Module

1

Thermodynamics

Basic Concepts of Thermodynamics

Dr. Ramesh P Sah
Department of Mechanical Engineering

Objectives:

- To learn about system & control volume
- To learn about property, state & process
- To understand Exact & Inexact differentials
- To review work and thermodynamic definition of work

examples; displacement work, electrical, magnetic, gravitational, spring and shaft work.

Contents:

- System & Control volume
- Property, State & Process
- Exact & Inexact differentials
- Work-Thermodynamic definition of work
- examples; Displacement work; Path dependence of displacement work and illustrations for simple processes; electrical, magnetic, gravitational, spring and shaft work.

Outcomes:

- After completing this course, the students will be able to understand system, control volume, property, state & process
- Students can solve Exact & Inexact differentials
- The students will be able to evaluate displacement work, electrical, magnetic, gravitational, spring and shaft work.

Definitions

System: A quantity of matter or a region in space chosen for study or investigation.

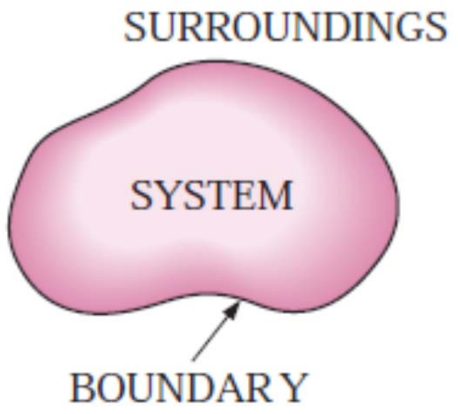


Fig. 1: System, surroundings and boundary

Surroundings: Mass or region outside the system

Boundary: The real or imaginary surface that separates the system from its surroundings.

- can be *fixed* or *movable.*
- the contact surface shared by both the system and the surroundings
- Examples*:* Walls of the kettle, the housing of the engine

Types of System

Closed System: It consists of fixed mass and no mass crosses its boundary. **It is also called as control mass system.**

- That is, no mass can enter or leave a closed system, as shown in Fig. 2.
- But energy, in the form of heat or work, can cross

the boundary; and the volume of a closed system does not have to be fixed.

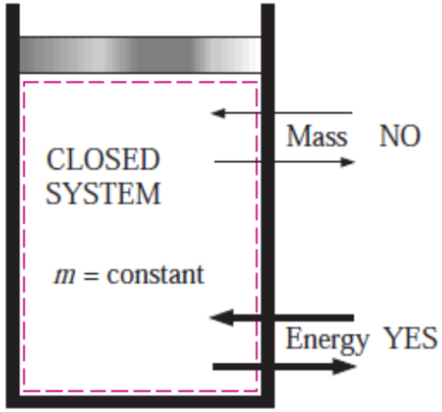


Fig. 2: Mass cannot cross the boundaries of a closed system, but energy can (with fixed boundary)

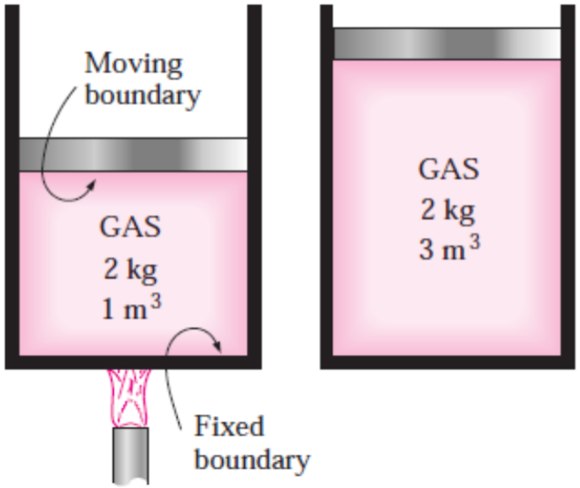


Fig. 3: A closed system with moving boundary

Open System: It is called as control volume system. Both mass and energy can cross the boundary of a control volume.

- *Most of the engineering devices are open system.*

For example: Compressor, nozzle, pump, turbine.

