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INTRODUCTION TO FLUID MECHANICS

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ВВЕДЕНИЕ В МЕХАНИКУ ГИДРОИЗОЛЯЦИИ.

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ANNOTATION

Mechanics is the oldest physical science that deals with both stationary and moving bodies under the influence of forces. The branch of mechanics that deals with bodies at rest is called statics, while the branch that deals with bodies in motion is called dynamics.

Keywords: fluid kinematics, fluid mechanics, hydraulics, fluid dynamics, hydrodynamics.

АННОТАЦИЯ

Механика — старейшая физическая наука, изучающая как неподвижные, так и движущиеся тела под действием сил. Раздел механики, изучающий покоящиеся тела, называется статикой, а раздел, изучающий движущиеся тела, — динамикой.

Ключевые слова: гидрокинематика, гидромеханика, гидравлика, гидродинамика, гидродинамика.

DEFINITION

Mechanics is the oldest physical science that deals with both stationary and moving bodies under the influence of forces. The branch of mechanics that deals with bodies at rest is called statics, while the branch that deals with bodies in motion is called dynamics. The subcategory fluid mechanics is defined as the science that deals with the behaviour of fluids at rest (fluid statics) or in motion (fluid dynamics), and the interaction of fluids with solids or other fluids at the boundaries.

The study of fluids in motion, where pressure forces are not considered, is called **fluid kinematics** and if the pressure forces are also considered for the fluids in motion that branch of science is called **fluid dynamics**. Fluid mechanics itself is also divided into several categories. The study of the motion of fluids that are practically incompressible (such as liquids, especially water, and gases at low speeds) is usually referred to as **hydrodynamics.** A subcategory of hydrodynamics is **hydraulics,** which deals with liquid flows in pipes and open channels. Gas dynamics deals with the flow of fluids that undergo significant density changes, such as the flow of gases through nozzles a thigh speeds. The category aerodynamics deals with the flow of gases (especially air) over bodies such as aircraft, rockets, and automobiles at high or low speeds. Some other specialized categories such as meteorology, oceanography, and hydrology deal with naturally occurring flows.

What is a fluid?

A substance exists in three primary phases: solid, liquid, and gas. A substance in the liquid or gas phase is referred to as a **fluid.** Distinction between a solid and a fluid is made on the basis of the substance's ability to resist an applied shear (or tangential) stress that tends to change its shape. A solid can resist an applied shear stress by deforming, whereas a fluid deforms continuously under the influence of shear stress, no matter how small. In solids stress is proportional to strain, but in fluids stress is proportional to strain rate. When a constant shear force is applied, a solid eventually stops deforming, at some fixed strain angle, whereas a fluid never stops deforming and approaches a certain rate of strain.

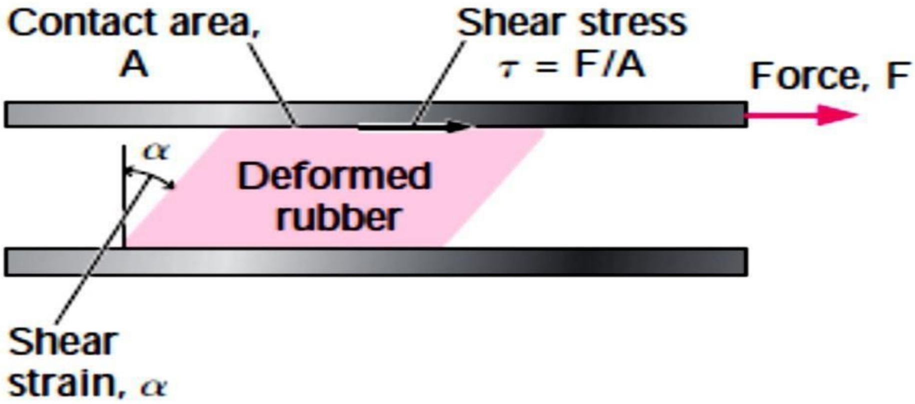
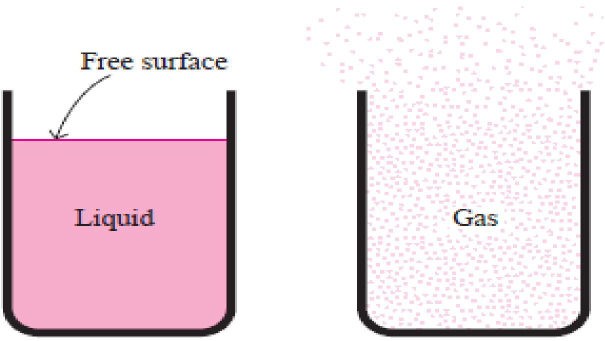


