Lecture One

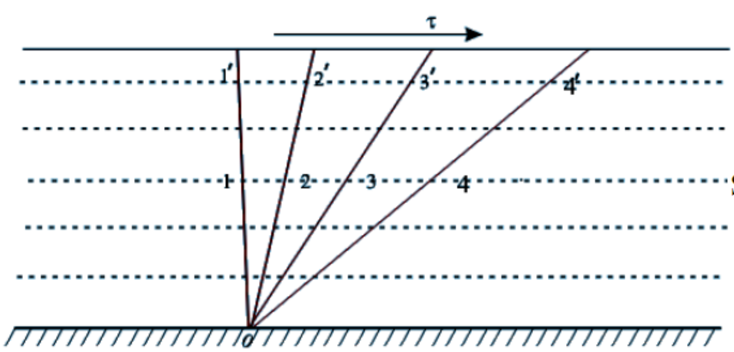
Introduction and Fundamental Concepts

1- Introduction.

There are two classes of fluids, ***liquids*** and ***gases***. The distinction is a technical one concerning the effect of cohesive forces. A liquid, being composed of relatively close-packed molecules with strong cohesive forces, tends to retain its volume and will form a free surface in a gravitational field. Since gas molecules are widely spaced with negligible cohesive forces.

2- *Definition of Fluid.*

A fluid is a substance that deforms continuously in the face of tangential or shear stress, irrespective of the magnitude of shear stress. This continuous deformation under the application of shear stress constitutes the flow.



Shear stress on a fluid body.

3- Fluid Properties.

a) Density (ρ):-

The density ρ *(rho)* may be defined as the mass per unit volume (m/∀) at a standard temperature and pressure. If a fluid element enclosing a point ***P*** has a volume $\Delta\forall$ and mass Δm Fig. 1.1, then density ρ at point ***P*** is written as

$$\rho = \lim_{\Delta\forall \to \Delta\forall_c} \left(\frac{m}{\Delta\forall}\right)$$

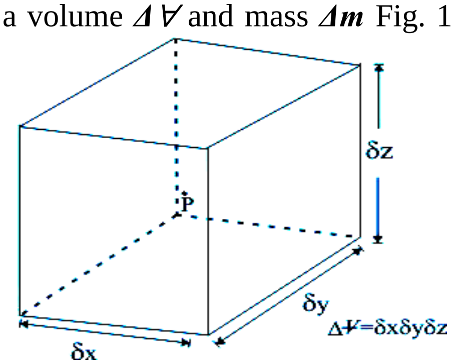


Figure 1.1: A fluid element enclosing point P

b) Specific weight (γ):-

The specific weight γ*(gamma)* is defined as the weight of fluid per unit volume at the standard temperature and pressure, and is given by

$$\gamma = \rho g \quad \left[\frac{N}{m^3}\right] \qquad (1.1)$$

Where g is the gravitational acceleration.

c) Specific volume (v):-

The specific volume ***v*** is the volume occupied by unit mass of fluid, thus

$\upsilon = 1/\rho \quad (m^3/kg)$ (1.2)

d) Specific gravity (S.G.):-

The specific gravity is the ratio of density of a liquid at actual conditions to the density of pure water at ($101kN/m^2$) and at 4C°.

$S.G._{liquid} = \rho_{liquid}/\rho_{water} = \rho_{liquid}/1000$ (1.3)

$S.G._{gas} = \rho_{gas}/\rho_{air} = \rho_{gas}/1.205$ (1.4)

e) Temperature (T):-

The temperature is a measure of the internal energy level of a fluid.

f) Pressure (p):-

The pressure is the stress at a point in a static fluid, and is the differences or gradients in pressure after drive a fluid flow especially in ducts.

