FLUID MECHANICS FOR MECHANICAL ENGINEERING (ME 208F)

Section A:
Fluid Properties & Fluid Statistics -I

Introduction

- Fluid mechanics is a study of the behavior of fluids, either at rest (fluid statics) or in motion (fluid dynamics).
- The analysis is based on the fundamental laws of mechanics, which relate continuity of mass and energy with force and momentum.
- An understanding of the properties and behavior of fluids at rest and in motion is of great importance in engineering.

Objectives

1. Identify the units for the basic quantities of time, length, force and mass.
2. Properly set up equations to ensure consistency of units.
3. Define the basic fluid properties.
4. Identify the relationships between specific weight, specific gravity and density, and solve problems using their relationships.

1.1 Definition of Fluid

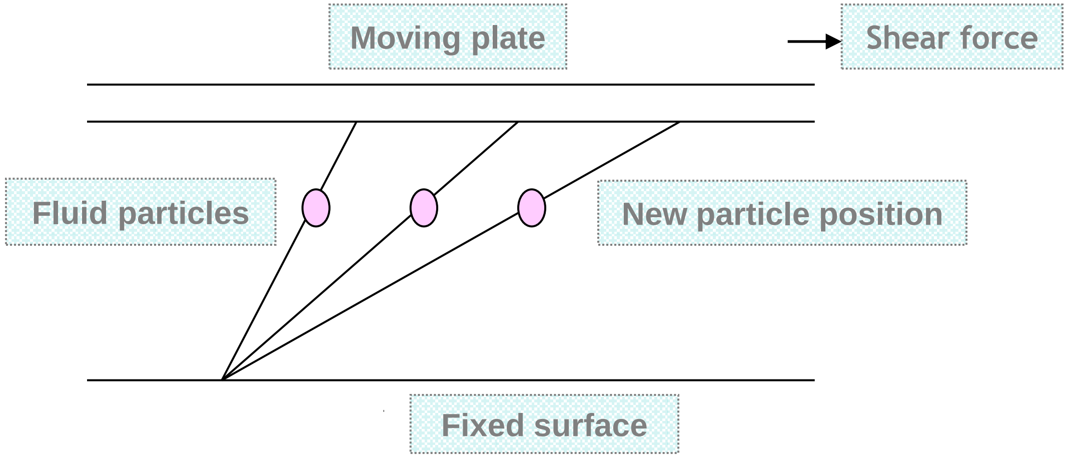
- A fluid is a substance, which deforms continuously, or flows, when subjected to shearing force
- In fact if a shear stress is acting on a fluid it will flow and if a fluid is at rest there is no shear stress acting on it.

Fluid Flow → Shear stress – Yes

Fluid Rest → Shear stress – No

Shear stress in moving fluid

- If fluid is in motion, shear stress are developed if the particles of the fluid move relative to each other. Adjacent particles have different velocities, causing the shape of the fluid to become distorted
- On the other hand, the velocity of the fluid is the same at every point, no shear stress will be produced, the fluid particles are at rest relative to each other.



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.

Newtonian and Non-Newtonian Fluid

Fluid --obey--> Newton's law of viscosity --refer--> Newtonian fluids

Example:
Air
Water
Oil
Gasoline
Alcohol
Kerosene
Benzene
Glycerine

Newton's' law of viscosity is given by;

$$\tau = \mu \frac{du}{dy} \quad (1.1)$$

τ = shear stress
μ = viscosity of fluid
du/dy = shear rate, rate of strain or velocity gradient

- The viscosity μ is a function only of the condition of the fluid, particularly its temperature.
- The magnitude of the velocity gradient (du/dy) has no effect on the magnitude of μ.

Newtonian and Non-Newtonian Fluid

Fluid --- Do not obey ---> Newton's law of viscosity ---> Non- Newtonian fluids

- The viscosity of the non-Newtonian fluid is dependent on the *velocity gradient* as well as the *condition of the fluid*.

