Chapter 1 :

Reminders: A- Properties of fluids, Statics of fluids, Dynamics of perfect fluids.

Intoduction

Mechanics is a branch of physics whose object is the study of movement, deformations or states of equilibrium of physical systems. This science applies the laws governing the movements of different kinds of bodies. Fluid mechanics is a branch of mechanics which studies the flow of fluids* when they are subject to forces or constraints. It is the science that applies the fundamental principles of general mechanics to liquids and gases. These principles are conservation of mass, conservation of energy and Newton's law of motion. To study compressible fluids, we need to consider the laws of thermodynamics.

*The fluid: the fluid is any body which takes the form of the vase which contains it. It is a continuous body without rigidity which can flow and undergo large deformations even under the action of very weak forces. Liquids and gases are fluids. Their movement is governed by the same equations with the difference that liquids are very little compressible and gases are compressible and expandable indefinitely.

Fluid mechanics is made up of two sub-branches:

- Fluid statics or hydrostatics which studies fluids at rest.
- Fluid dynamics which studies fluids in motion by calculating various fluid properties such as speed, pressure, density and temperature as functions of space and time.

Fluid mechanics has many applications in various fields such as turbomachines, internal combustion engines, pollution, hydraulic networks, naval engineering, the study of blood flow (hemodynamics), the study of behavior pasta, lubrication theory, meteorology, climatology and even oceanography

I-Properties of fluids

I-1-Density

Consider a mass of fluid ∂m having a volume ∂V. The density of the fluid in a point A inside the volume is:$\rho=\partial m/\partial v$. Its unit is kg/m^3.

- Numerical values of density in kg/m^3 for air and water at pressure atmospheric are represented in Table I-1 below:

Fluid/temperature	0 ° C	4 ° C	20 ° C	100 ° C
Air	1.294		1.20	0.95
Water	999.87	1000	998.2	958.7

Table I-1 density of air and water at different temperatures

The variation in density is important in gases and varies with the pressure and temperature. In liquids, it is almost constant: the density of water only increases by 1% if the pressure increases by a factor of 220. For this the Most liquids are considered incompressible fluids.

In general, the value of the density of liquids is greater than that gases at atmospheric pressure. The heaviest liquid is mercury, and the lightest gas is hydrogen. Their densities at 20°C and 1 atm are: ρHg≈13600 kg/m3 and ρH2=0.0838 kg/m3. The report between the two densities is 162000. Most often the value of the density of mercury used in applications is ρHg=13600 kg/m3**.**

I-2-Density

Density is the ratio of the density of a fluid to that of the fluid of reference, which is water for liquids and air for gases. Density is therefore unitless.

$$d_{gaz} = \frac{\rho_{gaz}}{\rho_{air}} \text{ et } d_{liquid} = \frac{\rho_{liquid}}{\rho}$$

I-3-Specific weight

The specific gravity of a fluid, denoted by γ (gamma), is its weight per unit volume γ=ρg. Its unit is N/m^3.

I-4-1-Dynamic viscosity µ

Viscosity µ is a property of a fluid due to the cohesion and interaction between the molecules that exhibit resistance to deformation. All fluids are viscous and obey the law of viscosity established by Newton

$$\tau = \frac{F}{A} = \mu \frac{dU}{dz}$$

dU/dz : shear strain rate

µ: dynamic viscosity of the fluid. Its unit is Poiseuille Pl, Pl= Pa.s=N m-2 s = kg/m s

One poise P =0.1 Pl

I-4-2-Kinematic viscosity ν

$$\nu = \frac{\mu}{\rho}.$$

Its unit is therefore m2s-1(kg m-1s-1/kg m-3). We notice that it is independent of the unit of mass kg and only depends on the units of the kinematics, i.e. the units of length and time hence the name kinematic viscosity

1-4-3-Newtonian fluids and non-Newtonian fluids

Fluids for which the shear stress is proportional (varies

linearly) at the strain rate (therefore at the speed gradient) are called fluids

Newtonians. Most common fluids such as water, air, gasoline and oils are

Newtonians.

I-5-Some Definitions

1-Perfect fluid: is a non-viscous fluid, ($\mu=0$).

