow of non-viscous liquids can never become streamline, whatever the value of ν may be (except at ν = 0!!).