Newtonian Fluids

- a linear relationship between shear stress and the velocity gradient (rate of shear),
- the slope is constant
- the viscosity is constant

non-Newtonian fluids

- slope of the curves for non-Newtonian fluids varies

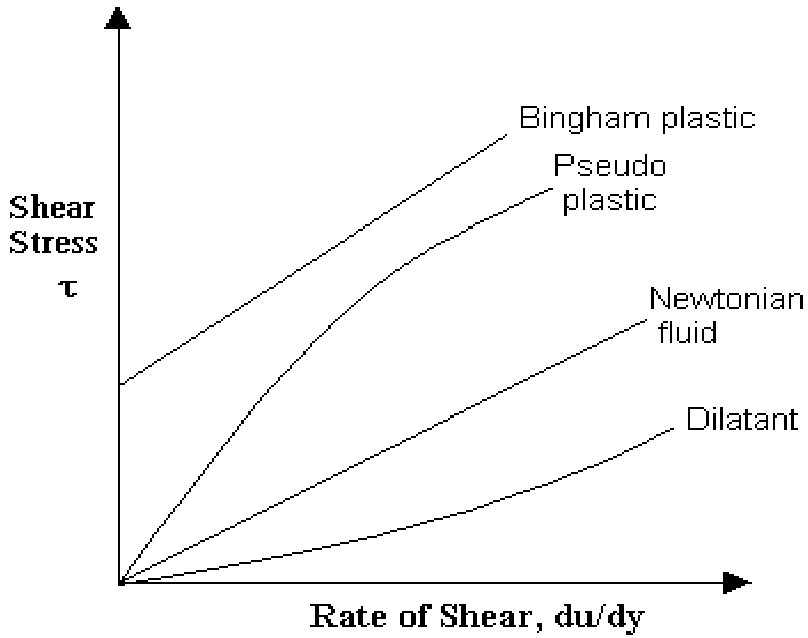


Figure 1.1
Shear stress vs. velocity gradient

Bingham plastic : resist a small shear stress but flow easily under large shear stresses, e.g. sewage sludge, toothpaste, and jellies.

Pseudo plastic : most non-Newtonian fluids fall under this group. Viscosity decreases with increasing velocity gradient, e.g. colloidal substances like clay, milk, and cement.

Dilatants : viscosity decreases with increasing velocity gradient, e.g. quicksand.

1.2 **Engineering Units**

Primary Units

Quantity	SI Unit
Length	Metre, m
Mass	Kilogram, kg
Time	Seconds, s
Temperature	Kelvin, K
Current	Ampere, A
Luminosity	Candela

In fluid mechanics we are generally only interested in the top four units from this table.

Derived Units

Quantity	SI Unit	
velocity	m/s	-
acceleration	m/s^2	-
force	Newton (N)	$N = kg.m/s^2$
energy (or work)	Joule (J)	$J = N.m = kg.m^2/s^2$
power	Watt (W)	$W = N.m/s = kg.m^2/s^3$
pressure (or stress)	Pascal (P)	$P = N/m^2 = kg/m/s^2$
density	kg/m^3	-
specific weight	$N/m^3 = kg/m^2/s^2$	$N/m^3 = kg/m^2/s^2$
relative density	a ratio (no units)	dimensionless
viscosity	$N.s/m^2$	$N.s/m^2 = kg/m/s$
surface tension	N/m	$N/m = kg/s^2$

Unit Cancellation Procedure

1. Solve the equation algebraically for the desired terms.
2. Decide on the proper units of the result.
3. Substitute known values, including units.
4. Cancel units that appear in both the numerator and denominator of any term.
5. Use correct conversion factors to eliminate unwanted units and obtain the proper units as described in Step 2.
6. Perform the calculations.

Example 1.1

Given m = 80 kg and $a=10\ m/s^2$. Find the force

Solution

- F = ma
- $F = 80\ kg \times 10\ m/s^2 = 800\ kg.m/s^2$
- **F= 800N**