Elements of Mechanical Engg.(BMEC-1201)

Course Name: Elements of Mechanical Engg.

Semester: 2nd

Prepared by: Dr. Sachin Saini

FLUID MECHANICS

Definition

- **Mechanics** is the oldest physical science that deals with both stationary and moving bodies under the influence of forces.
- The branch of mechanics that deals with bodies at rest is called **statics**, while the branch that deals with bodies in motion is called **dynamics**.
- The subcategory **fluid mechanics** is defined as the science that deals with the behavior of fluids at rest (*fluid statics*) or in motion (*fluid dynamics*), *and the interaction of fluids with solids* or other fluids at the boundaries.
- The study of fluids at rest is called **fluid statics**.

Fluid Mechanics

Definition

- The study of fluids in motion, where pressure forces are not considered, is called **fluid kinematics** and if the pressure forces are also considered for the fluids in motion. that branch of science is called **fluid dynamics**.
- Fluid mechanics itself is also divided into several categories.
- The study of the motion of fluids that are practically incompressible (such as liquids, especially water, and gases at low speeds) is usually referred to as **hydrodynamics.**
- A subcategory of hydrodynamics is **hydraulics,** which deals with liquid flows in pipes and open channels.

Defining Fluid

What is a Fluid?

- A substance exists in three primary phases: solid, liquid, and gas. A substance in the liquid or gas phase is referred to as a **fluid.**
- Distinction between a solid and a fluid is made on the basis of the substance's ability to resist an applied shear (or tangential) stress that tends to change its shape.
- A solid can resist an applied shear stress by deforming, whereas a fluid deforms continuously under the influence of shear stress, no matter how small.
- In solids stress is proportional to *strain, but in fluids stress is proportional* to *strain rate.*

What is a Fluid?

What is a Fluid?

- *When a constant shear force is applied, a solid eventually* stops deforming, at some fixed strain angle, whereas a fluid never stops deforming and approaches a certain rate of strain.

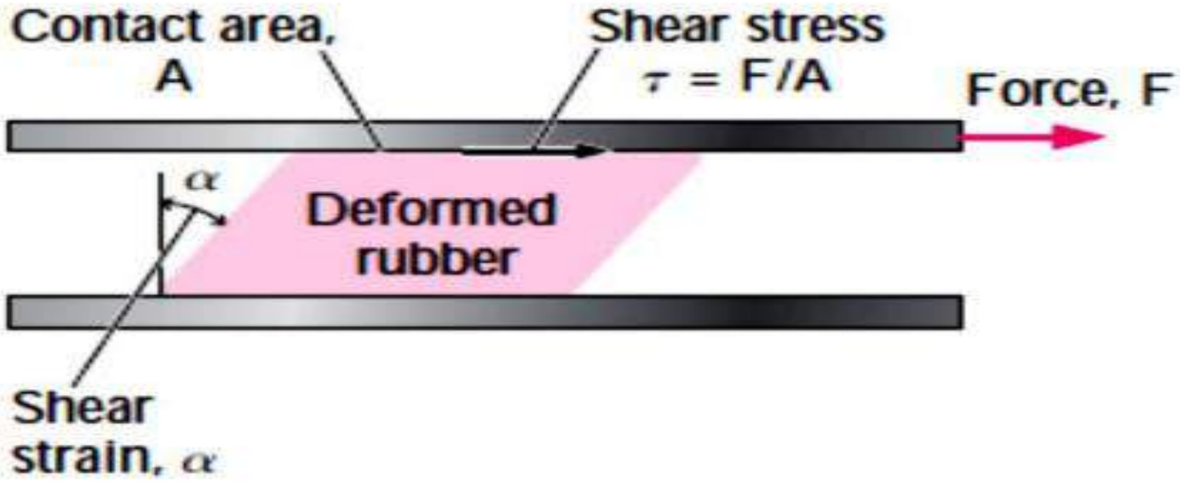


Figure.
Deformation of a rubber eraser placed between two parallel plates under the influence of a shear force.

Differentiating Liquid and Gases

- Differences between liquid and gases

Liquid	Gases
Difficult to compress and often regarded as incompressible	Easily to compress – changes of volume is large, cannot normally be neglected and are related to temperature
Occupies a fixed volume and will take the shape of the container	No fixed volume, it changes volume to expand to fill the containing vessels
A free surface is formed if the volume of container is greater than the liquid.	Completely fill the vessel so that no free surface is formed.

