Mechanical Properties of Fluids

Brief Overview

All the substances in nature and otherwise, which flow, are known as fluids. And the study of the mechanical properties of fluids is known as Fluid Mechanics. However, before proceeding, there are 2 important concepts that you must be aware about:

- The density of fluids is independent of any pressure variation and remains constant. This property is known as incompressibility.
- Two-fluid surfaces in contact do not exert a tangential force on each other. This property is known as non-viscosity.

Now that you have got a brief idea, let us understand the important mechanical properties of fluid in detail.

Fluid Dynamics

Fluid dynamics incorporate energy into the study of the mechanical properties of fluids. The type of flow in which the velocity of particles crossing a particular point is the same irrespective of time is known as steady flow. The path taken by particles is known as the line of flow.

Surface Tension

Surface tension is defined as the force per unit length in the plane of the liquid surface at right angles to either side of an imaginary line drawn on that surface. Surface energy is the work done over the surface of a liquid to increase its surface area.

Atmospheric Pressure

Atmospheric pressure is the pressure of the earth's atmosphere. The value generally taken is 1 bar or 1.013×10^5 Pa. Pressure above atmospheric pressure is termed as gauge pressure, while the total pressure is termed as the absolute pressure. A barometer is used to measure total pressure while a manometer is used to measure the gauge pressure. With its applications rooted across aviation and other sectors, understanding this mechanical property of the fluid is essential.

Fluid Pressure

It is the pressure at any point in the fluid and is defined as the normal force per unit area. The SI unit of pressure is Pascal. The pressure is a scalar quantity and has no direction of its own. It acts perpendicular to any surface in the fluid. The following are the rules governing the determination of pressure with respect to the mechanical properties of fluids:

- The pressure at two points at the same horizontal level in the fluid is the same if it is at rest or moving with a constant velocity.
- If the fluid is accelerating, the pressure difference between two points at different vertical levels is given by the formula:

$$p_2 - p_1 = \rho a l$$

Where P1 = Pressure at Point 1, P2= Pressure at Point 2, l = distance between two points, and a = acceleration.

Viscosity

The property of a fluid by virtue of which it opposes relative motion between two layers is known as viscosity. Stokes' Law states that when a solid moves through a medium, its motion is opposed by a viscous force depending on the velocity and shape and size of the body. This law is used extensively in studies of the mechanical properties of fluids.

Pascal's Law

Pascal's Law is an important axiom in the study of the mechanical properties of fluids. It states that a change in the pressure applied to a closed fluid is transmitted undiminished to every portion of the fluid and to the walls of the containing vessel. It is used in various industrial applications. Its formula is given as:

$$F=PA$$

Where F = Force, P = Pressure, and A = Area

Archimedes' Principle

This is another important rule in the study of the mechanical properties of fluids. It states that when a body is partially or fully dipped in a fluid, the fluid exerts a contact force on

the body which is equal to the weight of the fluid displaced by the body. This force is known as the buoyant force. This force acts vertically against the weight of the body through the centre of gravity of the displaced liquid, known as the centre of buoyancy.

Note *The rules of flotation state that a body will float if its average density is less than that of the liquid. The centre of gravity of the body and the centre of buoyancy must be along the same straight line, while the weight of the liquid displaced by the immersed part of the body must be equal to the weight of the body.*

Bernoulli's Theorem

This is an essential theorem in the determination of the mechanical properties of fluids. It states that in the streamlined flow of an ideal fluid, the sum of pressure energy per unit volume, potential energy per unit volume, and kinetic energy per unit volume is always constant at all cross-sections of the liquid.

$$p + \frac{1}{2} \rho v^2 + \rho g h = \text{constant}$$

Here, p = Fluid Pressure, v = Fluid Velocity, ρ = Fluid Density, and h = Container's Height