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FLUID MECHANICS

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

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Fluid Mechanics

Topics

1. Properties of Fluid ^{****} → obj flow.
 2. Fluid statics ^{***}
 - Fluid pressure & measurement
 - Hydrostatic forces on plane & curved surface
 - Liquid in Relative equilibrium
 - Buoyancy & FlotationObjective
 3. Fluid kinematics ^{***}
 4. Fluid Dynamics ^{****}
 - Moment equations
 - Energy Equations} obj flow.
 5. Flow measurement → obj
 6. Laminar flow ^{****}
 7. Turbulent flow ^{**}
 8. Boundary layer & Drag & Lift ^{****}
 9. Model Analysis (obj) ^{***}
 10. Pipe flow ^{****}
- obj flow conventional



Introduction

- A substance in liquid (or) gaseous phase is referred to as "Fluid".
- They are capable of deforming continuously under the action of shear stress however small the shear stress might be.

in solids, $\sigma \propto \epsilon$

in fluids, $\tau \propto \frac{d\gamma}{dt}$; $\gamma = \int d\gamma = \int \tau dt$.

- Fluid mechanics deals with properties of fluid at rest as well as in motion.

→ Study of fluid at rest → Fluid statics

② Study of fluid in motion when forces responsible for motion are not considered → Fluid kinematics.

③ Study of fluid in motion by considering the forces responsible for motion is called "Fluid Dynamics".

→ Ideal Fluid :-

→ Ideal fluid is a theoretical conception there is no fluid like Ideal fluid.

→ Ideal fluid does not have surface tension, viscosity and are incompressible.

1. Properties of Fluid

Vapour pressure and Cavitation :-

→ Vapour pressure is the pressure exerted by the vapour molecules.
→ whenever in the flow absolute pressure of flow falls below the Vapour pressure, vaporisation starts and vapours and dissolved gases starts coming out in the form of vapour bubble (or) Air bubble. Thus creating cavity in the flow.

→ these vapour bubbles are swept away from low pressure zone to high pressure zone due to momentum of flowing fluid.

In High pressure zone, these vapour bubbles collapse, giving rise to highly destructive extremely high pressure waves. This phenomenon is called "Cavitation".

Cavitation generates noise, vibration, causes surface pitting & fatigue failure.

→ Cavitation occurs when $P_{abs} < P_{vapour\ pressure}$ ^(ie, pressure at specified points falls below vapour pressure)

→ Vapour pressure increases with temperature, hence at higher temp.

changes of cavitation is more, i.e. there is a greater chance that

vapour pressure exceeds the P_{abs} . & Vapour pressure of a liquid is independent of the externally exerted pressure.

⇒ Bulk modulus & Compressibility :-

Bulk modulus →
$$K = - \frac{dP}{\left(\frac{dv}{v}\right)}$$

$$m = \rho v$$

$$d(m) = \rho dv + v d\rho = 0$$

$$\frac{-dv}{v} = \frac{d\rho}{\rho}$$

($dm=0$, because mass is neither created nor destroyed)

$$\therefore K = \frac{dP}{\left(\frac{d\rho}{\rho}\right)}$$

Compressibility $\rightarrow \boxed{\frac{1}{k} = \frac{dP}{\rho dP}}$

if $d\rho = 0 \rightarrow$ incompressible

Isothermal bulk modulus ;

$$P = \rho RT$$

$$\frac{dP}{d\rho} = RT$$

$$k = \rho \frac{dP}{d\rho} = \rho RT = P$$

$$\therefore \boxed{k = P}$$

i.e., Isothermal bulk modulus is equal to pressure.

Adiabatic bulk modulus ;

In adiabatic process $\rightarrow PV^\gamma = \text{constant}$

$$\gamma = \frac{C_p}{C_v} = \text{adiabatic constant}$$

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

$$\frac{P \cdot m^\gamma}{\rho^\gamma} = \text{constant}$$

$$P = (\text{constant}) \cdot \rho^\gamma$$

$$\frac{dP}{d\rho} = \text{constant} \cdot \gamma \rho^{\gamma-1}$$

$$k = \rho \frac{dP}{d\rho} = \text{constant} \cdot \gamma \rho^\gamma = \gamma P$$

$$\therefore \boxed{k = \gamma P}$$

check ρ^γ

∴ The density of sea water at free surface is 1030 kg/m^3 and pressure is 98 kPa . Bulk modulus of sea water is $2.34 \times 10^9 \text{ N/m}^2$ (constant). The variation of pressure with depth is given by $dP = \rho g dz$. Determine the density and pressure at a depth of 2500 m . neglect change in temperature