Figure.

Deformation of a rubber eraser placed between two parallel plates under the influence of a shear force.

In a liquid, molecules can move relative to each other, but the volume remains relatively constant because of the strong cohesive forces between the molecules. As a result, a liquid takes the shape of the container it is in, and it forms a free surface in a larger container in a gravitational field. A gas, on the other hand, expands until it encounters the walls of the container and fills the entire available space. This is because the gas molecules are widely spaced, and the cohesive forces between them are very small. Unlike liquids, gases can not form a free surface



Differences between liquid and gases

Liquid	Gases
Difficult to compress and often regarded as incompressible	Easily to compress – changes of volume is large, cannot normally be neglected and are related to temperature
Occupies a fixed volume and will take the shape of the container	No fixed volume, it changes volume to expand to fill the containing vessels
A free surface is formed if the volume of container is greater than the liquid.	Completely fill the vessel so that no free surface is formed.

Application areas of Fluid Mechanics.

Mechanics of fluids is extremely important in many areas of engineering and science. Examples are:

❑ **Biomechanics**
- Blood flow through arteries and veins
- Airflow in the lungs
- Flow of cerebral fluid

❑ **Households**
- Piping systems for cold water, natural gas, and sewage
- Piping and ducting network of heating and air-conditioning systems
- Refrigerator, vacuum cleaner, dishwasher, washing machine, water meter, natural gas meter, air conditioner, radiator, etc.

❑ **Meteorology and Ocean Engineering**
- Movements of air currents and water currents

❑ **Mechanical Engineering**
- Design of pumps, turbines, air-conditioning equipment,
- pollution-control equipment, etc.
- Design and analysis of aircraft, boats, submarines, rockets, jet engines, wind turbines, biomedical devices, the cooling of electronic components, and the transportation of water, crude oil, and natural gas.

❑ **Civil Engineering**
- Transport of river sediments
- Pollution of air and water
- Design of piping systems
- Flood control systems

