# **Summary | Fluid Dynamics**

## Introduction

#### **Flow**

Motion with relative movement between fluid particles where continuous deformation happens.

#### Classification of fluid flow

#### **Density**

#### Incompressible

Density doesn't vary significantly.

#### Examples:

- Pipe and channel flows of liquids
- Gas flows in pipes

$$rac{|\Delta
ho|}{
ho}\ll 1$$

#### Compressible

Density varies significantly.

#### Examples:

• Pressure surges in pipes

### **Viscosity**

#### Non-viscous

Fluid doesn't show any resistance to the flow.

#### **Viscous**

Fluid shows any resistance to the flow.

- Newtonian:  $\mu$  is constant Examples: Water
- Non-newtonian:  $\mu$  is not constant Examples: Paints, Clay, Plastics

#### Variation of parameters

The parameters:

- ullet Velocity V
- ullet Pressure P
- ullet Flow rate Q

#### **Temporal Variation**

The variation of the parameters with time.

- ullet Steady: no variation with time  $\,V=f(x,y,z)\,$
- ullet Unsteady: variation of flow parameters with time  $\,V=f(t,x,y,z)\,$

#### **Spatial Variation**

The variation of the parameters with coordinates.

- ullet Uniform: no variation with spatial parameters  $\,V=f(t)\,$
- ullet Non-uniform: spatial variation of flow parameters  $\,V=f(t,x,y,z)\,$

#### **Dimensional**

If a variation of flow parameter in a certain direction can be neglected, that can reduce the calculations.

#### Nature of movement

- Laminar: Fluid particles move in a orderly fashion
- Turbulent: Fluid particles move disorderly

#### **Rotation of particles**

- Rotational: Usually due to shear forces. Flow of real fluids.
- Non-rotational: Flow of frictionless forces.

### Flow patterns

#### **Streamline**

A line tangential to the flow velocity.

#### Streamtube

A passage enclosed by a collection of streamlines.

#### **Pathline**

Path traced by an individual fluid particle.

#### **Streakline**

Suppose a dye is injected into a fluid flow. Streakline indicates the positions of all particles passed through the point of injection.

(i) Note

In steady flow: streamline, pathline and streakline all coincide.

## **Conservation Laws**

In fluid dynamics, 4 laws are used to analyse the fluid flow.

- Laws of mechanics
- Conservation of mass
- Conservation of energy
- Conservation of momentum

These laws are applied to a specific volume of the fluid in motion, and it's called as control volume.

#### **Control volume**

A volume, through which a fluid flows.

- It's a fixed volume
- Can either be real or imaginary

#### Conservation of mass

Mass cannot be created nor destroyed.

## Conservation of energy

Energy cannot be created nor destroyed, but can be converted from one form to another.

#### Conservation of momentum

Unless a resultant force is exerted on a mass, it cannot gain or lose momentum.

#### **Momentum**

$$M = \text{mass} \times \text{velocity} = mv$$

## **Derivations**

## Continuity equation

From the conservation of mass law, the below equation can be derived for an incompressible fluid:

$$Q = Av$$

Here:

- ullet Q Flow rate
- ullet A Cross-sectional area
- $oldsymbol{\cdot}$   $oldsymbol{v}$  velocity

## Bernoulli's equation

For an incompressible fluid in steady flow, total head on a point is constant throughout a <u>streamline</u>. Can be derived from the conservation of energy law.

$$\text{Total head } H = z + \frac{P}{\rho g} + \frac{v^2}{2g}$$

Here:

- ullet z Datum head. Height to the point from a reference level.
- $\frac{P}{\rho g}$  Pressure head.
- $\frac{v^2}{2g}$  Velocity head. Kinetic energy per unit weight.

#### (i) Note

- Head is the energy per unit weight.
- Piezometric head is equal to  $\frac{P^*}{
  ho g}$  where  $P^*$  is the piezometric pressure.

## Steady flow momentum equation

$$F_S = \dot{M_o} - \dot{M_i}$$

Here:

- ullet  $F_S$  Force exerted on the fluid within the control volume
- ullet  $\dot{M}_o$  Rate of change of momentum of the inflow fluid
- ullet  $\dot{M}_i$  Rate of change of momentum of the outflow fluid

## (i) Note

Below equation can be useful in applications.

$$\dot{M}=
ho Q v$$

Where:

- $\rho$  density
- ullet Q flow rate
- $oldsymbol{\cdot}$   $oldsymbol{v}$  velocity

## **Power**

$$P = \gamma QH$$

Here:

- $oldsymbol{\circ}$   $\gamma$  specific weight of the fluid
- ullet Q flow rate
- ullet H total head

## Losses

Energy losses in a fluid under motion.

## **Types**

#### **Local loss**

Occurs when there is a sudden change in flow.

$$K_L rac{v^2}{2g}$$

#### Here:

- ullet  $K_L$  local loss coefficient
- ullet v velocity
- ullet g gravitational acceleration

#### **Friction loss**

Occurs because of

- viscosity
- friction between fluid and pipe wall

When the fluid is under turbulent flow:

$$\lambda \frac{L}{D} \frac{v^2}{2g}$$

Here:

- $oldsymbol{\lambda}$  friction factor
- ullet length of the pipe
- ullet D diameter of the pipe
- ullet v velocity
- ullet g gravitational acceleration

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