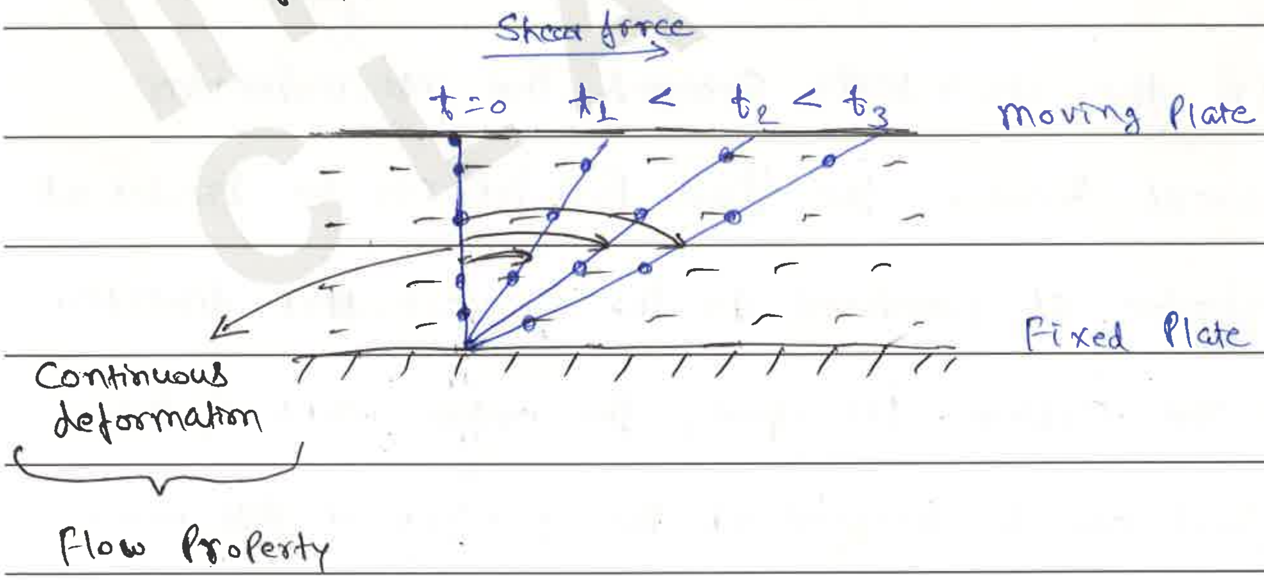
Chapter 1. Fluid Properties

Fluids:

A fluid is a substance which is capable of flowing under the action of shear force, even with a small amount of shear force exerted on it. Whereas a solid offers resistance to the force because very strong intermolecular attraction exists in it.

Note: If there is no shear force, the fluid will be at rest.



In the solids if the force is within the elastic limit the solid will come back to the original position after the removal of force but in fluids it will not comeback to the original position after the removal of force.

In solids deformation does not vary with time but in fluids deformation varies with time and hence rate of deformation is important in fluids then deformation.

Fluid as a continuum:

"In the macroscopic systems, the intermolecular distances between the fluid particles can be treated as negligible as compared to the characteristics dimension of the system. Therefore, the entire mass of the fluid can be treated as the continuous distribution of mass, which is known as continuum."

Basic Fluid Properties:

i) Density (ρ): It is defined as mass per unit volume of the substance.

$$\rho = \frac{m}{V}$$

S.I unit: kg/m^3

CGS unit: gm/cm^3

water (4°c) → 1000 kg/m^3, water (0°c) → 998 kg/m^3

Air (atm.) → 1.21 kg/m^3.

ii) Specific weight: weight per unit Volume

$$\frac{mg}{V} = \rho g \quad N/m^3.$$

iii) Specific Gravity (S.G)

$$(S.G)_{Fluid} = \frac{\text{Density of Fluid}}{\text{Density of Stnd. Fluid.}}$$

For Liquid: Standard fluid → Water (4°c).

For Gas: Standard fluid → Atm. Air or H_2

iv) Relative density (R.D)

$$(R.D)_{1/2} = \frac{\rho_1}{\rho_2}$$

Note: If relative density is given like; RD = 0.8, then treat it w.r.t water (i.e, treat it like S.G).

v) Compressibility (β)

$$\beta = \frac{-(dV/V)}{dP}$$

mass (m) = $\rho \cdot V$ = const.

$$\rho \cdot dV + V d\rho = 0$$

$$-\frac{dV}{V} = \frac{d\rho}{\rho}$$

$$\Rightarrow \beta = \frac{1}{\rho} \cdot \frac{d\rho}{dP}$$

If ρ is not changing w.r.t Pressure

$\frac{d\rho}{dP} = 0 \Rightarrow \boxed{\beta = 0}$ ⟶ Incompressible

If ρ is changing w.r.t Pressure

$\frac{d\rho}{dP} \neq 0 \Rightarrow \boxed{\beta \neq 0}$ ⟶ Compressible

Note: Reciprocal of compressibility is known as Bulk Modulus of elasticity. i.e, $\boxed{K = 1/\beta}$

→ Gas is highly compressible but if Mach number (Ma) $Ma < 0.3$, then gases can be treated as Incompressible.

vi) Isothermal compressibility of gas

$$\beta = \frac{1}{\rho}\frac{d\rho}{dP}$$

Ideal gas: $PV = mRT \Rightarrow P = \rho RT \Rightarrow \rho = P/RT$

$\Rightarrow \dfrac{d\rho}{dP} = \dfrac{1}{RT}$

$\Rightarrow \beta_{Iso} = \dfrac{1}{\rho} \times \dfrac{1}{RT} = \dfrac{1}{P}$

$\Rightarrow \boxed{\beta_{Iso} = 1/P}$

$\boxed{\text{Bulk modulus } (K) = 1/\beta = P} \Rightarrow \boxed{K_{Iso} = P}$

vii) Adiabatic Compressibility of gas:

$\beta = \dfrac{1}{\rho} \dfrac{d\rho}{dP}$

Adiabatic eqn: $PV^{\gamma} = \text{const.}$

$\Rightarrow P \cdot (m/\rho)^{\gamma} = \text{Const.}$

$\Rightarrow P \cdot \rho^{-\gamma} = \text{Const.}$

$\Rightarrow P(-\gamma) \cdot \rho^{-\gamma-1} d\rho + \rho^{-\gamma} \cdot dP = 0$

$\Rightarrow \boxed{\dfrac{d\rho}{dP} = \dfrac{\rho}{\gamma P}}$

$$\beta_{adia} = \frac{1}{\rho}\frac{d\rho}{dP} = \frac{1}{\rho}\cdot\frac{\rho}{\gamma P}$$

$$\Rightarrow \boxed{\beta_{adia} = \frac{1}{\gamma P}} \qquad \Rightarrow \boxed{K_{adia} = \gamma P}$$

Ques 1: The increase in pressure required to decrease unit volume of mercury (Bulk modulus = 28.5 MPa) by 0.1% is

a) 285 GPa b) 285 MPa

c) 2.85 MPa d) 28.5 KPa

Soln:

Bulk modulus, $K = 28.5$ MPa

$= (28.5 \times 10^6)$ Pa

$= (28.5 \times 10^6)$ N/m^2

Decrease in volume, $\frac{-dV}{V} = 0.1\% = \frac{0.1}{100}$