LECTURE 2

~~10-J~~ 11-JAN-2015

# FLUID AND ITS PROPERTIES

~~The Concept~~ In the last class, we discussed about

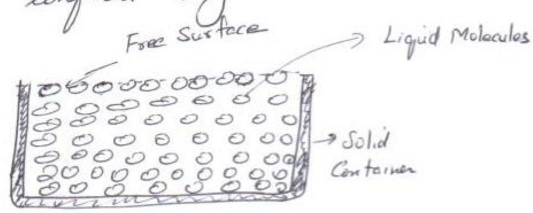
* Mechanics
* Fluid in brief
* History of fluid mechanics
* Briefing of the course syllabus

## The Concept of Fluid

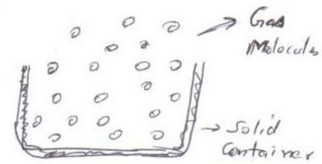
→ All matter on earth are constituted by molecules. irrespective of whether it is solids, liquids, and gases.

→ For solids, the molecules are packed tightly and they are bonded strongly. The packing can retain a definite shape and volume. eg. →

→ Liquids are composed of relatively closed packed molecules. They have good cohesive forces and can mostly retain its volume. Liquids don't have definite shape. Liquids can form a free surface in a gravitational field, if the upper portion is not confined by a solid.



→ Gas molecules are spreaded widely. They have negligible cohesive forces. They also don't have definite volume like liquids. It can expand and can go out of the container, in which it is stored.
Gases cannot form free surfaces.




→ So now it is clear that molecules constitute the matter.
A body or a matter have molecules with empty spaces.
To analyse the motion or properties of this body (or matter), we can analyse it at molecular level

- i.e. Movement of molecules
- Tracking the path of individual molecules, etc.

→ If we try to go at such molecular level and try to do analyses, one average human life will also not be sufficient to study even ~~the~~ small percent of molecular motions.

→ The science then further developed by assuming that the entire body (or matter) of concern is a continuum.

- A continuum is one, ~~in which the~~ that occupies space and is filled with continuous objects called particles.

## The fluid as a continuum

As solids, liquids, and gases consist of molecules,
we can say a collection of molecules as ~~par~~ a particle.
This particle can occupy a spatial location.
A continuum is the one that is filled with such particles.

→ We can also treat fluid as a continuum.

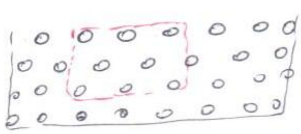
→ As we are treating fluid as a continuum,
there are certain properties associated with it.

→ For which size, we can treat fluid as continuum?

* Definitely, at molecular size, we cannot treat fluid as continuum, because each molecule may have its own path and properties.
* That means that there should be some minimum size or collection of molecules, from which we can start treating fluid as continuum.
* Consider a fluid property called - density - which can be defined only at continuum level.

Density you know $= \dfrac{\text{Mass}}{\text{Volume}}$

Liquids contains molecules and empty spaces

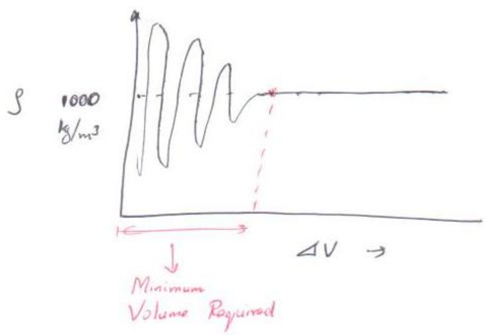


→ You can now try to plot density versus volume graph.

→ The red box ~~xxx~~ indicates the volume of interest, of fluid, for you.

Density . $\rho = \frac{Mass}{Volume}$.

If we decrease, the volume of liquid at molecular level.... you may see fluctuations in graph.




This is because the space may be occupied by a fluid molecule or empty space.

→ So you cannot define DENSITY at that size.

→ You require a minimum representative volume to define density.

→ That minimum volume can be defined as a particle and a continuum is an ensemble of several particles.

→ By adopting fluid as a continuum, we can directly apply the mechanics principles on that, rather than going at molecular level.

[ Also, if you look into this cluster. If we move it through space, rather than analysing the movement of molecules in it, it is better to analyse the continuous cluster → CONTINUUM].

From, FM WHITE's "Fluid Mechanics" (our course text book), this minimum volume to treat fluid as a continuum ~~as~~ is given as $\approx 10^{-9}\ mm^3$ for all liquids and gases at atmospheric pressure.

e.g. $10^{-9}\ mm^3$ of air at standard conditions $\rightarrow 3 \times 10^7$ molecules.

## Dimensions and Units

We will be following the SI units in our class. However ~~we~~ you should also be aware of CGS, FPS, etc. unit system for certain parameters. There may be exercises asking to convert units.

$\Rightarrow$ The primary dimensions are:

| Dimension | Mass (M) | Length (L) | Time (T) | Temperature ($\theta$) |
|---|---|---|---|---|
| SI Unit | kg | m | s | K |
| FPS Unit | Slug | ft | s | Rankine |

$\Rightarrow$ Other properties in fluid mechanics can be derived from these primary dimensions.

e.g. Velocity, $v = \frac{\text{Length}}{\text{Time}} \rightarrow \frac{m}{s}$

Acceleration, $a \Rightarrow \frac{L}{T^2} \rightarrow \frac{m}{s^2}$

Force $= m * a \rightarrow M\frac{L}{T^2} \rightarrow kg\frac{m}{s^2}$

→ In coming classes, you will learn about fluid properties like

- ★ Density (Already seen today)
- ★ Velocity
- ★ Acceleration
- ★ Viscosity
- ★ Force, etc.

## Velocity Field Properties

→ In fluid mechanics, what we do while solving the problems is, the properties of the fluid can be determined as a function of position and time.

e.g. $V(x, y, z, t)$, $a(x, y, z, t)$, $h(x, y, z, t)$, etc.

→ There are two different approach through which we can study mechanics of continuous objects.

i) We can take individual particles in the continuum and then track the changes in fluid properties like velocity, acceleration, pressure, etc. of that particle during its motion. This type of approach is called Lagrangian approach.

ii) Rather than taking individual particles, if we take the whole domain or field and then find the properties like velocity, acceleration, pressure, etc. with respect to space and time

i.e. $V(x,y,z,t)$, $a(x,y,z,t)$, $p(x,y,z,t)$, etc.

This way of solving is called <u>Eulerian</u> approach.

⇒ For fluid mechanics → Eulerian description is useful.

e.g. a pressure probe measures pressure at a location (not the pressure of an individual particle - as the probe cannot move).

⇒ The Velocity Field is the most important property in fluid mechanics. $V(x,y,z,t)$.

(Please note that we are talking about three-dimensional domain).

Velocity is a vector function of position and time

$$\vec{V}(x,y,z,t) = \hat{i}\,u(x,y,z,t) + \hat{j}\,v(x,y,z,t) + \hat{k}\,w(x,y,z,t)$$

⇒ Acceleration, $\vec{a} = \dfrac{d\vec{V}}{dt}$

In Eulerian approach, to follow the particle of Lagrangian approach, total derivative has to be introduced.

$$\vec{a} = \frac{d\vec{V}}{dt} = \frac{\partial \vec{V}}{\partial t} + u\frac{\partial \vec{V}}{\partial x} + v\frac{\partial \vec{V}}{\partial y} + w\frac{\partial \vec{V}}{\partial z}$$