MADE EASY

Mechanical Engineering

Toppers Handwritten Notes

FULUD MECHANICS

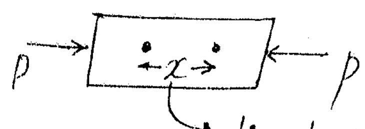
By- Varun Pathak Sir

Fluid (Mechanics)

load → effect

is the study of application of load and its effects on structure, Machine, fluid etc.

- Engg. Mechanics → Rigid Bodies
- SOM → Deformable bodies
- fluid Mechanics



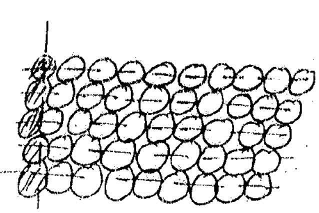
fixed → do not changes with load.

Fluid → A fluid is a substance that is having the ability to Flow OR Deform continuously under the action of shear force.

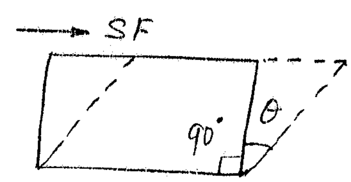
shear force → tangential force

No matter how much small the force is.

Solid

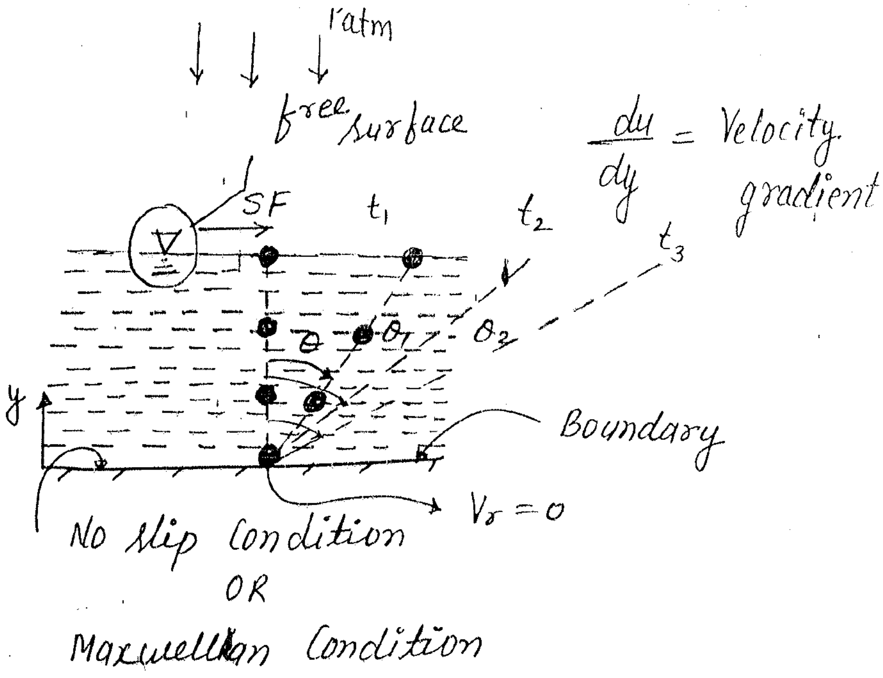


Continuum



deformation const with t

Static fluid
⇒ $SF = 0$



$\frac{d\theta}{dt}$ → Rate of angular deformation (Not Constant)

S → SOM

L, G] → fluids (FM)

Introduction

→ A fluid is a substance that is having the ability to flow and deform continuosly under the action of shear force (No matter how much small the force is)

→ liquids and gases are generally taken in category of fluids example, air, water, steam murcury etc.

→ A static fluid is the one over which shear force is zero.

→ ** No slip Condition means that the molecule which is in Contact with boundary will stick to boundary if boundary at rest the molecule is also at rest. if boundary is moving the molecules sticking to boundary will also move.

it means the relative motion will be zero

→ Free surface is the surface over which P_{atm} is acting. OR Normal force is acting.

→ Differences b/w solids and fluids

① in case of solids the deformation is const with respect to time. whereas in case of fluids the deformation is continuos wrt time and hence in case of fluids $\frac{d\theta}{dt}$ rate of deformation is Important than deformation.

② In case of solids on removal of Load, solids will try to regain their original shape or size whereas fluids will never try to regain there original shape and size.

Note The intermolecular forces of attraction b/w molecules of same Nature is known as Cohesion.

whereas intermolecular force of attraction b/w molecules of diff Nature is known as Adhesion.