❑ **Chemical Engineering**
- Design of chemical processing equipment

❑ **Mechanical Engineering**
- Design of pumps, turbines, air-conditioning equipment,
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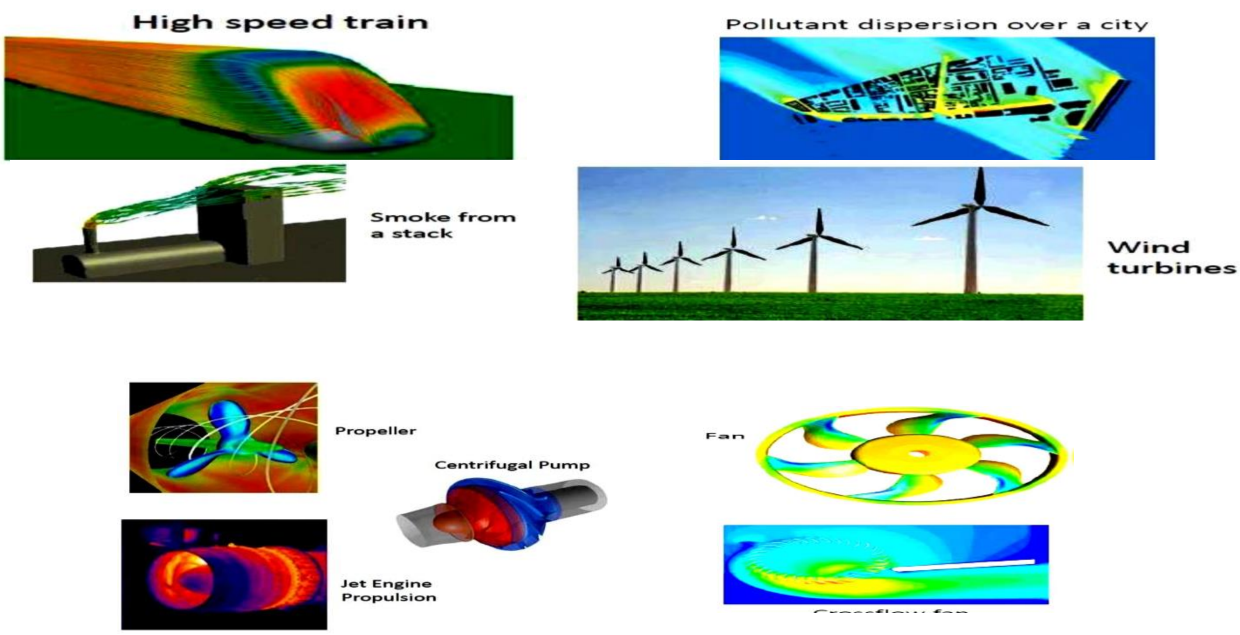
wind turbines, biomedical devices, the cooling of electronic components, and the transportation of water, crude oil, and natural gas.

- **Civil Engineering**
- Transport of river sediments
- Pollution of air and water
- Design of piping systems
- Flood control systems
- **Chemical Engineering**
- Design of chemical processing equipment
- **Turbomachines:** pump, turbine, fan, blower, propeller, etc.
- **Military:** Missile, aircraft, ship, underwater vehicle, dispersion of chemical agents, etc.
- **Automobile:** IC engine, air conditioning, fuel flow, external aerodynamics, etc.
- **Medicine:** Heart assist device, artificial heart valve, glucose monitor, controlled drug delivery, etc.
- **Electronics:** Convective cooling of generated heat.
- **Energy:** Combustor, burner, boiler, gas, hydro and wind turbine, etc.
- **Oil and Gas:** Pipeline, pump, valve, offshore rig, oil spill clean up, etc.
- Almost everything in our world is either in contact with a fluid or is itself a fluid.

Application areas of Fluid Mechanics



Historical development

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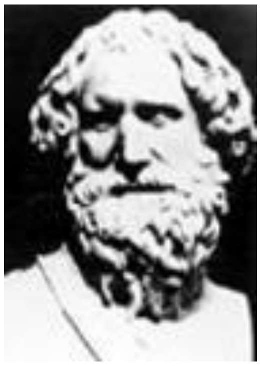
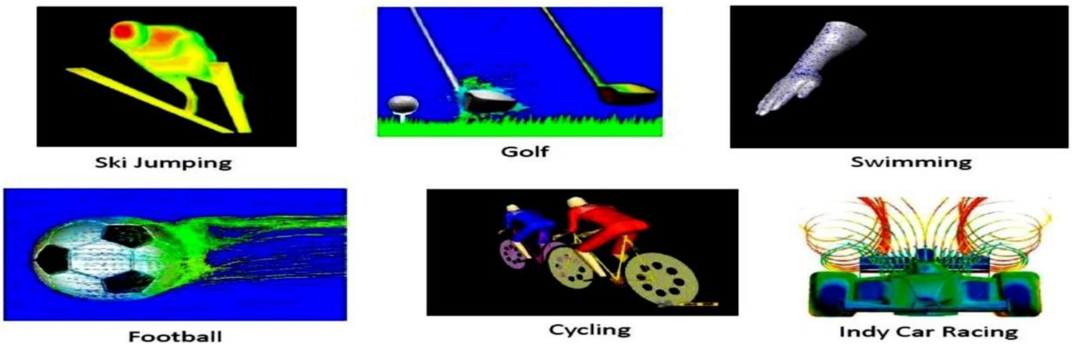
（1） The First Satge (before 17th century)

Archimedes(285-212 BC)