Areas of Fluid Mechanics

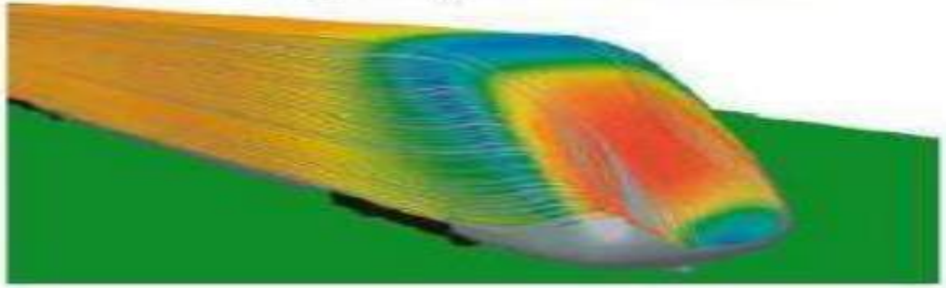
Application areas of Fluid Mechanics

- Mechanics of fluids is extremely important in many areas of engineering and science. Examples are:
- **Biomechanics**
  - Blood flow through arteries and veins
  - Airflow in the lungs
  - Flow of cerebral fluid
- **Households**
  - Piping systems for cold water, natural gas, and sewage
  - Piping and ducting network of heating and air-conditioning systems
  - refrigerator, vacuum cleaner, dish washer, washing machine, water meter, natural gas meter, air conditioner, radiator, etc.
- **Meteorology and Ocean Engineering**
  - Movements of air currents and water currents

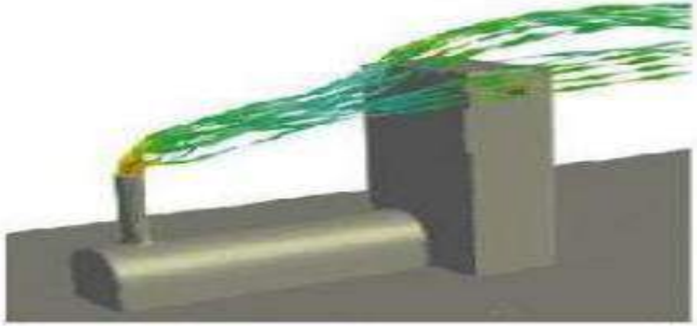
Applications of Fluid Mechanics

Application areas of Fluid Mechanics

High speed train

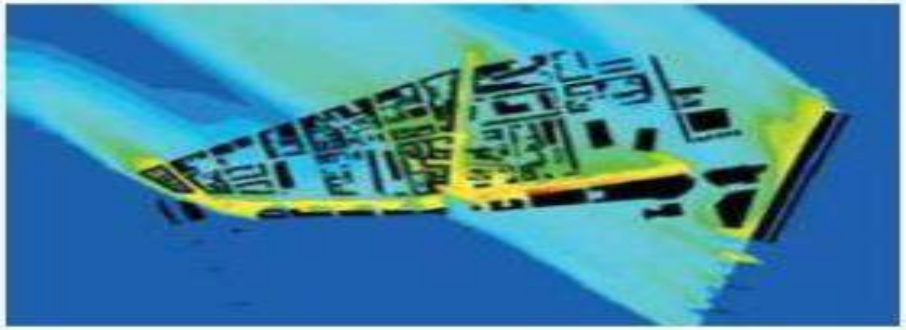


Wind turbines



Smoke from a stack

Pollutant dispersion over a city



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Fluid Flows

Classification of Fluid Flows

- There is a wide variety of fluid flow problems encountered in practice, and it is usually convenient to classify them on the basis of some common characteristics to make it feasible to study them in groups.

Viscous versus Inviscid Regions of Flow

- When two fluid layers move relative to each other, a friction force develops between them and the slower layer tries to slow down the faster layer.
- This internal resistance to flow is quantified by the fluid property *viscosity,* which is a measure of internal stickiness of the fluid.
- Viscosity is caused by cohesive forces between the molecules in liquids and by molecular collisions in gases.

