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Fluid Mechanics

Introduction to Fluid Mechanics

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Chapter Description

- Aims
  - Describe Fluid Properties and the fundamentals of Fluid Mechanics concept.

- Expected Outcomes
  - Define fluid mechanics
  - Describe Fluid Properties and the fundamentals of Fluid Mechanics concept.

- References

  - Douglas F.J., Gasiorek J.M., Swaffield J.A. Fluid Mechanics. Prentice Hall 4th Edition.
  - Bruce R. M., Donald F.Y and Theodore H.O. Fundamentals of Fluid Mechanics. Wiley.
  - Nakayama Y and Broucher R.F. Introduction to Fluid Mechanics. Revised. Butterworth Heinmann.

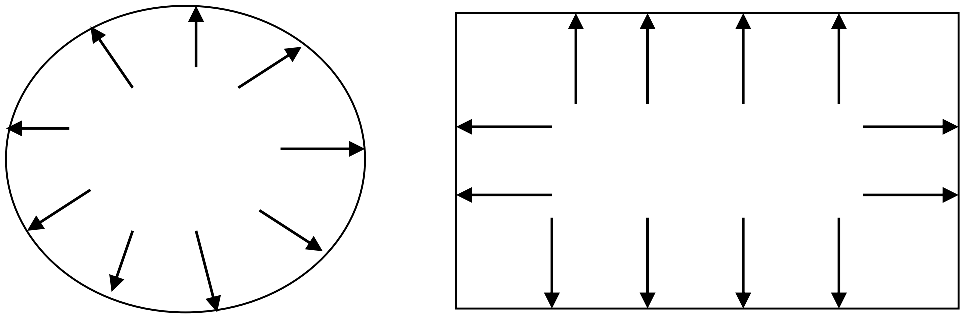
1.4 Fluid Properties

- Fluid properties are intimately related to fluid behaviour.
  - Pressure
  - Compressibility
  - Density
  - Specific weight
  - Specific gravity
  - Surface tension
  - Dynamic viscosity
  - Kinematics viscosity

1.4.1 Pressure

- Pressure : The amount of force exerted on a unit area of a substance.
  - $$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$

- Pascal's principle, also called Pascal's law in fluid (gas or liquid) mechanics, states that : in a fluid at rest in a closed container, a pressure change in one part is transmitted without loss to every portion of the fluid and to the walls of the container.



Pascal's Laws

1.4.2 Compressibility & Bulk Modulus

- Compressibility refers to the change in volume (V) of a substance that is subjected to a change in pressure on it.
- The usual quantity used to measure this phenomenon is the bulk modulus of elasticity or simply , bulk modulus (E).
  - $$E = \frac{-\Delta P}{\left(\frac{\Delta V}{V}\right)}$$
- **Students' activity :** Student is required to obtain the table for Value for Bulk Modulus for liquids at atmospheric pressure and 20^{O}C

1.4.3 Density

- Density, ρ (rho) : The amount of mass per unit volume of a substance.
  - Mass per unit volume : $\rho = \dfrac{m}{V}$
  - Unit : kg/m^3 (SI unit)
  - Absolute – depends on mass, which is independent of location
  - Dimensions : ML^{-3}
  - Typical values : water = 1000 kg/m^3

    sea water =1025 kg/m^3

    air = 1.23 kg/m^3

    mercury = 13600 kg/m^3

1.4.4 Specific Weight

- Specific Weight, γ : The amount of weight per unit volume of a substance
  - Weight per unit volume : $\gamma = \frac{w}{V} = \frac{mg}{V}$
  - γ : Weight per unit volume;
  - Unit : N/m^3 (SI unit)
  - Not absolute – depends on the value of the gravitational acceleration,
  - The weight, w depends on gravitational attraction, w = mg

- Density & Specific Weight are related as :
  - $\rho = \gamma/g$ or $\gamma = \rho g$

1.4.5 Specific Gravity

- Specific Gravity/ Relative density, σ : The relative density of a substance is defined as the ratio of its mass density to the mass density of water taken at atmosphere pressure at a temperature of $4^{O}C$
  - Mass density of a substance : $$\sigma = \frac{\rho_{\text{substance}}}{\rho_{\text{H2O}}}$$
  - Units : none (ratio is a pure number)
  - ρH2O (4°C) : $1000 kg/m^3$
  - Units : no unit
  - Dimensions : dimensionless
  - Typical values : water = 1.0;
    castor oil = 0.96;
    mercury =13.6

1.4.6 Surface Tension

- The force acting across a unit length of a line drawn in the liquid surface.
- This force , σ, acts in the plane of the surface, normal to any line in the surface.
- Surface tension tends to reduce area of a body of liquid.
- Surface tension acts somewhat like a film at the interface between the liquid water surface and the air above it.

Source : https://commons.wikimedia.org/wiki/File:Wasserl%C3%A4ufer_bei_der_Paarung_crop.jpg

1.4.7 Viscosity

- May be defined as a resistance of a liquid to shear forces (and hence to flow)
- Fluid at rest cannot resist shearing forces.
- Shear stresses opposing the relative motion of these layers are set up,(magnitude depending on the velocity gradient from layer to layer),
- From Newton's Law of viscosity, taking the motion's direction as x direction, therefore, the shear stress;
- $\tau x = \mu dvx / dy$

i) Dynamic Viscosity, μ

- The shear force per unit area (shear stress, τ) needed to drag a layer of fluid with a unit velocity past another layer at a unit distance away from it in the fluid.

$$\mu = \frac{\tau}{(\Delta v / \Delta y)}$$

- Shear force per unit area (or shear stress, $\tau = \frac{F}{A}$)
- $\mu = \dfrac{\text{shear stress}}{\text{shear strain}} = \dfrac{\left(F/A\right)}{\left(v/h\right)}$

- Units : Ns/m² or kg/ms
- Often measured : Poise (P); 10P = 1kg/ms
- Dimensions : $ML^{-1}T^{-1}$
- Typical values : water = 1.14×10^{-3} kgm-1s^{-1}
- air = 1.78×10^{-5} kgm-1s^{-1}

ii) Kinematic viscosity, ν

- Kinematic viscosity, ν is the ratio of dynamic viscosity to mass density.
- Given as : $\nu = \mu / \rho$
- Units : $m^2\ s^{-1}$
- Dimensions : $L^2\ T^{-1}$
- Typical values : water $= 1.14 \times 10^{-6}\ m^2 s^{-1}$

  air $= 1.46 \times 10^{-5}\ m^2 s^{-1}$

Conclusion of The Chapter

- Conclusion 1
  - The knowledge of fluid mechanics are important to be applied in human's life, for example in building water structure like water supply system and for weather & climate, medical, & vehicle application.

- Conclusion 2
  - Fluid may be in liquid & gas and maybe in condition of static, dynamic & kinematic

- Conclusion 3
  - Fluid properties like density, specific weight, specific gravity, compressibility, viscosity and many more has its own characteristics and formula.