FLUID MECHANICS
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FLUID MECHANICS

- Fluid Mechanics is a branch of engineering, that deals with the properties of the fluid at rest as well as in motion.

- It is further analysed in following forms.
  - Fluid Statics
  - Fluid Kinematics
  - Fluid Dynamics

- Fluid statics :- It deals with fluid in rest condition.

- Fluid kinematics :- It deals with fluid in motion without considering the force responsible for motion.

- Fluid Dynamics :- It deals with fluid in motion by considering the forces responsible for motion.

- In general matter exist in following states
  (A) SOLID
  (B) FLUID → LIQUID, GASES

- A fluid is a substance which exists in liquid and gaseous phase.

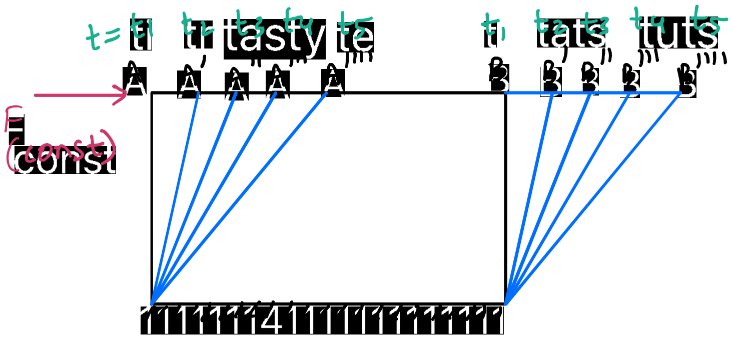
- Fluid is capable of deforming continuously under the action of shear force, shear stress or tangential stress. However small the magnitude of stress may be.

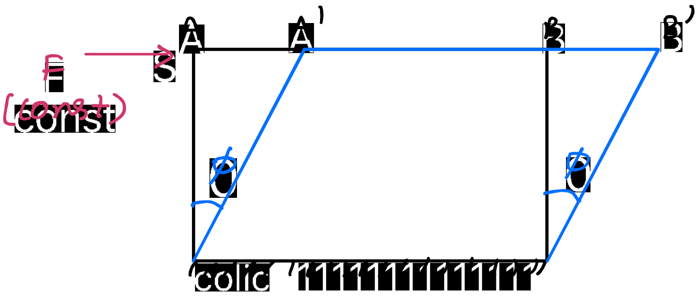
- Hence in solids where stress is proportional to strain, in fluid stress is proportional to rate of deformation or rate of strain.

NOTE :- Here continuous deformation of the fluid means that when a constant shear stress is applied over the fluid, it will continue to deform as long as stress is present.

But in case of SOLID, deformation eventually stops at fixed strain angle.

FLUID | SOLID





$\tau \propto \frac{d\theta}{dt}$

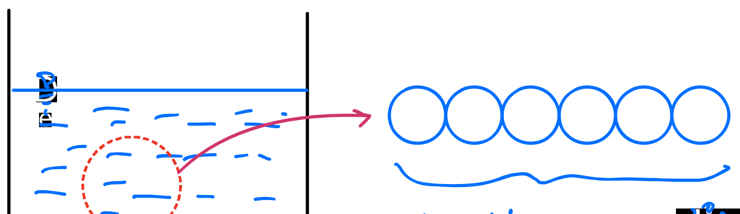
θ = shear strain.

$\tau \propto \theta$

- Hence in fluid, we are more concerned with rate of deformation and in solids we are more concerned with its magnitude.

- Fluid can also be stated to be in CONTINUUM for its analysis.

In macro system, when the intermolecular distances are very small as compared to dimensions of the medium (system), we can assume that the adjacent to one molecule, there is another molecule without any space in between. Hence the entire fluid mass can be considered as continuous distribution of mass, which is termed as continuum.



GLASS/BOTTLE etc.

- Fluid may also be defined as the substance that is capable of flowing and has no definite shape of its own and conforms to the shape of the container.

- Fluid can be classified as :-

(a) **LIQUID** :- It is a fluid which has a definite volume, and it changes slightly with temp and pressure. (For practical purposes it is considered to be incompressible i.e donot show change in volume)

(b) **GAS** :- It is a fluid, which is compressible & posseses no definite volume & always expands up till its volume is equal to the volume of container, it is placed in.

NOTE :- A vapour is a gas, temp and pressure of which is very near to liquid.
Eg → steam.

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(c) **IDEAL FLUID** :- This are the fluids which have no viscosity, SURFACE TENSION, and are INCOMPRESSIBLE.

- They donot offer resistance against flow.
- It is an imaginary or hypothetical fluid, considered only for simplicity in mathematical calculation.

Eg :- Those fluids having very low viscosity may be considered as ideal fluid. Eg water, air.

(d) **REAL / PRACTICAL** :- All fluid that exist in nature are Real fluids.

- They offer resistance against flow
- posses viscosity, surface tension and compressibility.