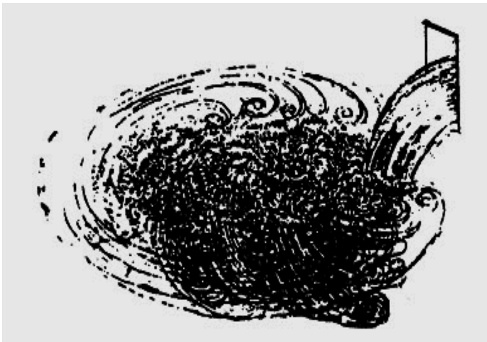


- Ancient civilizations: irrigation, ships
- Ancient Rome: aqueducts, baths (4th century B.C.)
- Ancient Greece: Archimedes – buoyancy (3rd century B.C.)
- Leonardo (1452-1519): experiments, research on waves, jets, eddies, streamlining, flying

Parallelogram law for addition of vectors Law of buoyancy,
Leonardo da Vinci (1452-1519)



* Equation of conservation of mass in one-dimensional steady flow
* Experimentalist
* Turbulence



达・芬奇画笔下的湍流（取自 Chapmem 和 Tohak，1985年）

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Fig. 1. Sketch from Leonardo da Vinci's notebooks.

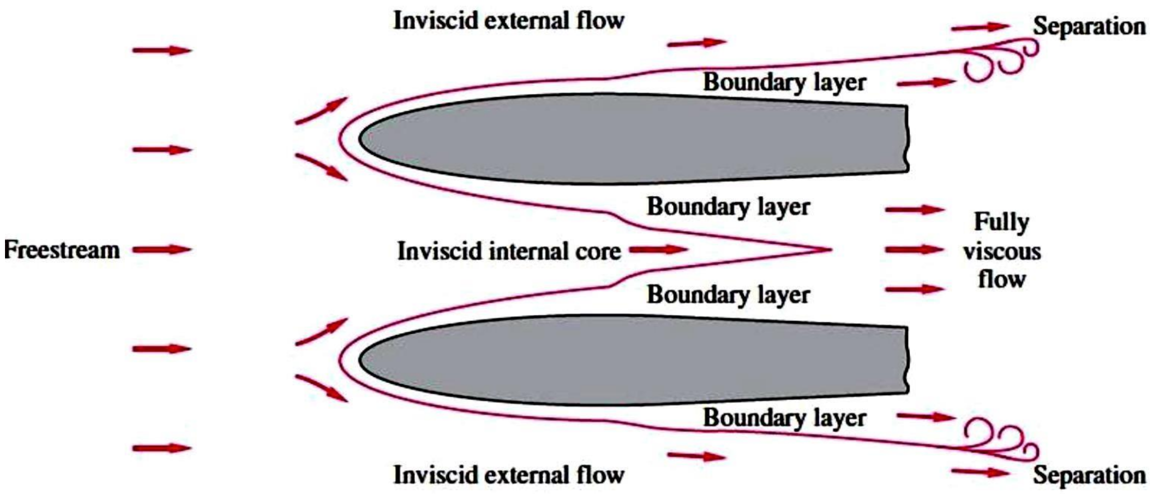
Classification of Fluid Flow

- There is a wide variety of fluid flow problems encountered in practice, and it is usually convenient to classify them on the basis of some common characteristics to make it feasible to study them in groups.

Viscous Regions of Flow

- When two fluid layers move relative to each other, a friction force develops between them and the slower layer tries to slow down the faster layer.
- This internal resistance to flow is quantified by the fluid property viscosity, which is a measure of internal stickiness of the fluid.
- Viscosity is caused by cohesive forces between the molecules in liquids and by molecular collisions in gases.

Viscous versus Inviscid Regions of Flow



Internal versus External Flow

A fluid flow is classified as being internal or external, depending on whether the fluid is forced to flow in a confined channel or over a surface. The flow of an unbounded fluid over a surface such as a plate, a wire, or a pipe is **external flow.** The flow in a pipe or duct is **internal flow** if the fluidis completely bounded by solid surfaces. Water flow in a pipe, for example, is internal flow, and airflow over a ball or over an exposed pipe during a windy day is external flow.

