FLUID MECHANICS.

Fluid mechanics is the branch of physics concerned with the mechanics of fluids (liquids, gases, and plasmas) and the forces on them. It has applications in a wide range of disciplines, including mechanical, civil, chemical and biomedical engineering, geophysics, oceanography, meteorology, astrophysics, and biology. It can be divided into fluid statics, the study of fluids at rest; and fluid dynamics, the study of the effect of forces on fluid motion. It is a branch of continuum mechanics, a subject which models matter without using the information that it is made out of atoms; that is, it models matter from a *macroscopic* viewpoint rather than from *microscopic*. Fluid mechanics, especially fluid dynamics, is an active field of research, typically mathematically complex. Many problems are partly or wholly unsolved and are best addressed by numerical methods, typically using computers. A modern discipline, called computational fluid dynamics (CFD), is devoted to this approach. Particle image velocimetry, an experimental method for visualizing and analysing fluid flow, also takes advantage of the highly visual nature of fluid flow.

The study of fluid mechanics goes back at least to the days of ancient Greece, when Archimedes investigated fluid statics and buoyancy and formulated his famous law known now as the Archimedes' principle, which was published in his work *On Floating Bodies*—generally considered to be the first major work on fluid mechanics. Rapid advancement in fluid mechanics began with Leonardo da Vinci (observations and experiments), Evangelista Torricelli (invented the barometer), Isaac Newton (investigated viscosity) and Blaise Pascal (researched hydrostatics, formulated Pascal's law), and was continued by Daniel Bernoulli with the introduction of mathematical fluid dynamics in *Hydrodynamica* (1739).

Inviscid flow was further analysed by various mathematicians (Jean le Rond d'Alembert, Joseph Louis Lagrange, Pierre-Simon Laplace, Siméon Denis Poisson) and viscous flow was explored by a multitude of engineers including Jean Léonard Marie Poiseuille and Gotthilf Hagen. Further mathematical justification was provided by Claude-Louis Navier and George Gabriel Stokes in the Navier–Stokes equations.

Main branches

Fluid statics.

Fluid statics or **hydrostatics** is the branch of fluid mechanics that studies fluids at rest. It embraces the study of the conditions under which fluids are at rest in stable equilibrium; and is contrasted with fluid dynamics, the study of fluids in motion. Hydrostatics offers physical explanations for many phenomena of everyday life, such as why atmospheric pressure changes with altitude, why wood and oil float on water, and why the surface of water is always level whatever the shape of its container. Hydrostatics is fundamental to hydraulics, the engineering of equipment for storing, transporting and using fluids. It is also relevant to some aspects of geophysics and astrophysics (for example, in understanding plate tectonics and anomalies in the Earth's gravitational field), to meteorology, to medicine (in the context of blood pressure), and many other fields.

Fluid dynamics.

Fluid dynamics is a subdiscipline of fluid mechanics that deals with **fluid flow**—the science of liquids and gases in motion. Fluid dynamics offers a systematic structure—which underlies these practical disciplines—that embraces empirical and semi-empirical laws derived from flow measurement and used to solve practical problems. The solution to a fluid dynamics problem typically involves calculating various properties of the fluid, such as velocity, pressure, density, and temperature, as functions of space and time. It has several subdisciplines itself, including **aerodynamics** (the study of air and other gases in motion) and **hydrodynamics** (the study of liquids in motion). Fluid dynamics has a wide range of applications, including calculating forces and movements on aircraft, determining the mass flow rate of petroleum through pipelines, predicting evolving weather patterns, understanding nebulae in interstellar space and modelling explosions. Some fluid-dynamical principles are used in traffic engineering and crowd dynamics.

