Introduction to fluid mechanics

Fluid mechanics is concerned with the behaviour of fluid at rest (fluid static) & in motion (fluid dynamic) and the interaction of fluid with other fluids or solids at the boundaries.

Fluid is a substance, might be liquid or gas, that deforms continuously (flow) when subjected to a shear stress.

Solids & Liquids

From Microscopic point of view

Solid: large intermolecular forces with small spacing between molecules.

Liquid: the intermolecular forces are smaller than for solids with bigger spacing between molecules.

From Fluid Mechanics Perspective

When shear stress is subjected to a substance:

- If the substance deforms continuously (flow), it is a fluid
- If the substance experiences a small deformation δl (strain), it is a solid

Fluid Mechanics is divided into several categories:

- ***Hydrodynamics:*** deals with the flow of incompressible fluids (especially water) at low speed such as hydro power plants (Dams).
- ***Aerodynamics:*** deals with the flow of compressible fluids (especially air) over bodies such as aircrafts, rockets and cars.
- ***Gas dynamics:*** deals with the flow of fluids (especially gases) that undergoes significant density change such as the flow of natural gas through nozzles at high speed, for example the flow of natural gases in to the combustion chamber of gas turbine.

Property of Fluids

Density (ρ): The ratio of the mass of a fluid to its volume (kg/m^3). It characterizes a mass of the fluid system.

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

The density of the water is 1000 kg/m^3.

The variations in pressure and temperature generally have only a small effect on the value of ρ for liquid. In contrast to liquid, the density of a gas is strongly influenced by both pressure and temperature.

Specific weight (γ): The ratio of the weight of a fluid to its volume (N/m^3). It characterizes the weight of a fluid system.

$$\gamma = \frac{weight\ of\ fluid}{Volume\ of\ fluid}$$

$$\gamma = \frac{m\ x\ g}{v} = \frac{\rho\ x\ v\ x\ g}{v} = \rho\ x\ g$$

The specific weight of the water is $\boldsymbol{\gamma_{water} = \rho_{water}\ x\ g = 1000\ x\ 9.81 = 9810\ N/m^3}$.

Specific Gravity (SG): The specific gravity of a fluid is the ratio of fluid density to the density of standard fluid (Water for liquids & air for gases).

$$SG = \frac{density\ of\ fluid}{density\ of\ water} = \frac{\rho_{liquid}}{\rho_{water}} = \frac{\gamma_{liquid}}{\gamma_{water}}$$

This give us an indication about the heaviness of the Liquids

- If SG > 1, The liquid is heavier than the water
- If SG < 1, The liquid is lighter than the water

Specific volume (υ): is defined as the volume of a fluid occupied by a unit mass. Thus, it is the reciprocal of the density.

$$\upsilon = \frac{Volume\ of\ fluid}{Mass\ of\ fluid} = \frac{1}{density} = \frac{1}{\rho}$$

Ex) 200 litres of a certain oil weights 180 kg. Calculate the specific weight, specific gravity and specific volume of it.

Ex) Calculate the density, specific weight and weight of one litre of petrol of specific gravity equals to 0.7.

Compressibility and bulk modulus

Compressibility (C) shows how easily can the volume of a fluid change when the pressure changes.

Bulk Modulus K: A property that is commonly used to characterize compressibility. It is defined as the ratio of pressure change to volumetric strain.

$$K = \frac{pressure\ change}{volumetric\ strain} = -\frac{\Delta P}{\Delta V/V} \quad \text{or} \quad \frac{\Delta P}{\Delta\rho/\rho}$$

The negative sign means that the increase in pressure will cause a decrease in volume. Compressibility is reciprocal of bulk modulus.

For most purposes, liquids can be considered as incompressible fluids. For example**,** it would require a pressure of 220 bar to compress a unit volume of water by 1%.

Ideal Gas Law

Gases are highly compressible in comparison to liquids, changes in gas volume (and hence density) can be directly related to changes in pressure and temperature through the ideal gas equation:

PV = mRT or P = ρRT … (Ideal Gas Law)

P: Absolute pressure (Pgauge +Patm)
T: Absolute temperature (T (K) = T (^{o}C) + 273)
m: Mass
ρ: Density
R: Gas constant, (Air: 287$\frac{J}{Kg.K}$)

Ex) A compressed air tank has a volume of 0.3 m3. When the tank is filled with air at a gage pressure of 0.2 Mpa, determine the density of the air and the weight of air in the tank. Assume the temperature is 30 C and the atmospheric pressure is 101.3 Kpa.