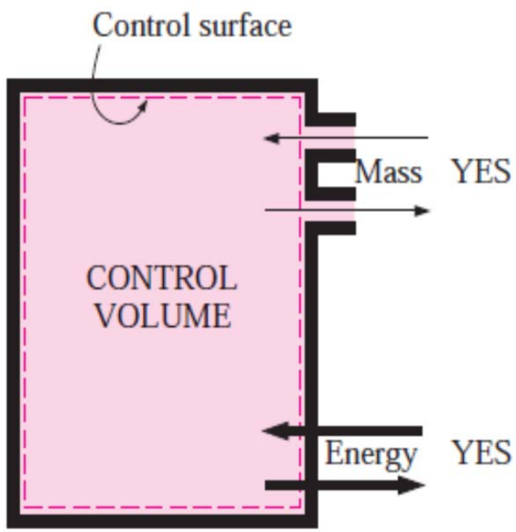


Fig. 3: Both mass and energy can cross the boundaries of a control volume

- A control volume can involve fixed, moving, real, and imaginary boundaries

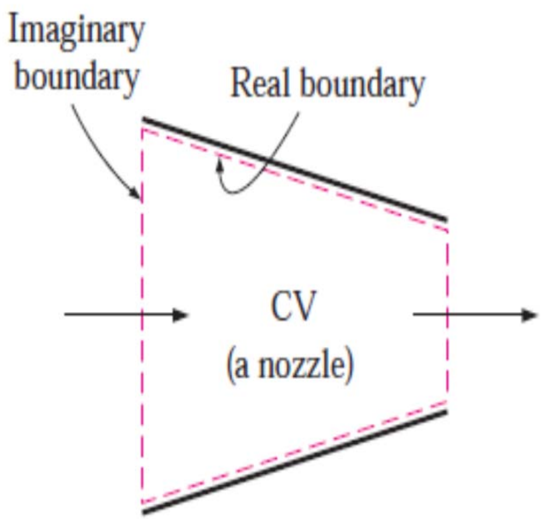


Fig. 4: A control volume with real and imaginary boundaries

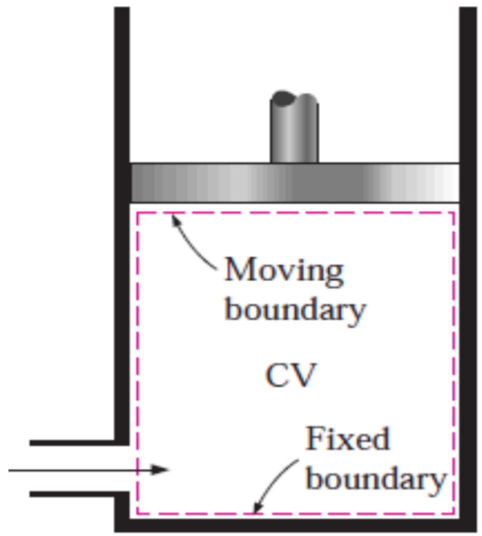
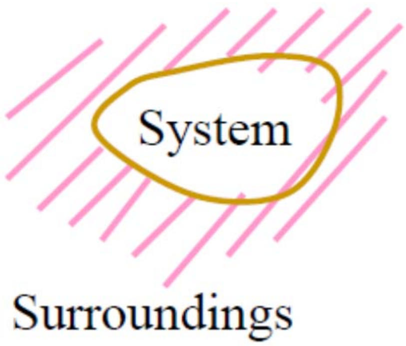


Fig. 5: A control volume with fixed and moving boundaries

- Isolated System: there is no interaction between system and the surroundings. It is of fixed mass and energy, and hence there is no mass and energy transfer across the system boundary.
- Thermo flask is an isolated system.



Macroscopic and Microscopic Approaches

Behaviour of matter can be studied by these two approaches.

In macroscopic approach, certain quantity of matter is considered, without a concern on the events occurring at the molecular level.

These effects can be perceived by human senses or measured by instruments.

- eg: pressure, temperature

In microscopic approach, the effect of molecular motion is Considered.

eg: At microscopic level the pressure of a gas is not constant, the temperature of a gas is a function of the velocity of molecules.

- Most microscopic properties cannot be measured with common instruments nor can be perceived by human senses

Property

PROPERTY: Any characteristic of a system

Classification of Properties

EXTENSIVE PROPERTY: are those whose values depend on the size—or extent—of the system. Mass, volume, and total energy are some examples of extensive properties.

- If mass of a system changes, the value of extensive property also

changes.

- Generally, uppercase letters are used to denote extensive properties (with mass *m* being a major exception)

- INTENSIVE PROPERTIES are those that are independent of the size of a system, such as temperature, pressure, and density.
- If mass of a system changes, the value of intensive property remains same.
- Lowercase letters are used for intensive properties (with pressure *P* and temperature *T* are exceptions).

Specific property:

- It is the value of an extensive property per unit mass of system. (lower case letters as symbols) e.g. specific volume (*v*), density (ρ).
- It is a special case of an intensive property.
- Most widely referred properties in thermodynamics.
- *Specific Entropy (s=S/m); Specific Enthalpy (h=H/m); Specific Internal energy (u=U/m)*

State:

- It is the condition of a system as defined by the values of all its properties.
- It gives a complete description of the system.
- Any operation in which one or more properties of a system change is called a change of state.

