SNS COLLEGE OF TECHNOLOGY
(An Autonomous Institution)
COIMBATORE-35

19MCT203 – Fluid Mechanics and Thermal Systems

Unit – I
Fluid Concepts and Fluid Statics

UNIT 1 FLUID PROPERTIES

Fluids: Substances capable of flowing are known as fluids. Flow is the continuous deformation of substances under the action of shear stresses.

Fluids have no definite shape of their own, but confirm to the shape of the containing vessel. Fluids include liquids and gases.

Fluid Mechanics:

Fluid mechanics is the branch of science that deals with the behavior of fluids at rest as well as in motion. Thus,it deals with the static, kinematics and dynamic aspects of fluids.

The study of fluids at rest is called fluid statics. The study of fluids in motion, where pressure forces are not considered, is called fluid kinematics and if the pressure forces are also considered for the fluids in motion, that branch of science is called fluid dynamics.

Fluid Properties:

*1.**Density (or)Mass Density***:

Density or mass density of a fluid is defined as the ratio of the mass of the fluid to its volume. *Thus, **Mass per unit volume of a fluid is called density***.

$$\text{Mass density, } \rho = \frac{\text{Mass of fluid}}{\text{Volume of fluid}}$$

S.I unit of density is kg/m^3.

The value of density for water is 1000 kg/m^3.

*2.**Specific weight (or) Weight Density (w)***:

Specific weight or weight density of a fluid is the ratio between the weight of a fluid to its volume.

The weight per unit volume of a fluid is called specific weight or weight density.

$$\text{Weight density} = \frac{\text{Weight of fluid}}{\text{Volume of fluid}}$$

$$w = \frac{\text{Mass of fluid} \times g}{\text{Volume of fluid}}$$

$$w = \rho g$$

S.I unit of specific weight is N/m^3.

The value of specific weight or weight density of water is 9810N/m^3 or 9.81 kN/m^3.

*3. **Specific Volume (v)***:

Specific volume of a fluid is defined as the volume of a fluid occupied by unit mass.

Volume per unit mass of a fluid is called Specific volume.

$$\text{Specific volume} = \frac{\text{Volume of a fluid}}{\text{Mass of fluid}} = \frac{1}{\rho}$$

Thus specific volume is the reciprocal of mass density. **S.I unit: m^3 /kg**.

4. <u>Specific Gravity (s)</u>:

Specific gravity is defined as the ratio of the specific weight of a fluid to the specific weight of a standard fluid.

$$\text{Specific gravity} = \frac{\text{Specific weight of liquid}}{\text{Specific weight of water}}$$

Specific gravity is also equal to Relative density. Relative density = ________________

5. <u>Viscosity</u>:

Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over adjacent layer of the fluid.

When two layers of a fluid, at distance ‘dy’ apart, move one over the other at different velocities, say u and u+du as shown in figure. The viscosity together with relative velocity causes a shear stress acting between the fluid layers.

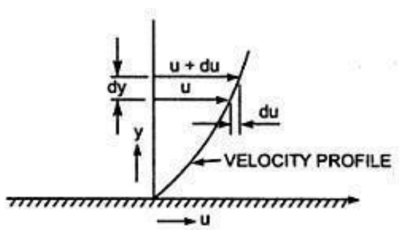
The top layer causes a shear stress on the adjacent lower layer while the lower layer causes a shear stress on the adjacent top layer.

This shear stress is proportional to the rate of change of velocity with respect to y.

$$\tau \; \alpha \frac{du}{dy}$$

or

$$\tau = \mu \frac{du}{dy}$$



Velocity variation near a solid boundary.

Fig.1. Velocity distribution curve

Thus the viscosity is also defined as the shear stress required to produce unit rate of shear strain.

S.I unit: Ns/m^2. It is still expressed in poise (P) as well as centipoises (cP).

$$\text{One poise} = \frac{1}{10}\frac{Ns}{m^2}\;; \qquad 1 \text{ centipoise} = \frac{1}{100} \text{ poise}$$

Kinematic Viscosity (ν): It is defined as the ratio between the dynamic viscosity and density of fluid. It is denoted by the nu.

V = Viscosity/Density = μ/ρ

In MKS and SI unit of kinematic viscosity is metre^2/sec or m^2/sec while CGs units it is written as cm2/s. In CGS units kinematic viscosity is also known as stoke.

One stoke = $cm^2/s = (1/100)^2\ m^2/s = 10^{-4}\ m^2/s$ and centistokes means = 1/100 stoke

Newton's Law of Viscosity:

It states that the shear stress (τ) on a fluid element layer is directly proportional to the rate of shear strain. The constant of proportionality is called the co-efficient of viscosity.

$$\tau = \mu \frac{du}{dy}$$

6.Compressibility:

Compressibility is the reciprocal of the bulk modulus of elasticity, K, which is defined as the ratio of compressive stress to volumetric strain.