Properties of Fluids

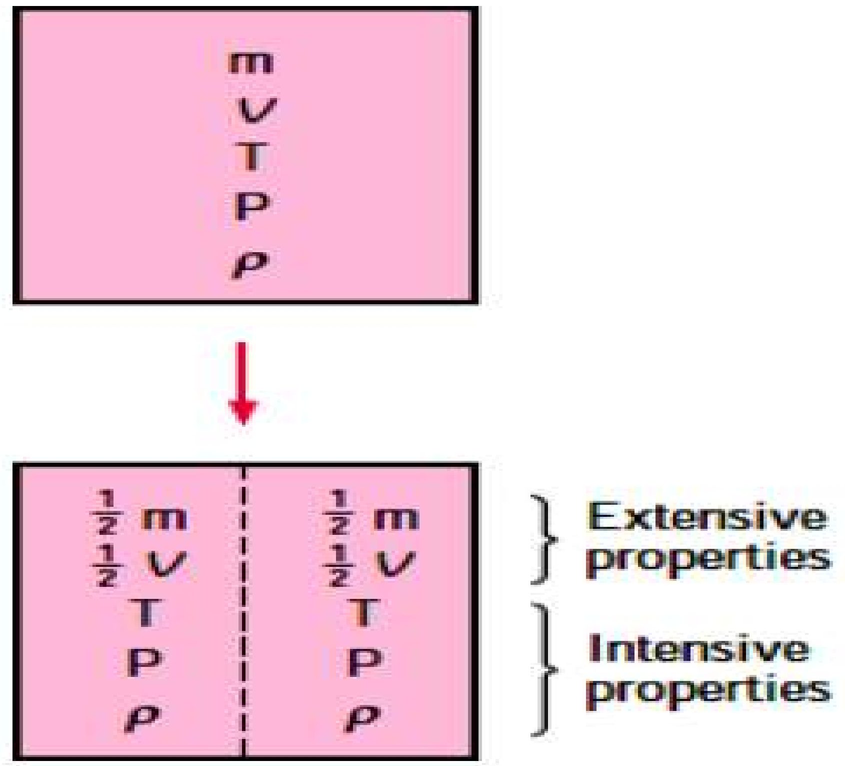
Properties of Fluids

- Any characteristic of a system is called a **property.**
- Some familiar properties are pressure *P*, temperature T, volume V, and mass m.
- Other less familiar properties include viscosity, thermal conductivity, modulus of elasticity, thermal expansion coefficient, electric resistivity, and even velocity and elevation.
- Properties are considered to be either ***intensive or extensive***.
- ***Intensive*** properties are those that are independent of the mass of a system, such as temperature, pressure, and density.
- **Extensive** properties are those whose values depend on the size—or extent—of the system. Total mass, total volume *V*, and total momentum are some examples of extensive properties.

Properties of Fluids

Properties of Fluids

- An easy way to determine whether a property is intensive or extensive is to divide the system into two equal parts with an imaginary partition.
- Each part will have the same value of intensive properties as the original system, but half the value of the extensive properties.



Density

Properties of Fluids

Density or Mass Density

- Density or mass density of a fluid is defined as the ratio of the mass of a fluid to its volume. Thus mass per unit volume of a fluid is called density. It is denoted the symbol ρ (rho). The unit of mass density in SI unit is kg per cubic meter, i.e ., kg/m^3.
- The density of liquids may be considered as constant while that of gases changes with the variation of pressure and temperature.
- Mathematically mass density is written as.

$$\rho = \frac{\text{Mass of fluid}}{\text{Volume of fluid}}$$

- The value of density of water is 1 gm/cm^3 or 1000 kg/m^3.

Specific Weight

Properties of Fluids

Specific weight or Weight Density

- Specific weight or weight density of a fluid is the ratio between the weight of a fluid to its volume.
- Thus weight per unit volume of a fluid is called weight density and it is denoted by the symbol w.
- Mathematically,

$$w = \frac{\text{Weight of fluid}}{\text{Volume of fluid}} = \frac{(\text{Mass of fluid}) \times \text{Acceleration due to gravity}}{\text{Volume of fluid}}$$

$$= \frac{\text{Mass of fluid} \times g}{\text{Volume of fluid}}$$

$$= \rho \times g$$

$$w = \rho g$$

Specific Volume

Properties of Fluids

Specific Volume

- Specific volume of a fluid is defined as the volume of a fluid occupied by a unit mass or volume per unit mass of a fluid is called specific volume.
- Mathematically, it is expressed as

$$\text{Specific volume} = \frac{\text{Volume of fluid}}{\text{Mass of fluid}} = \frac{1}{\frac{\text{Mass of fluid}}{\text{Volume}}} = \frac{1}{\rho}$$

- Thus specific volume is the reciprocal of mass density. It is expressed as m^3/kg.
- It is commonly applied to gases.

Specific Gravity

Properties of Fluids

Specific Gravity.

