# **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

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

### 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  $oldsymbol{P}$
- ullet Flow rate  $oldsymbol{Q}$

## **Temporal Variation**

The variation of the parameters with time.

• Steady: no variation with time

$$V = f(x, y, z)$$

• Unsteady: variation of flow parameters with time

$$V = f(t, x, y, z)$$

# **Spatial Variation**

The variation of the parameters with coordinates.

• **Uniform**: no variation with spatial parameters

$$V = f(t)$$

• 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.



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**

$$M = \mathrm{mass} imes \mathrm{velocity} = mv$$

# **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
- $oldsymbol{v}$  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:

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

(i) Note

- Head is the energy per unit weight.
- ullet Piezometric head is equal to  $rac{P^*}{
  ho g}$  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
- $oldsymbol{\dot{M}_o}$  Rate of change of momentum of the inflow fluid
- $oldsymbol{\dot{M}_i}$  Rate of change of momentum of the outflow fluid

# (i) Note

Below equation can be useful in applications.

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

Where:

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

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