Assumptions

The assumptions inherent to a fluid mechanical treatment of a physical system can be expressed in terms of mathematical equations. Fundamentally, every fluid mechanical system is assumed to obey:

- Conservation of mass

- Conservation of energy
- Conservation of momentum
- The continuum assumption

For example, the assumption that mass is conserved means that for any fixed control volume (for example, a spherical volume)—enclosed by a control surface—the rate of change of the mass contained in that volume is equal to the rate at which mass is passing through the surface from *outside* to *inside*, minus the rate at which mass is passing from *inside* to *outside*. This can be expressed as an equation in integral form over the control volume.

The **continuum assumption** is an idealization of continuum mechanics under which fluids can be treated as continuous, even though, on a microscopic scale, they are composed of molecules. Under the continuum assumption, macroscopic (observed/measurable) properties such as density, pressure, temperature, and bulk velocity are taken to be well-defined at "infinitesimal" volume elements—small in comparison to the characteristic length scale of the system, but large in comparison to molecular length scale. Fluid properties can vary continuously from one volume element to another and are average values of the molecular properties. The continuum hypothesis can lead to inaccurate results in applications like supersonic speed flows, or molecular flows on nano scale. Those problems for which the continuum hypothesis fails can be solved using statistical mechanics. To determine whether or not the continuum hypothesis applies, the Knudsen number, defined as the ratio of the molecular mean free path to the characteristic length scale, is evaluated. Problems with Knudsen numbers below 0.1 can be evaluated using the continuum hypothesis, but molecular approach (statistical mechanics) can be applied to find the fluid motion for larger Knudsen numbers.

So basically, Fluid Mechanics is a Branch of science which deals with behavior of fluids (liquids / gases) at rest as well in motion. Let’s define a few terms briefly:
- Static mechanics, this is the study of fluids at rest
- Kinematic fluid mechanics: This is the study of fluids in motion where pressure force not considered.
- Dynamic Fluid mechanics: This is the study of fluid in motion where pressure forces are considered.

Properties of Fluids

1.Density or Mass density ρ – ratio of mass of a fluid to its volume.

ρ = Mass / Unit volume of fluid – density

Unit – kg/m^3

$$\rho = \frac{\text{Mass}}{\text{Volume}}$$

Density of fluids may be considered constant

2.Specific weight or weight density – Ratio between the weight of a fluid to its volume

Weight / unit volume weight density (w)

$$W = \frac{\text{weight of fluid}}{\text{Volume of fluid}}$$

$$= \frac{\text{mass of fluid x g}}{\text{Volume of fluid}}$$

W= ρg volume =9.81 x 1000 N/m^3

3. Specific volume – Volume of a fluid occupied by a unit mass

Volume / unit mass of fluid – specific volume

$$\text{Specific volume} = \frac{\text{volume of fluid}}{\text{Mass of fluid}}$$

Reciprocal of mass density

Unit – m^3/kg

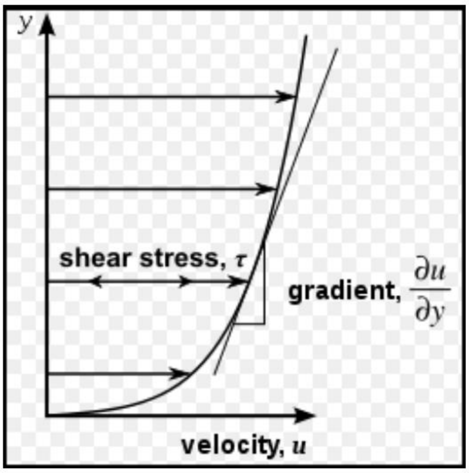
4. Specific gravity – Ratio of density of fluid to density of standard fluid

Liquids – standard fluid – water

Gases – Standard fluid – Air

Also relative density, dimensionless

Viscosity – Property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid



When 2 layers of fluid, a distance 'dy' apart, move over one another at different velocities, u and u+dv, viscosity together with relative viscosity causes a shear stress acting between the fluid layers.

Top layer causes shear stress on bottom layer and vice versa

Shear stress is proportional to rate of change of velocity with respect to y.