PROPERTIES OF FLUID :-

(A) MASS DENSITY / SPECIFIC MASS :-

- It is defined as ratio of mass of fluid and its volume

OR

- It is the mass of the fluid which possesses per unit volume.

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

UNIT

kg/m^3, g/cm^3
(MKS) (CGS)

June 2

- Mass density of the fluid depends upon its Temperature and pressure.

- With increase in Temperature, molecular activity of random ness increases thus spacing b/w molecules increases hence lesser number of molecules would pack in same volume that results in reduced mass density.

$$\rho \propto \frac{1}{T}$$

- With increase in pressure, large number of molecules can be forced into given volume, that results in higher mass density.

$$\rho \propto P$$

- At STP, ρ_{water} = 999.9 kg/m^3 ≈ 1000 kg/m^3
  T = 0°C
  P = 1 Atm.
  ρ_{air} = 1.292 kg/m^3

(B) SPECIFIC WEIGHT / WEIGHT DENSITY (γ)

- It is the weight of the fluid per unit volume.

$$\gamma = \frac{W}{V}$$

units :- N/m^3, kgf/m^3
$dyne/cm^3$

$1\ dyne/cm^3 = 10\ N/m^3$
$1\ kgf/m^3 = 9.81\ N/m^3$

- It signified the force exerted by gravity over the unit volume of fluid.

- It varies with location as "g" varies from location to location.

$$\gamma = \rho g$$

- Thus, "γ" also depend upon temperature and pressure as ρ varies

$$\gamma \propto p \quad , \quad \gamma \propto \frac{1}{T}$$

At STP, $\gamma_{water} = 9807\ N/m^3 \simeq 9810\ N/m^3$

$\gamma_{air} = 12.670\ N/m^3$

(c) SPECIFIC VOLUME (Sv) :-

- It is the volume of the fluid per unit wt or mass.

$$S_v = \frac{V}{M \text{ or } W} \qquad S_v = \frac{1}{\rho} \text{ or } \frac{1}{\gamma}$$

- For problems involving gas → use $S_v = \frac{V}{M}$
- " " " liquid → use $S_v = \frac{V}{W}$

All the above properties (ρ, γ, S_v) for fluid depends on temperature and Pressure but its impact on gases is considerably more than in liquids.

(d) SPECIFIC GRAVITY (G) :-

- It is the ratio of weight of given volume of fluid to the weight of same volume of standard fluid

$$G = \frac{W_{fluid}}{W_{std\,fluid}} \qquad V_f = V_{sf}$$

$$G = \frac{W_f}{W_{sf}} \cdot \frac{V_f}{V_f} = \frac{W_f / V_f}{W_{sf} / V_f}$$

$$G = \frac{W_f}{V_f} \cdot \frac{1}{\left(\frac{W_{sf}}{V_{sf}}\right)} = \frac{\gamma_f}{\gamma_{sf}}$$

$$G = \frac{\gamma_f}{\gamma_{sf}}$$

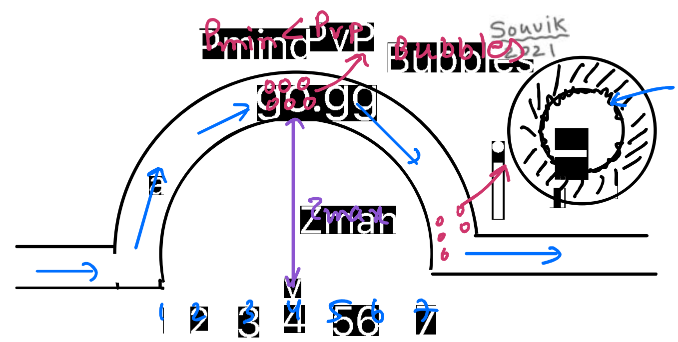
- hence, G can also be defined as ratio of specific weight or specific density of fluid to the specific weight or specific density of the standard fluid

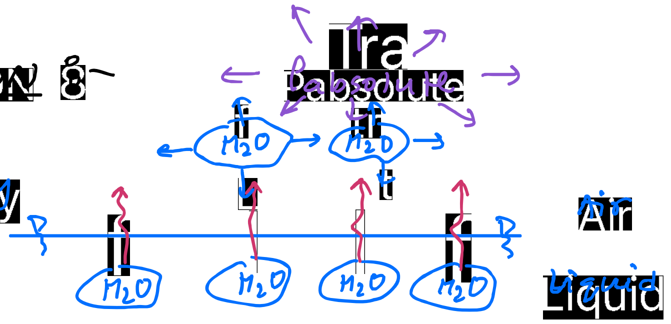
- For LIQUID, standard fluid is taken as PURE WATER at 4°C.

- For GASES, std. fluid is considered as HYDROGEN or AIR at std. temp & press.

- Since weight density and mass density varies with temp, temp must also be reported when G is reported.