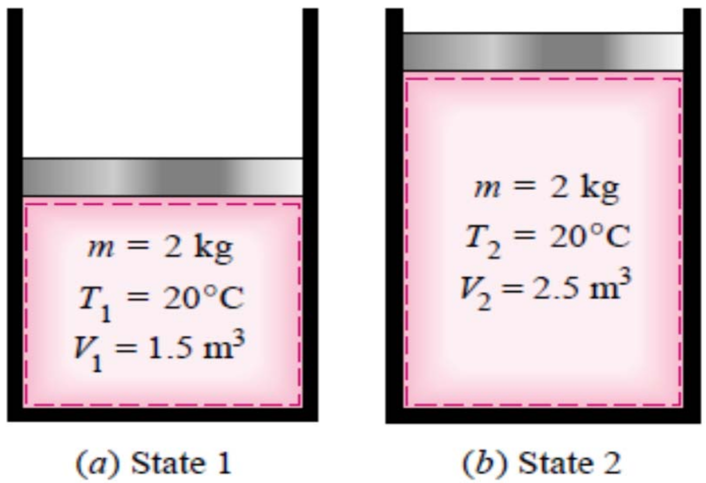


Fig. 6: A system at two different states

Equilibrium:

- It implies a state of balance.
- In an equilibrium state there are no unbalanced potentials (or driving forces) within the system.
- A system in equilibrium experiences no changes when it is isolated from its surroundings.
- There are mechanical, thermal, phase, and chemical equilibria.

a) Thermal equilibrium:

- The temperature is the same throughout the entire system.
- There is no heat flow within the system.

b) Mechanical equilibrium:

- There is no change in pressure at any point of the system with time.

c) Phase equilibrium: If a system involves two phases, it is in **phase equilibrium** when the mass of each phase reaches an equilibrium level and stays there.

d) Chemical equilibrium: A system is in **chemical equilibrium** if its chemical composition does not change with time, that is, no chemical reactions occur.

- A system will not be in equilibrium unless all the relevant equilibrium criteria are satisfied.

Phase:

- It is a quantity of mass that is homogeneous throughout in chemical composition and physical structure.

e.g. solid, liquid, vapour, gas.

- Phase consisting of more than one phase is known as heterogeneous system .

Path And Process:

The succession of states passed through during a change of state is called the *path of the system*. A system is said to go through a process if it goes through a series of changes in state. Consequently:

- A system may undergo changes in some or all of its properties.
- A process can be construed to be the locus of changes of state
- Processes in thermodynamics are like streets in a city

eg: we have north to south; east to west; roundabouts; crescents

Quasi-static Process:

When a process proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times, it is called a **quasi-static,** or **quasi-equilibrium, process.**

- A quasi-equilibrium process can be viewed as a sufficiently slow process that allows the system to adjust itself internally so that properties in one part of the system do not change any faster than those at other parts.

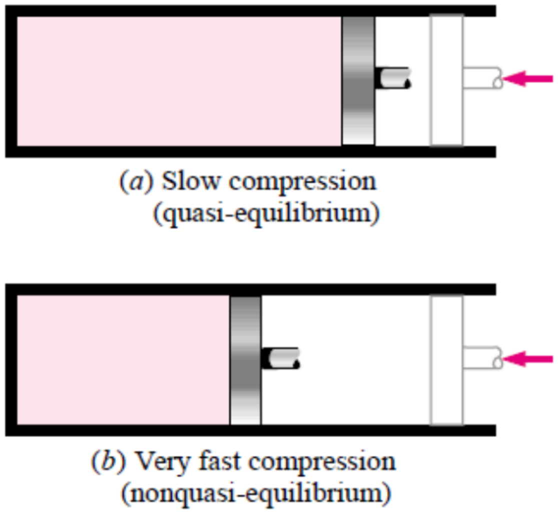


Fig. 7: Quasi-equilibrium and non quasi-equilibrium compression processes.

This is explained in Fig. 7.

- When a gas in a piston-cylinder device is compressed suddenly, the molecules near the face of the piston will not have enough time to escape and they will have to pile up in a small region in front of the piston, thus creating a high-pressure region there. Because of this pressure difference, the system can no longer be said to be in equilibrium, and this makes the entire process non quasi-equilibrium.
- However, if the piston is moved slowly, the molecules will have sufficient time to redistribute and there will not be a molecule pileup in front of the piston. As a result, the pressure inside the cylinder will always be uniform and will rise at the same rate at all locations. Since equilibrium is maintained at all times, this is a quasi-equilibrium process

Types of Processes:

The prefix *iso-* is often used to designate a process for which a particular property remains constant.

- Isothermal (T): Temperature remains constant

Phase change processes are isothermal e.g. Evaporation, Condensation

- Isobaric (p): Pressure remains constant

Phase change processes are isobaric e.g. Evaporation, Condensation

- Isochoric (v): Volume remains constant

Heating a gas in closed rigid container is isochoric as it raises pressure but volume remains constant.

- Isentropic (s): Entropy remains constant

Adiabatic and reversible

- Isenthalpic (h): Enthalpy remains constant

Throttling is isenthalpic process.

- Isosteric (concentration): Concentration remains constant
- Adiabatic (no heat addition or removal): Heat remains constant

Expansion of gas in perfectly insulated cylinder and piston arrangement

Thank You