$\tau = \mu \frac{\partial u}{\partial y},$ $\partial u / \partial y$ = Rate of shear strain $\mu.$ = constant coefficient of dynamic viscosity

Units of viscosity: SI Unit = Ns/m^2

In CGS –(Poise) =kg f sec/m^2 1 kg f=9.81N

Newton's law of viscosity – Shear stress on fluid element layer is proportional to rate of shear stress.

$$\tau = \mu \frac{\partial u}{\partial y},$$

$\mu.$ = coefficient of viscosity.

Types of fluids

1. Ideal fluid
2. Real fluid
3. Non – Newtonian fluid
4. Ideal Plastic fluid

Ideal fluid – incompressible and no viscosity

- Imaginary fluid
- All fluids have some viscosity

Real fluid – fluid which possess viscosity

- All fluids are real fluids

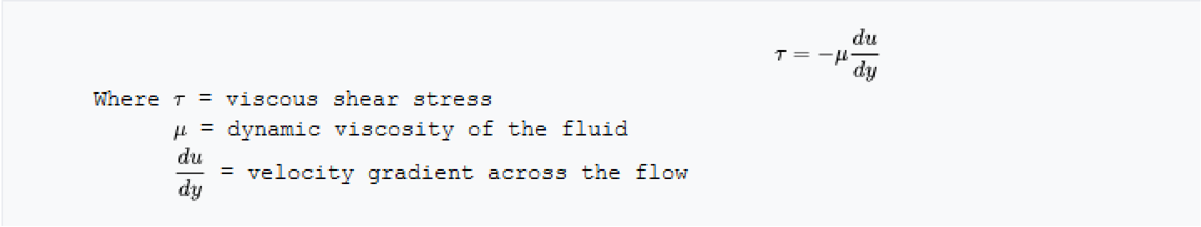
Non-newtonian fluid – real fluid in which shear stress is directly proportional to rate of shear strain (velocity gradient)

Non-newtonian fluid – real fluid in which shear stress is not proportional to rate of shear stress

Ideal Plastic Fluid – fluid in which shear stress is more than yield value and is proportional to rate of shear stress

In nonideal fluid dynamics, the Hagen–Poiseuille equation, also known as the Hagen–Poiseuille law, Poiseuille law or **Poiseuille equation**, is a physical law that gives the pressure drop in an incompressible and Newtonian fluid inlaminar flow flowing through a long cylindrical pipe of constant cross section. It can be successfully applied to air flow inlung alveoli, for the flow through a drinking straw or through a hypodermic needle

An Ideal Fluid is a fluid that has no viscosity, means it will offer no resistance, pragmatically this type of fluid does not exist. It is incompressible in nature. Real fluids are compressible in nature. They offer some resistance and thus have viscosity. All Fluids existing are real fluids. A Newtonian Fluid is a fluid whose viscous shear stresses (acting between different layers of fluid and between the fluid layer and surface over which it is flowing) are directly proportional to the rate of change of velocity of the flow of the fluid with respect to the distance in the transverse direction (distance measured perpendicular to the flow), also known as velocity gradient. The constant of proportionality is known as the dynamic viscosity of the fluid denoted by 'μ'. The functional relationship between viscous shear stress and velocity gradient is linear in a Newtonian fluid. This relationship may be written as:



$$\tau = -\mu\frac{du}{dy}$$

Where τ = viscous shear stress
μ = dynamic viscosity of the fluid
$\frac{du}{dy}$ = velocity gradient across the flow

Newtonian fluids:

Fluids which obey the Newton's law of viscosity are called as Newtonian fluids. Newton's law of viscosity is given by

t = mdv/dy

where t = shear stress

m = viscosity of fluid

dv/dy = shear rate, rate of strain or velocity gradient

All gases and most liquids which have simpler molecular formula and low molecular weight such as water, benzene, ethyl alcohol, CCl_4, hexane and most solutions of simple molecules are Newtonian fluids.

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