2-Real fluid: is a viscous fluid, ($\mu\neq0$).

3-Compressible or incompressible fluid: the density of the fluid varies or does not vary

not during flow respectively.

4- Subsonic, supersonic flow: the flow is subsonic (supersonic) if the

fluid speed V is less (greater) than the speed of sound c. In this case, the number of

Mach = $V/c < 1$ (> 1).

5- Laminar, turbulent flow: A flow can be laminar or turbulent

6- External, internal flow: external flows are flows in the environment

open, not confined around objects. Internal flows are confined, for example to

inside a conduit. They are limited by fixed or movable walls.

7- One-dimensional, two-dimensional, three-dimensional flow: a flow is

one-dimensional, two-dimensional or three-dimensional if the parameters that characterize it

(such as speed, pressure, temperature etc.) depend on one, two or three variables of space respectively.

8- Permanent or stationary, non-permanent or unsteady flow: a flow is permanent or stationary (non-permanent or unsteady) when the characteristic quantities, at each given point of the domain, do not vary (vary) with the time,

II-1- Fluid Statics

Fluid statics is the science that studies the equilibrium conditions of fluids at rest. The resultant of all forces acting on any particle is zero.

-Concept of pressure at a point of a fluid

$$P_M = \lim_{dA \to 0} \frac{dF_n}{dA}$$

The unit of pressure is the pascal Pa: 1Pa=1N/m2

We also have a bar = 105 Pa

Another unit of pressure is the atmosphere such that 1atm=1.01325 ×105 Pa=1.01325 bar

Remarks

-A fluid always has pressure.

-The absolute pressure pabs is a scalar always positive.

- The effective pressure is given by: $p_{eff} = p_{abs} - p_{atm}$ where p_{atm} is the atmospheric pressure

II-2-fluids Dynamic

are moving fluids, studied in the field of fluid dynamics. This branch of physics examines the behavior of fluids, whether liquid or gaseous, when they are in motion or subject to external forces.

In general, dynamic fluids take into account the complex interactions between pressure, speed, density and viscosity of fluids. These interactions can lead to a variety of phenomena, such as the laminar flow (fluid which flows in order, in parallel layers), the turbulent flow (more chaotic and unstable) or the generation of hydrodynamic forces on submerged objects.

The dynamics of fluids also studies mathematical equations which describe the movement of fluids, such as the mass conservation equation, the equation of conservation of the movement (also known as the Navier-Stokes equation for non -compressible fluids) and the energy conservation equation.

The applications of dynamic fluids are vast and affect many areas, from aeronautics to process engineering, including meteorology, fluid mechanics in the human body and many other sectors. Understanding the principles of dynamic fluids is crucial for the effective design of aircraft, vehicles, hydraulic infrastructure and to solve complex engineering problems.

II-3 fundamental laws in fluid dynamics

The dynamics of fluids are governed by several fundamental physical laws which describe the behavior of moving fluids. Here are some of the most important laws in fluid dynamics:

Mass conservation law: this law stipulates that the mass of a closed fluid system remains constant over time, provided that there is no input or mass output in the system. It is expressed by the continuity equation for incompressible fluids.

Law of conservation of the quantity of movement (or equation of Navier-Stokes): this law describes how the amount of movement of a fluid changes in response to the forces applied to it. For incompressible fluids, it is represented by the Navier-Stokes equations, which describe the variation in the speed of fluid as a function of pressure, viscosity and external forces.

Energy conservation law: this law states that total energy in a closed fluid system remains constant. It takes into account kinetic energy, potential energy and heat exchanged, and it is often expressed in the form of an energy equation.

Bernoulli's law: This law is derived from the energy conservation equation and describes the behavior of an ideal fluid along a current line. It connects the pressure, speed and altitude of an incompressible flow in flow.

Law of viscosity: it describes how viscosity forces act within a fluid. For Newtonian fluids, Newton's viscosity law states that shear stress is proportional to the fluid deformation rate.

These laws are fundamental to understanding and modeling the behavior of moving fluids. They are used in many areas such as engineering, meteorology, aeronautics, medicine, and many others, to analyze and predict the behavior of fluids in various situations.