- Specific gravity is defined as the ratio of the weight density (or density) of a fluid to the weight density (or density) of a standard fluid.
- For liquids, the standard fluid is taken water and for gases, the standard fluid is taken air. Specific gravity is also called relative density. It is dimensionless quantity and is denoted by the symbol *S*.

$$S(\text{for liquids}) = \frac{\text{Weight density (density) of liquid}}{\text{Weight density (density) of water}}$$

$$S(\text{for gases}) = \frac{\text{Weight density (density) of gas}}{\text{Weight density (density) of air}}$$

$$\text{Thus weight density of a liquid} = S \text{ x Weight density of water} = S \text{ x } 1000\text{x } 9.81 \text{N/m}^3$$

$$\text{Thus density of a liquid} = S \text{ x Density of water} = S \text{ x } 1000 \text{kg/m}^3$$

Newtonian Fluids

- Fluids which obey the above relation are known as Newtonian fluids and the fluids which do not obey the above relation are called Non-newtonian fluids.

Variation of Viscosity with Temperature

- Temperature affects the viscosity.
- The viscosity of liquids decreases with the increase of temperature while the viscosity of gases increases with increase of temperature. This is due to reason that the viscous forces in a fluid are due to cohesive forces and *molecular momentum transfer.*
- *In liquids the cohesive forces predominates the molecular momentum* transfer due to closely packed molecules and with the increase in temperature, the cohesive forces decreases with the result of decreasing viscosity.

Types of Fluids

Types of Fluids

1. Ideal Fluid. A fluid, which is incompressible and is having no viscosity, is known as an ideal fluid. Ideal fluid is only an imaginary fluid as all the fluids, which exist, have some viscosity.
2. Real fluid. A fluid, which possesses viscosity, is known as real fluid. All the fluids: in actual practice, are real fluids.
3. Newtonian Fluid. A real fluid, in which the shear stress is directly, proportional to the rate of shear strain (or velocity gradient), is known as a Newtonian fluid.
4. Non-Newtonian fluid. A real fluid, in which shear stress is not proportional to the rate of shear strain (or velocity gradient), known as a Non-Newtonian fluid.

Types of Fluids

Ideal Plastic Fluid.

A fluid, in which shear stress is more than the yield value and shear stress is proportional to the rate of shear strain (or velocity gradient), is known as ideal plastic fluid.

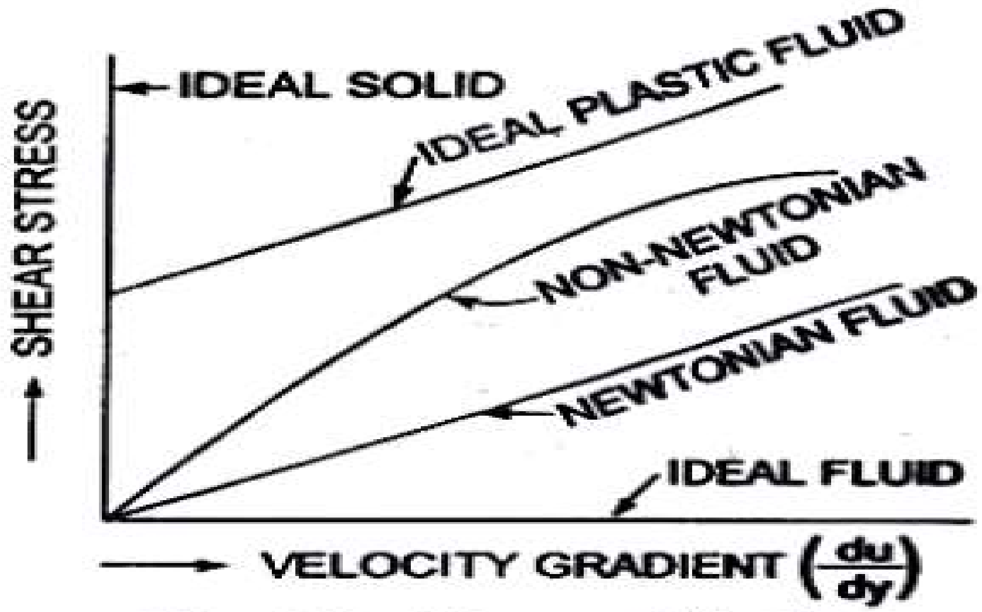


Fig. 1.2 *Types of fluids.*

Pascal's Law

PASCAL'S PRINCIPLE

A change in the pressure applied to an enclosed incompressible fluid is transmitted undiminished to every portion of the fluid and to the walls of the containing vessel.