*** Cohesion and adhesion are dependent on Nature of surfaces in contact.

H_2O + glass → Adhesion is more

Hg + glass → Cohesion is more

H_2O + plastic sheet → Cohesion is more

Note → A fluid will never show resistance to shear under static condition but it will show resistance to shear under dynamic condition

→ A fluid will flow as long as external shear force is applied OR deform continuosly

(external force) ✗ (external shear force) ✓

- shear ✓
- tension ✗
- compression ✗

Telegram :- 9811524231 / @VarunPathakSir] Mension your Name

Facebook :- Varun.Pathak.399

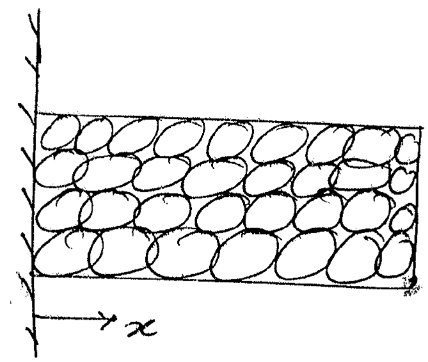
Note liquids has the ability to form free surface whereas gases don't have to ability to form a free surface.

A free surface is the special interface b/w liquid and gas.

→ gases have the ability to expand without limits.

Concept of Continuum :— (mainly for interview)

(Assumption)
- → Uniformly
- → Continuosly
- → Voids must be very less
- → No. of molecules are large in comparison to voids and hence voids can be neglected



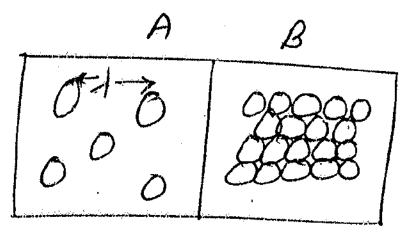
Knudsen (Kn) $= \frac{\lambda}{L}$

No

↓ $Kn < 0.01$

Empirical relation

L → system dimension



λ – mean free path

Note: if λ is very small in comparison to system dimension L such tath $Kn < 0.01$ then concept of continuum is applicable

Continuymm fails → ① Rarefired gas field
② High vaccum

Fluid Properties

properties are certain measurable characteristic that can be quantified.

with the help of properties we can identify a fluid.

① Density (OR) mass Density (ρ)

$$\rho = \frac{\text{mass}}{\text{Volume}} \quad (Kg/m^3)^{SI}$$

$\rho_{H_2O} = 10^3 \ Kg/m^3$

$\rho_{Hg} = 13.6 \times 10^3 \ Kg/m^3$

$\rho_{air} = 1.2 \ Kg/m^3$

→ $\rho_{liq} > \rho_{gas}$

→ Heaviness of fluid

ρ → $p\uparrow \Rightarrow \rho\uparrow$ [molecules will come closer]

ρ → $T\uparrow \Rightarrow \rho\downarrow$ [Bonds will break]

applicable for both liquid and gas.

② Weight Density OR Specific Weight (w)

$$w = \frac{\text{Weight}}{\text{Volume}} \quad (N/m^3)^{SI}$$

$$w = \frac{mg}{V} \Rightarrow w = \rho g$$

<u>Note</u> Hg is approx. 13.6 time heavier than water.

$$w_{H_2O} \rightarrow 10^3 \times 9.81 \rightarrow 9810 \ N/m^3$$

$weight = wV \Rightarrow$ ** $[weight = \rho g V]$ **
↓
in fluid mechanics.

$w \begin{cases} \rho \begin{cases} P \\ T \end{cases} \\ g \end{cases} \Rightarrow w \begin{cases} P \\ T \\ g \end{cases}$

<u>Note</u> ρ is a absolute quantity with respect to location (g) whereas w is variable quantity wrt location.

③ Specific Gravity (S)

→ S is defined as the ratio of density of the fluid to the density of <u>standard</u> fluid. it is a dimensionness quantity.

→ with the help of S we can identity which fluids are heavier than lighter than water

$S = 1 \rightarrow$ water

** $\left[S = \dfrac{\rho_{fluid}}{\rho_{standard\ fluid}} \right]$ ** → dimensionless

standard fluid
- gases → Air OR H_2
- liquid → water.

→ Hydrometer is used to measure specific gravity of liquids.

(i) $S = 0.750 \Rightarrow \rho_{fluid} = 750\ Kg/m^3$

(ii) $S = 1 \Rightarrow$ water

(iii) $S = 13.6 \Rightarrow Hg$

$S > 1 \rightarrow$ heavier than Reference fluid

$S < 1 \rightarrow$ lighter than refference fluid.

Relative density $\rightarrow \dfrac{\rho_s}{\rho_l}, \dfrac{\rho_l}{\rho_g}, \dfrac{\rho_g}{\rho_s}, \dfrac{\rho_g}{\rho_l}$

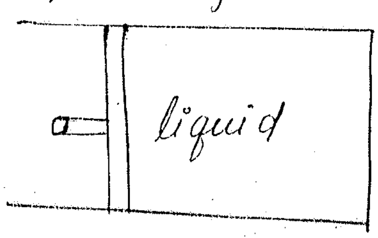
Note: All specific gravities are relative densities but all relative densities are not specific gravities

④ Compressibility (β)

If there is a change in Volume (OR density) with respect to pressure such fluids are known as compressible fluids.