Solⁿ

$$P_0 = 98 \text{ kPa}, \rho_0 = 1030 \text{ kg/m}^3$$

z

$$dP = \rho g dz$$

$$\frac{dP}{dP} = k \Rightarrow dP = \frac{k}{P} \cdot dP$$

$$\Rightarrow \rho g dz = \frac{k}{P} \cdot dP$$

$$\int \frac{dP}{P^2} = \frac{g}{k} \int dz$$

$$-\frac{1}{P} = \frac{gz}{k} + C$$

$$\text{at } z=0, P=P_0 \Rightarrow C = -\frac{1}{P_0}$$

$$\rightarrow \frac{1}{P} = \frac{gz}{k} - \frac{1}{P_0}$$

$$\frac{1}{P} = \frac{1}{P_0} - \frac{gz}{k}$$

$$P = \frac{1}{\frac{1}{P_0} - \frac{gz}{k}}$$

$$P_{\text{at } 2500 \text{ m}} = \frac{1}{\frac{1}{1030} - \frac{9.81 \times 2500}{2.34 \times 10^9}}$$

$$P_{\text{at } 2500 \text{ m}} = 1041.24 \text{ kg/m}^3$$

for Pressure:

$$dP = \rho g dz$$

$$dP = \frac{1}{\left(\frac{1}{\rho_0} - \frac{gz}{k}\right)} g dz$$

$$\rightarrow \rho \frac{dP}{dP} = k$$

$$P = \int dP = k \int \frac{dP}{\rho}$$

$$P = k \ln \rho + C$$

at $\rho = \rho_0$, $P = P_0$

$$P_0 = k \ln \rho_0 + C$$

$$C = P_0 - k \ln \rho_0$$

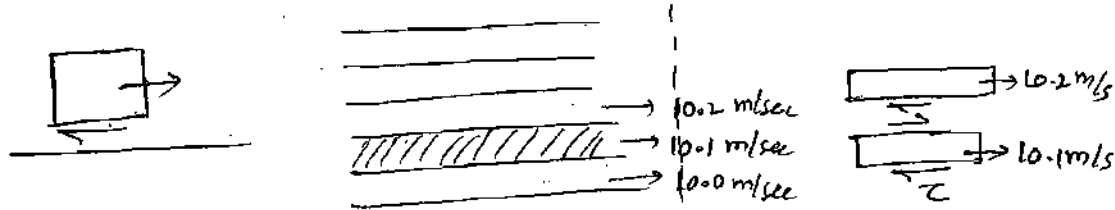
$$\rightarrow P = k \ln \rho + P_0 - k \ln \rho_0$$

$$P = P_0 + k \ln \left(\frac{\rho}{\rho_0}\right)$$

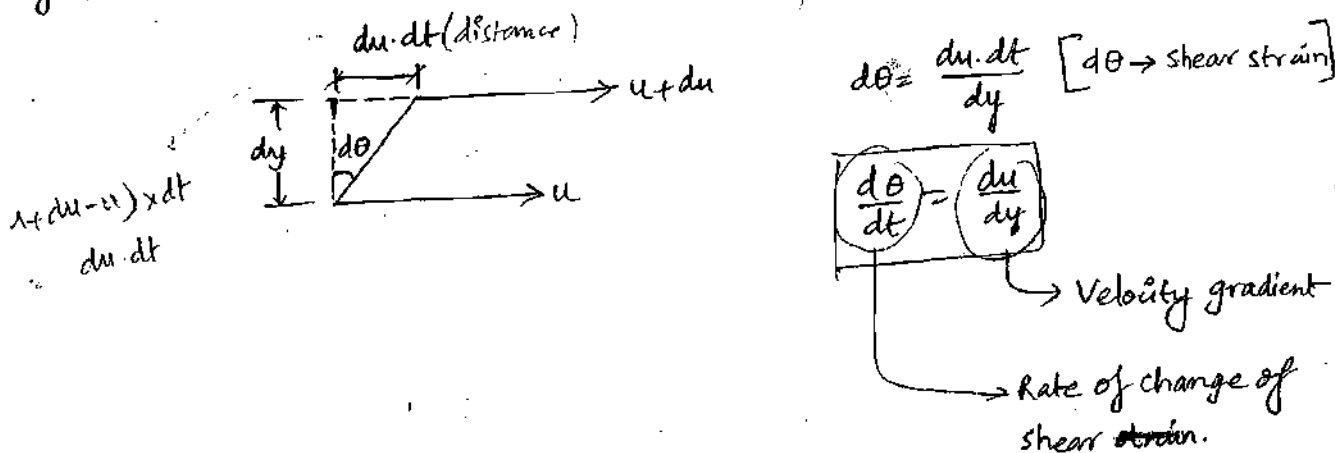
$$P_{at\ 2500m} = 98 \times 10^3 \frac{N}{m^2} + 2.34 \times 10^9 \frac{N}{m^2} \ln \left(\frac{1041.24}{1030}\right)$$

$$P_{at\ 2500m} = 25495.209 \text{ KPa}$$

viscosity :-



- Viscosity is a measure of resistance of fluid to deformation.
- It is due to internal friction forces that develop between different layers of fluid that are forced to move relative to each other.



→ In case of Newtonian fluid, shear stress \propto rate of shear strain

i.e, $\tau \propto \frac{d\theta}{dt}$

$\tau \propto \frac{du}{dy}$

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

→ Dynamic viscosity (or)
Absolute viscosity (or)
Coefficient of viscosity

• unit of Dynamic viscosity (μ) is $\frac{NS}{m^2}$ (or) $\frac{kg}{m \cdot s}$ (or) Poise

10 Poise = $1 \frac{NS}{m^2}$

& $\frac{N \cdot s}{m^2} = \frac{kg}{m \cdot sec} = \frac{gm}{cm \cdot sec}$