Compressible versus Incompressible Flow

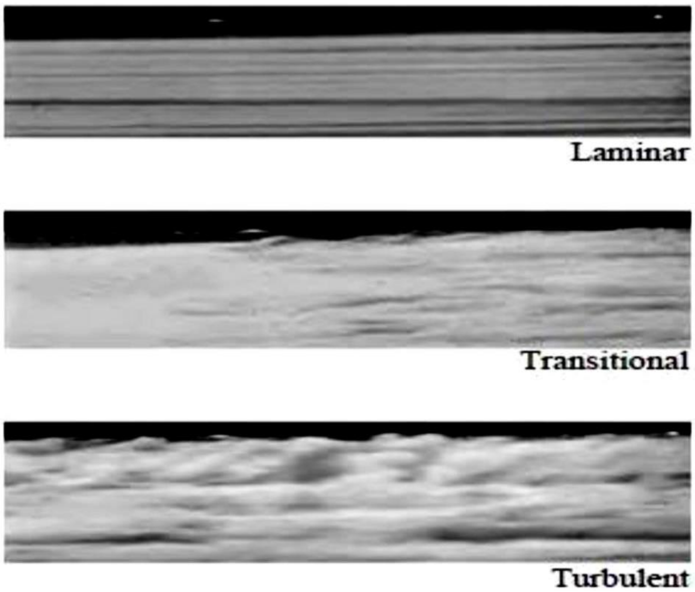
A flow is classified as being compressible or incompressible, depending on the level of variation of density during flow. Incompressibility is an approximation, and a flow is said to be **incompressible** if the density remains nearly constant throughout. Therefore, the volume of every portion of fluid remains unchanged over the course of its motion when the flow(or the fluid) is incompressible. The densities of liquids are essentially constant, and thus the flow of liquids is typically incompressible. Therefore, liquids are usually referred to as incompressible substances.

Compressible versus Incompressible Flow

A pressure of 210 atm, for example, causes the density of liquid water at 1 atm to change by just 1percent. Gases, on the other hand, are highly compressible. A pressure change of just 0.01 atm, for example, causes a change of 1 percent in the density of atmospheric air. Gas flows can often be approximated as incompressible if the density changes are under about 5 percent.

Laminar versus Turbulent Flow

Some flows are smooth and orderly while others are rather chaotic. The highly ordered fluid motion characterized by smooth layers of fluid is called **laminar.** The flow of high-viscosity fluids such as oils at low velocities is typically laminar. The highly disordered fluid motion that typically occurs at high velocities and is characterized by velocity fluctuations is called **turbulent.**



Laminar versus Turbulent Flow

The flow of low-viscosity fluids such as air at high velocities is typically turbulent. A flow that alternates between being laminar and turbulent is called transitional.

Natural (or Unforced) versus Forced Flow

A fluid flow is said to be natural or forced, depending on how the fluid motion is initiated. In **forced flow,** a fluid is forced to flow over a surface or in a pipe by external means such as a **pump or a fan**. In **natural flows,** any fluid motion is due to natural means such as the buoyancy effect, which manifests itself as the rise of the warmer (and thus lighter) fluid and the fall of cooler (and thus denser) fluid. In solar hot-water systems, for example, the thermosiphoning effect is commonly used to replace pumps by placing the water tank sufficiently above the solar collectors.

Steady versus Unsteady Flow

The terms steady and uniform are used frequently in engineering, and thus it is important to have a clear understanding of their meanings. The term steady implies **no change at a point with time.** The opposite of steady is **unsteady.** The term **uniform** implies **no change with location** over a specified region.

LITERATURE

1. Acknowledgement: The material, particularly diagrams, is collected from
2. the following sources:
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4. b. www.yukenindia.com/hydraulicstraining
5. c. www.faa.gov/.../handbooks_manuals/aircraft/...handbook/
6. d. "The Control of Fluid Power", Longman by D McCloy and HR Martin.