4- ***Viscosity (μ).***

A fluid is defined as a material which will continue to deform with the application of a shear force. However, different fluids deform at different rates when the same shear stress (force/area) is applied. If the force ***F*** acts over an area of contact ***A***, then the shear stress τ is defined as

$$\tau = F/A \qquad (1.5)$$

From above the viscosity of fluid may be defined as the property of a real fluid by virtue of which is offers resistance to shear force. Newton's law of viscosity states that the shear force to be applied for a deformation rate of (du/dy) over an area (A) is given by

$F = \mu A(du/dy)$

Or $(F/A) = \tau = \mu\,(du/dy) = \mu\,(u/y)$

5-

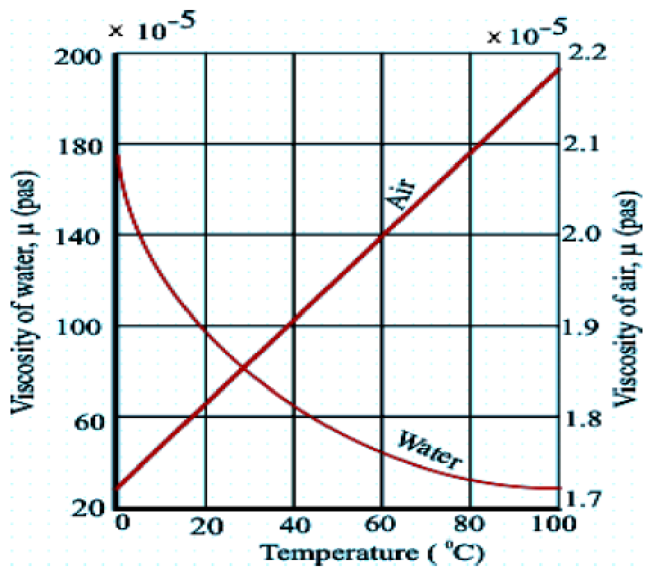
Causes of Viscosity.

The causes of viscosity in a fluid are possibly attributed to two factors

- ***Intermolecular force of cohesion.***
- ***Molecular momentum transfer.***

For Newtonian fluids the coefficient of viscosity depends strongly on temperature but varies very little with pressure

- For liquids, molecular motion is less significant than the forces of cohesion, thus viscosity of liquids decrease with increase in temperature.
- For gases, molecular motion is more significant than the cohesive forces, thus viscosity of gases increase with increase in temperature.



Change of water and air viscosity with temperature under 1 atm.

From above discussions about the fluid circumstances we can conclude that;

- ***Ideal Fluid*:-** Such a fluid having zero viscosity ***(μ=0)*** is called an ideal fluid and the resulting motion is called ideal fluid or inviscid flow. From this definition there is no existence of shear force.
- ***Real Fluid:-*** All fluids in reality having viscosity ***(μ > 0.0)*** are termed real fluid and their motion is known as viscous flow.
- ***Kinematic Viscosity (υ):-*** the kinematic viscosity υ (nu) is the ratio of viscosity to mass density

$$\upsilon = \mu / \rho$$

The kinematic viscosity gives the rate of momentum flux or momentum diffusivity.