Bernoulli's Equation

Bernoulli's Equation

Conservation of energy in a moving fluid

$$p + \frac{1}{2}\rho v^2 + \rho g y = \text{constant}$$

If the fluid is motionless, then v=0 and

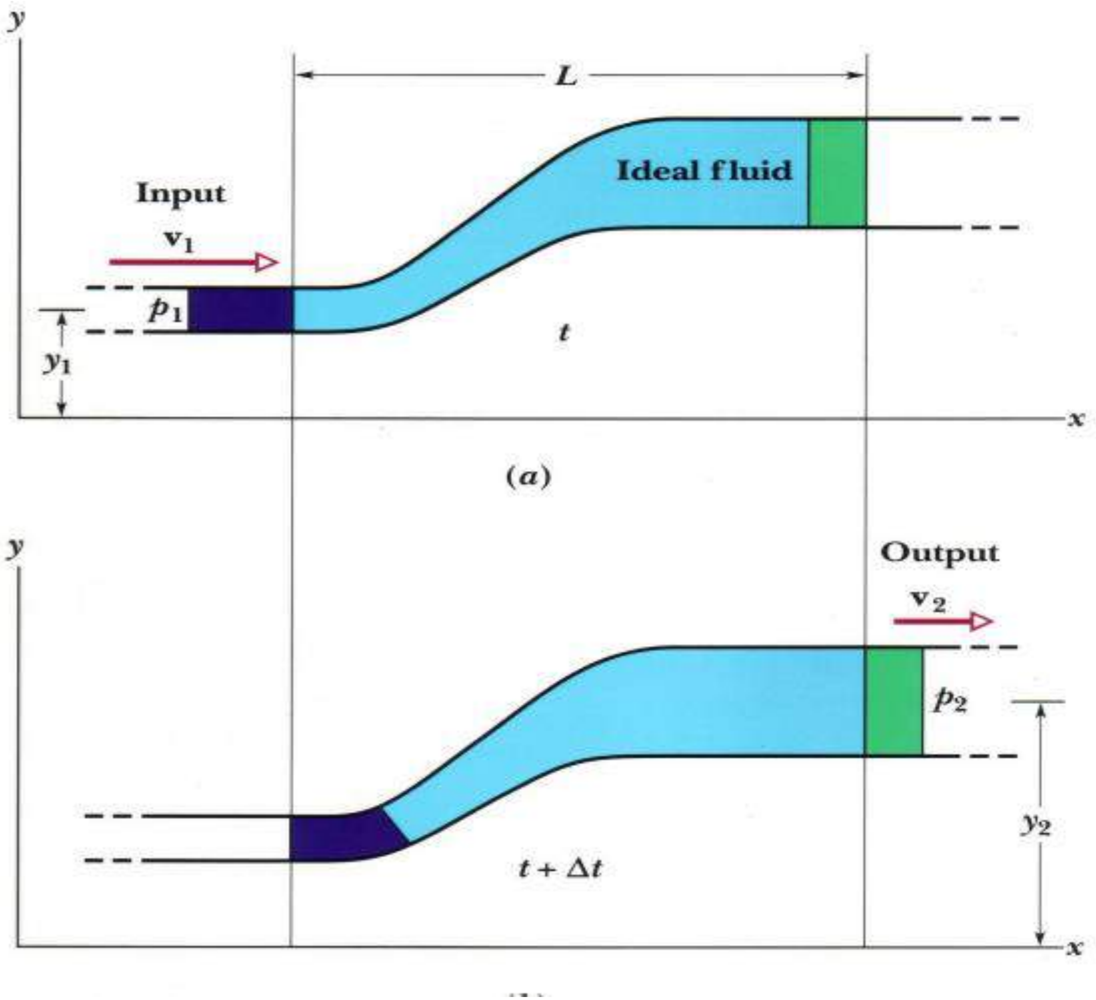
$$p + \rho g y = \text{constant}$$

which we've already seen.

If the fluid moves without changing it height,

$$p + \frac{1}{2}\rho v^2 = \text{constant}$$

This tells you how pressure changes with speed.



Summary

In this chapter, Fluid and their significance is looked out for his involvement in daily lives;

- Fluid and their types
- Properties of the fluids
- Pascal’s Law
- Bernoulli’s Equation

Topics to be Discussed in Next Lecture

In the next topic, Certain facts are glanced at which are significant for depicting various forces under different planes

- Free Body Diagram
- Triangle Law of forces
- Parallelogram Law of forces
- Lami’s Theorm