(g) VAPOUR PRESSURE & CAVITATION :-





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- At liquid air interface, continuous exchange of liquid molecule escape from the surface in to gaseous form termed as vapour, due to the energy posses by them.

- This vapour molecules exert partial pressure over the liquid surface (in general space) termed as vapour pressure.

- On increase in temperature as molecular activity increases, vapour pressure also increases.

- If absolute pressure impose over the liquid becomes less than vapour pressure, liquid boiling of the liquid will start.

- Hence it can be stated that the boiling of liquid can start at any given temperature, if the pressure above the liquid surface becomes less than vapour pressure.

- Liquid with a high vapour pressure evaporates readily are termed as volatile liquid. eg. Benzene.

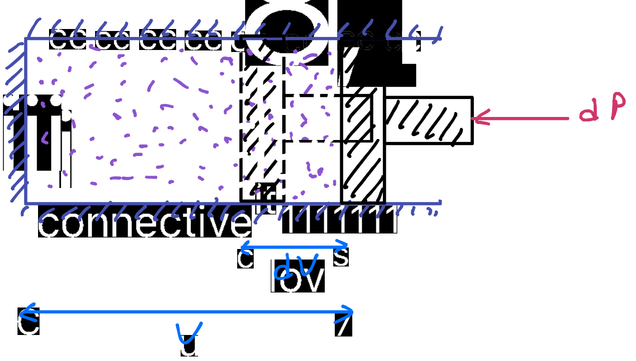
- Hg has very low VP, hence it doesn't vapourises even at very low pressure, thereby it is used in equipments to for pressure measurements.
- V.P of water at different temp. is as follows

T (°C)	VP (kPa)
10	1.2
20	2.3
100	101.3 = 1 atm. → Boiling start.

Cavitation :- If in any flow system pressure at any point in the liquid becomes less than V.P, vapourisation starts resulting in pockets of dissolved gases and vapours.

- This bubbles move with flow of liquid into the high pressure region where they burst or collapse giving rise to high impact pressure.
- Due to which VIBRATION, NOISE, EROSION, SURFACE PITTING and FATIGUE FAILURE of the material takes place.
- This phenomenon is termed as cavitation.
- With increase in temp., VP increases, tendency of vap. increases hence tendency of cavitation also increases.

(f) COMPRESSIBILITY AND ELASTICITY :-



- All fluids can be compressed by application of the pressure and when this pressure is removed fluid expand to their original volume (similar to that of elastic solid)

- This property of fluid to undergo volume change on application of pressure is termed as COMPRESSIBILITY.

- which is quantitatively related with Bulk modules of elasticity (K).

- BMOE (K) is defined as change in pressure per unit change in volume to the original volume.

$$K = \frac{\text{Volumetric steers}}{\text{volumetric strain}} = \frac{-dp}{\left(\frac{dv}{v}\right)}$$

unit :- N/mm^2, kgf/m^2, gmf/cm^2

At NTP, $K_{water} = 2.06 \times 10^9\ N/m^2$

$K_{air} = 1.03 \times 10^5\ N/m^2$

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* Air is 20000 or 2×10^4 more compressible than water.

- K is not const. for fluids it increases with increase in pressure, as when a fluid mass is compressed its molecule becomes close together and the resistance to further compression increases.

- For eg. K_{water} almost doubles when pressure is raised from 1atm to 3500atm

- "K" also varies with Temperature

• For "LIQUID", with increase in temperature, inter molecular bond b/w the particles decreases, hence resistance against vol. change decreases, thus more volume change occurs. Hence "K" decreases.

• For "GASES", with increase in temperature random motion of particles increases, that further increases resistance to vol. change thereby less volume change is observed. Hence "K" increases.

- Now, compressibility is quantitatively related to bulk modulus as follows.

$$\beta = \frac{1}{K}$$ (compressibility)   units :- $\frac{m^2}{N}$

- In general,

$$m = \text{const}$$
$$m = \rho V$$
$$dm = \rho\, dV + V\, d\rho$$
$$0 = \rho\, dV + V\, d\rho$$
$$-\frac{dV}{V} = \frac{d\rho}{\rho}$$

$$K = \frac{-dP}{\left(\frac{dV}{V}\right)} = \frac{-dP}{\left(\frac{d\rho}{\rho}\right)}$$

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

$$\therefore \beta = \frac{d\rho}{\rho\, dP}$$

→ If $\frac{d\rho}{dP} = 0 \Rightarrow \beta = 0$ → fluid is incompressible.

→ If $\frac{d\rho}{dP} \neq 0 \Rightarrow \beta \neq 0$ → Fluid is compressible.

For liquids (water) at 20°C

$P = 1$ Atm, $\rho_{water} = 998\ kg/m^3$

$P = 100$ Atm, $\rho_{water} = 1003\ kg/m^3$

% change in $\rho = \frac{1003 - 998}{998} \times 100 = 0.49\%$ (negligible)

Hence, liquids are considered to be incompressible.