Compression of fluids gives rise to pressure with the decrease in volume.

If dv is the decrease in volume and dp is the increase in pressure, Volumetric Strain = $\frac{-dV}{V}$

(- ve sign indicate the volume decreases with increase of pressure)

$$\text{Bulk modulus, } K = \frac{\text{Increase of pressure}}{\text{Volumetric Strain}}$$

$$= \frac{dp}{\frac{-dV}{V}}$$

$$\text{Compressibility} = \frac{1}{K}$$

7.Surface tension:

Surface tension is defined as the tensile force acting on the surface of a liquid in contact with a gas or on the surface between two immiscible liquids such that the contact surface behaves like a membrane under tension.

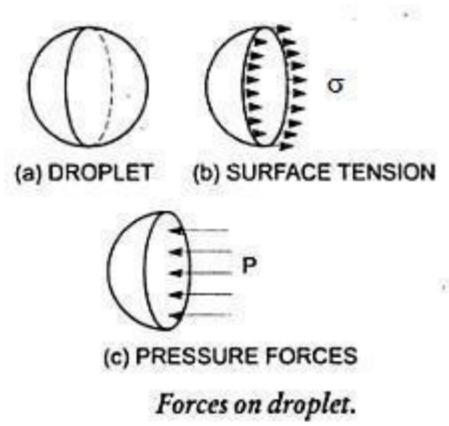


Fig.2. Forces on droplet

Surface Tension on Liquid Droplet:

Consider a small spherical droplet of a liquid of diameter ‘d’. On the entire surface of the droplet, the tensile force due to surface tension will be acting.

Let σ = Surface tension of the liquid

p = Pressure intensity inside the droplet (in excess of the outside pressure intensity) d = Dia. of droplet.

Let the droplet is cut into two halves. The forces acting on one half will be

i) Tensile force (F_T)due to surface tension acting around the circumference of the cut portion as shown in fig. and this is equal to = σ x Circumference = σ x π d

Pressure force (Fp) on the area C= p x (π/4) d^2 as shown in the figure.

These two forces are equal under equilibrium conditions. i.e.,

$p \times (\pi/4)\, d^2 = \sigma \times \pi\, d$

$P = (\sigma \times \pi\, d)/(\sigma \times \pi\, d) = 4\,\sigma/d$

Surface Tension on a Hollow Bubble*:*

A hollow bubble like a soap bubble in air has two surfaces in contact with air, one inside and other outside. Thus two surfaces arc subjected to surface tension. In that case,

$p\,(\pi/4)\, d^2 = 2(\sigma \times \pi\, d)$

$P = (2\sigma\, \pi\, d)/\, (\pi/4)\, d^2 = 8\,\sigma/d$

8. Capillarity:

Capillarity is defined as a phenomenon of rise or fall of a liquid surface in a small tube relative to the adjacent general level of liquid when the tube is held vertically in the liquid.

The rise of liquid surface is known as capillary rise while the fall of the liquid surface is known as capillary depression. It is expressed in terms of cm or mm of liquid. Its value depends upon the specific weight of the liquid, diameter of the tube and surface tension of the liquid.

Expression for Capillary Rise:

Consider a glass tube of small diameter 'd' opened at both ends and is inserted in a liquid. The liquid will rise in the lube above the level of the liquid.

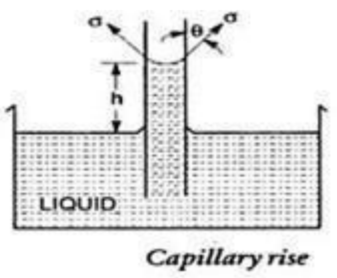


Fig.3. Capillary Rise

Let, h = height of the liquid in the tube. Under a state of equilibrium, the weight of liquid of height h is balanced by the force at the surface of the liquid in the tube. But the force at the surface of the liquid in the tube is due to surface tension.

Let, σ = Surface tension of liquid

θ= Angle of contact between liquid and glass lube.

The weight of liquid of height 'h' in the tube = (Area of tube x h) x ρ x g

where, ρ = density of liquid

Vertical component of the surface tensile force

= σ x Circumference x cos θ

= σ x πd x cos θ

Weight of liquid of height 'h' in the tube = Vertical component of the surface tensile force

$$\frac{\pi}{4}\, d^2 \times h \times \rho \times g = \sigma \times \pi d \times \cos\theta$$

$$h = \frac{\sigma \times \pi d \times \cos\theta}{\frac{\pi}{4} d^2 \times \rho \times g}$$

9. Vapour pressure:

***Vapour pressure** is the pressure of the vapor over a liquid which is confined in a closed vessel at equilibrium.* Vapour pressure increases with temperature. All liquids exhibit this phenomenon.