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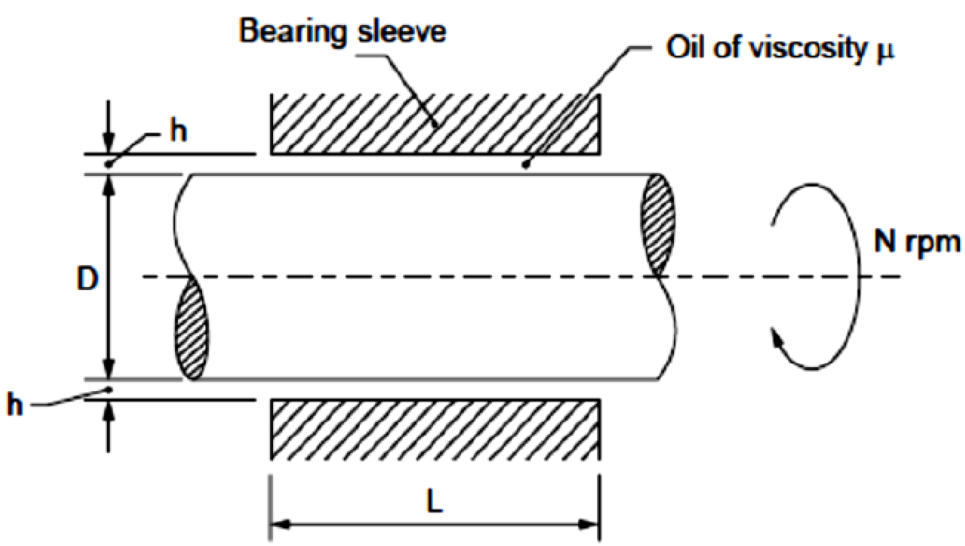
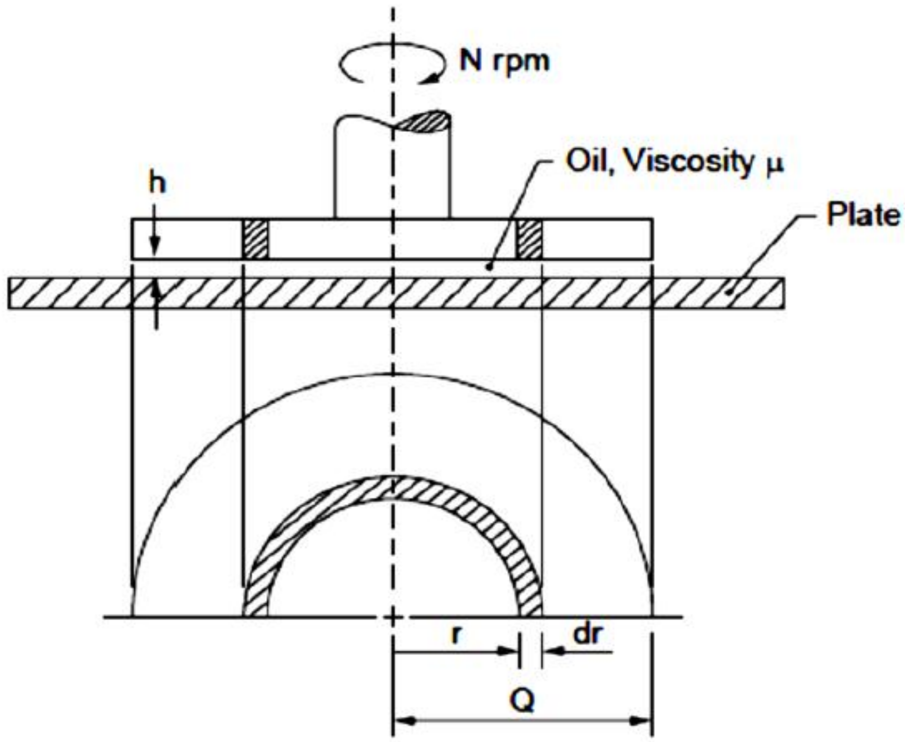
Application of Viscosity Concept.

Viscous Torque and Power-Rotating Shafts.



Rotating shaft in bearing

Viscous Torque – Disk Rotating over a Parallel Plate.



Rotating disk

7-

Compressibility.

The compressibility is the measure of its change in volume under the action of external forces. The degree of compressibility of a substance is characterized by the bulk modulus of elasticity ***E***, defined as

$$E = \lim_{\Delta \forall \to 0} \left(\frac{-\Delta p}{\Delta \forall / \forall} \right)$$

Where

$\Delta\forall$ the change in volume.

Δp the change in pressure.

$\forall$ the initial volume.

The negative sign is to make (E) positive. For a given mass of a substance, the change in its volume and density satisfies the relation

$\Delta m = 0.0, \ \Delta(\rho\forall) = 0.0$

$\rho\Delta\forall + \forall\Delta\rho = 0.0$

$$\left.\begin{array}{l} E = \lim_{\Delta\rho \to 0} \left(\frac{\Delta p}{\Delta\rho/\rho} \right) = \rho\frac{dp}{d\rho} \\ E = -\frac{dp}{\Delta\forall/\forall} \end{array}\right\}$$