Module Name: Fluid Mechanics and Hydraulics; FSE: 222

INTRODUCTION AND PROPERTIES OF FLUIDS

Fluid

Fluids are substances capable of flowing, having particles which easily move and change their relative position without a separation of the mass. Fluids offer practically no resistance to change of form. They readily conform to the shape of the solid body with which they come in contact.

Fluids may be divided into liquid and gases.

The principal difference between liquids and gases:

SL No.	Liquid	Gas
1	A liquid has a free surface	A gas doesn't have a free surface
2	A given mass of a liquid occupies only a given volume in a container	A given mass of a gas occupies all portions of any container regardless of its size
3	Liquids are practically incompressible	Gases are compressible
4	When heated its viscosity decreases	Its viscosity increases

General properties of fluid:

1. Density
2. Specific weight
3. Specific gravity
4. Compressibility
5. Surface tension
6. Capillarity
7. Viscosity

1. Density: The density of a liquid may be defined as the mass per unit volume at a standard temperature and pressure and is usually denoted as ρ. Mathematically, density,

$$\rho = \frac{\text{Mass}}{\text{Volume}}$$

The standard values for density of water and air are given as 1000kg/m3 and 1.2 kg/m3, respectively.

Example 1.1: Page-6

2. Specific weight: The specific weight (also known as the unit weight) is the weight per unit volume of a material at the standard temperature and pressure and is usually denoted as w. Mathematically, Specific weight,

$$w = \frac{\text{Weight}}{\text{Volume}}$$

A commonly used value is the specific weight of water on Earth at 4°C which is 9.807 kN/m^3 or 62.43 lbf/ft^3.

Example 1.2: Page-7

3. **Specific gravity:** The Specific gravity of a liquid may be defined as the ratio of its specific weight to that of a standard substance at a standard temperature. For liquids pure water is taken as a standard substance and at 4^oC. Mathematically specific gravity,

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

Example 1.3 & 1.4: Page-7 & 8

4. Compressibility of water: The compressibility of a liquid may be defined as the variation in its volume, with the variation of pressure. Thus, the water is considered to be an incompressible liquid and air is a compressible.

Tensile stress (or tension) is the stress state leading to expansion; that is, the length of a material tends to increase in the tensile direction. The volume of the material stays constant. When equal and opposite forces are applied on a body, then the stress due to this force is called tensile stress.

5. Surface tension: The surface tension of a liquid is its property, which enable it to resist tensile stress. It is due to the cohesion between the molecules at the surface of a liquid.

6. Capillarity: Capillary action (sometimes capillarity, capillary motion, or wicking) is the ability of a liquid to flow in narrow spaces without the assistance of, or even in opposition to, external forces like gravity.

The phenomenon of rising water in the tube of smaller diameter is called the capillary rise as shown in Fig.

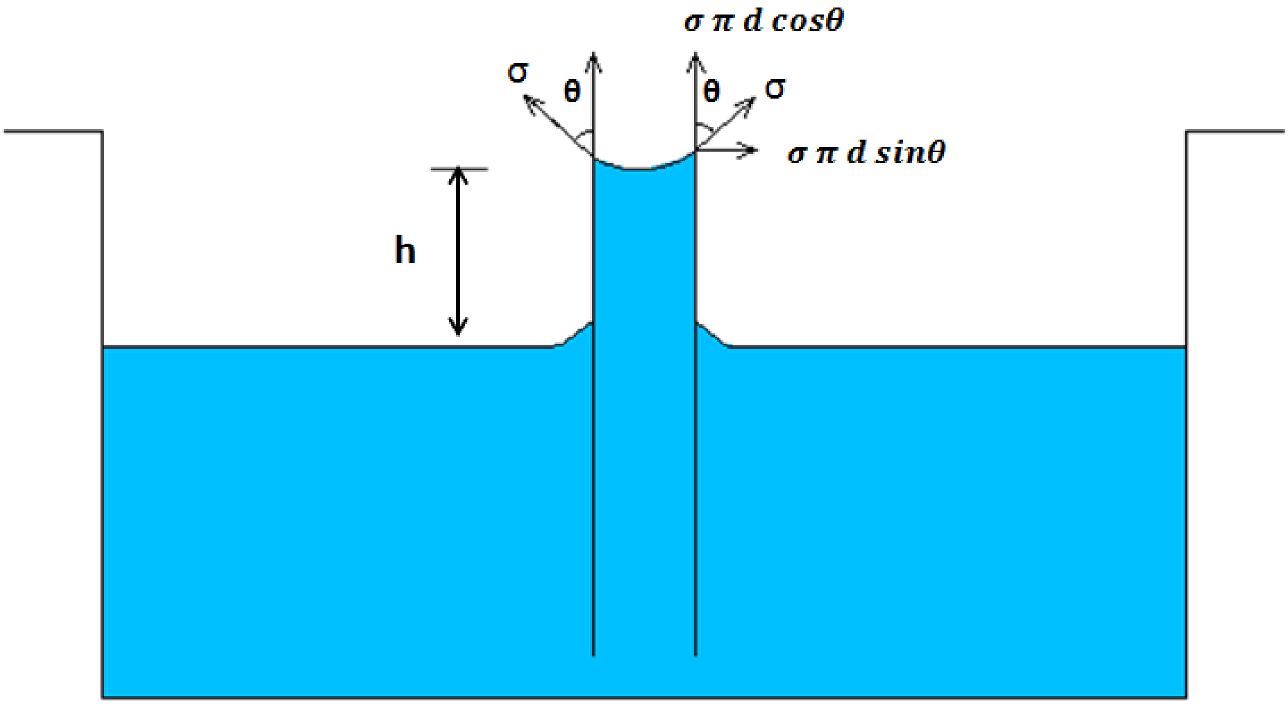

Fig.: Effect of capillarity

Equation: Page-9

Example 1.5: Page-9

7. Viscosity: Viscosity is that property of a fluid which determines its resistance to shearing stress.

Assumptions:

1) That the fluid particles in contact with a moving surface have the velocity of that surface.
2) That the rate of change of velocity is uniform in the direction of motion.
3) That the shearing stress in the fluid is proportional to the rate of change of velocity.

A **shear stress**, often denoted τ (Greek: tau), is the component of stress coplanar with a material cross section. Shear stress arises from the force vector component parallel to the cross section. Normal stress, on the other hand, arises from the force vector component perpendicular to the material cross section on which it acts.

Atmospheric pressure, sometimes also called **barometric pressure**, is the pressure within the atmosphere of Earth (or that of another planet). In most circumstances atmospheric pressure is closely approximated by the hydrostatic pressure caused by the weight of air above the measurement point. As elevation increases, there is less overlying atmospheric mass, so that atmospheric pressure decreases with increasing elevation.

Absolute pressure is defined as the pressure which is measured with reference to absolute vacuum pressure. Mathematically,

Absolute pressure = Atmospheric pressure + Gauge pressure

Gauge pressure is defined as the pressure which is measured with the help of a pressure measuring instrument, in which the atmospheric pressure is taken as datum. The atmospheric pressure on the scale is marked as zero.

Vacuum pressure is defined as the pressure below the atmospheric pressure. Mathematically,

Vacuum pressure = Atmospheric pressure - Absolute pressure

Vapor pressure or **equilibrium vapor pressure** is defined as the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases (solid or liquid) at a given temperature in a closed system. The equilibrium vapor pressure is an indication of a liquid's evaporation rate. It relates to the tendency of particles to escape from the liquid (or a solid). A substance with a high vapor pressure at normal temperatures is often referred to as *volatile*. The pressure exhibited by vapor present above a liquid surface is known as vapor pressure. As the temperature of a liquid increases, the kinetic energy of its molecules also increases. As the kinetic energy of the molecules increases, the number of molecules transitioning into a vapor also increases, thereby increasing the vapor pressure.

In fluid mechanics, **pressure head** is the internal energy of a fluid due to the pressure exerted on its container. It may also be called **static pressure head** or simply **static head** (but not **static head pressure**). It is mathematically expressed as:

$$¥ = \frac{p}{\gamma} = \frac{p}{\rho g}$$

where

¥ is pressure head (length, typically in units of m);
p is fluid pressure (force per unit area, often as Pa units); and
ϒ is the specific weight (force per unit volume, typically N/m^3 units)
ρ is the density of the fluid (mass per unit volume, typically kg/m^3)
g is acceleration due to gravity (rate of change of velocity, given in m/s^2)

A **free surface** is the surface of a fluid that is subject to zero parallel shear stress, such as the boundary between two homogeneous fluids, for example liquid water and the air in the Earth's atmosphere. Unlike liquids, gases cannot form a free surface on their own. Fluidized/liquified solids, including slurries, granular materials, and powders may form a free surface.

Pascal's Law:

It states, "The intensity of pressure at any point in a fluid at rest, is the same in all directions."

Proof: Consider a very small right-angled triangular element BCD of a liquid as shown in Fig.

Let P_1 = Intensity of horizontal pressure on the element of the liquid

P_2 = Intensity of vertical pressure on the element of the liquid

P_3 = Intensity of pressure on the diagonal of the triangular element of the liquid and

θ = Angle of the triangular element of the liquid

Since the element of the liquid is at rest, therefore sum of the horizontal and vertical components of the liquid pressure must be equal to zero.

Thus,

$\sum Fx = 0$

And $\sum Fy = 0$

Now, we get,

$F_1 - F_3 \sin\theta = 0$ ……………………… (1)

$F_2 - F_3 \cos\theta = 0$ ……………………… (2)

Intensity of pressure P_1, P_2 and P_3.

Now, from equation (1),

$P_1 A_1 - P_3 A_3 \sin\theta = 0$

And From (2),

$P_2A_2 - P_3A_3 \cos\theta = 0$

Now,

$P_1 A_1 - P_3 A_3 \sin\theta = 0$

Or, $P_1 A_1 = P_3 A_3 \sin\theta$

Or, $P_1 A_1 = P_3 A_1$ [$A_3 \sin\theta = A_1$]

So, , $P_1 = P_3$ ………… ……… (3)

Again, $P_2A_2 - P_3A_3 \cos\theta = 0$

Or, $P_2 A_2 = P_3 A_3 \cos\theta$

Or, $P_2 A_2 = P_3 A_2$ [$A_3 \cos\theta = A_2$]

So, $P_2 = P_3$ ………………… (4)

From equation (3) and (4) we get,

$P_1 = P_2 = P_3$

So, the intensity of pressure at any point in a fluid at rest, is the same in all directions. (Proved)