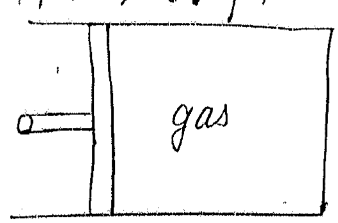
compress $\rightarrow$ Closed $\Rightarrow m = $ Const $\qquad \rho = \dfrac{m}{V}$ (m: const)

$P\uparrow \Rightarrow dv = d\rho = 0$



Incompressible fluid

$P\uparrow \Rightarrow V\downarrow\ \rho\uparrow$



highly compressible

water

$$p = 1\,atm \Rightarrow \rho_{H_2O} = 998\ Kg/m^3$$

$$p = 100\,atm \Rightarrow \rho_{H_2O} = 1003\ Kg/m^3$$

% change = 0.05% → can be Neglected.

Note *** Mathematically compressibility is defined as the reciprocal of bulk modulus of elasticity

$$**\left[\beta = \frac{1}{K} = \frac{-dV}{Vdp} = \frac{-[V_2 - V_1]}{V_1[P_2 - P_1]}\right]**$$

$$K = \frac{\text{Hydrostatic stress}}{\text{Volumetric strain}} = \frac{\text{direct stress}}{\text{Volumetric strain.}}$$

$$K = -\frac{dP}{\left(\frac{dV}{V}\right)} \Rightarrow K = -\frac{Vdp}{dV} = \frac{-V_1[P_2 - P_1]}{[V_2 - V_1]}$$

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

(m ↓ const)

$$0 = \rho\frac{\partial V}{\partial \rho} + V \Rightarrow -\frac{dV}{V} = \frac{d\rho}{\rho}$$

$$\beta = \frac{1}{K} = \frac{-dV}{Vdp} = \frac{d\rho}{\rho dp}$$

→ ρ = const ~~wrt~~ pressure

$d\rho = 0$

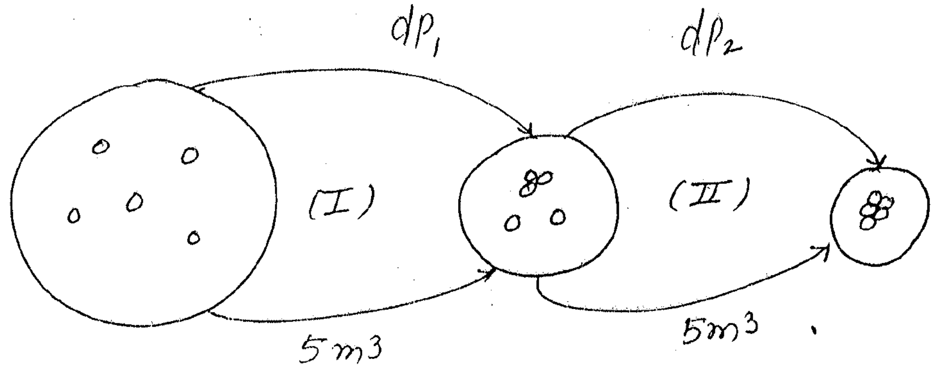
$\Rightarrow \beta = 0$

Incompressible fluid.

Note ** All those fluids whose density is a const wrt pressure such fluids are known as incompressible fluids. **

Note Air is approx. 20000 times more compressible than water.

$K_{air} = 101\ KN/m^2 \qquad K_{water} = 2 \times 10^6\ KN/m^2$



$dP_2 > dP_1$

$K_2 > K_1$ $\qquad P \uparrow \Rightarrow K \uparrow \Rightarrow \beta \downarrow$

$\beta_1 > \beta_2$

Q whether it is easier to compress an ideal gas isothermally or adiabatically.

Isothermal Bulk modulus $[K_T]$

$$K = \frac{\rho\, dP}{d\rho}$$

for ideal gas

$$P = \rho R T$$

$$dP/d\rho = RT$$

$$\Rightarrow K = \rho R T$$

$$\Rightarrow {}^{**}\left[K_T = P = \rho R T\right]^{**}$$

$P \downarrow$ instantaneous pressure.

Adiabatic Bulk modulus (K_a)

$pV^{\gamma} = \text{Const}$

$m = \rho V$

$m/V = \rho$

$\Rightarrow V = m/\rho$

$p\left(\frac{m}{\rho}\right)^{\gamma} = \text{Const}$

$\Rightarrow \frac{p}{\rho^{\gamma}} = \text{Const} = c$

$p = c\rho^{\gamma}$

$\frac{dp}{d\rho} = c\gamma \cdot \rho^{\gamma-1}$

$K_a = \frac{\rho\, dp}{d\rho} = \rho(c\gamma\rho^{\gamma-1}) = c\gamma\rho^{\gamma}$

$\Rightarrow$ ** $[K_a = \gamma P]$ ** — P: instantaneous pressure.

Note: Compressing an ideal gas isothermally is easier than compressing a gas adiabatically. because in case of adiabatic due to increase in temp the molecular energy increases and the molecule provides the resistance to motion of piston and hence compression in adiabatic is difficult.

$K_T = P \quad\quad K_a = \gamma P$

$\Rightarrow \beta_T = \frac{1}{P} \quad\quad \Rightarrow \beta_a = \frac{1}{\gamma P}$

(P → Absolute pressure)