1.4 Thermodynamic Properties, Processes and Cycles

Thermodynamic Properties

"A thermodynamic property refers to the characteristics which can be used to describe the physical condition or state of a system."

Examples of thermodynamic properties are: Temperature, Pressure, Volume, Energy, Mass, Viscosity, Thermal conductivity, Modulus of elasticity, velocity, etc.

Salient Aspects of a Thermodynamic Property

- It is a *macroscopic characteristic* of the system.
- It has a unique value when the system is in a particular state, and this value does not depend on the previous states that the system passed through; that is, it is not a *path function but it is a point function.*
- Since a property is not dependent on the path, any change depends only on the initial and final states of the system. *Hence its differential is exact.*

Types of Thermodynamic Properties

1. **Intensive Property**

- Intensive property is Independent of the mass of the system. Its value remains same whether one considers the whole system or only a part of it.
- **Examples:** Pressure, Temperature, Density, Viscosity, Thermal conductivity, Electrical potential, etc.

2. **Extensive Property**

- Extensive property depends on the mass of the system.
- **Examples:** Mass, Energy, Enthalpy, Volume, Entropy, etc.

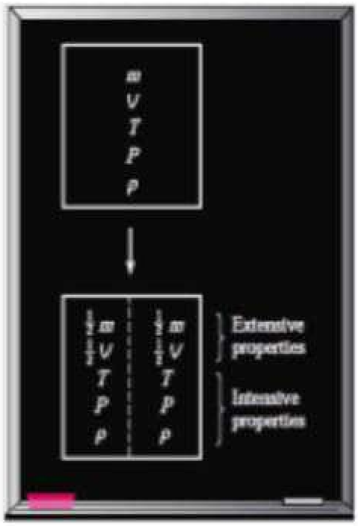

Fig. 1.5 Criterion to differentiate intensive and extensive properties

3. **Specific Property**

- Extensive properties per unit mass are called specific properties.
- **Examples:** Specific volume $\left(v = \frac{V}{m}\right)$ and specific total energy $\left(e = \frac{E}{m}\right)$.

> ❖ **Note:**
> An easy way to determine whether a property is intensive or extensive is to divide the system into two equal parts with an imaginary partition, as shown in Fig. 1.5. Each part will have the same value of intensive properties as the original system, but half the value of the extensive properties.

State

- *"**State** refers to the condition of a system as described by its properties."* It gives a complete description of the system. At a given state, all the properties of a system have fixed values.
- If the value of even one property changes, the state will change to a different one, any such kind of operation is called ***Change of state***.

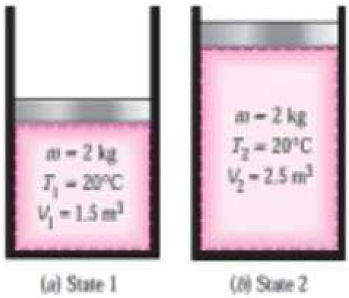

Fig. 1.6 A system at two different states

Process and Path

- Any change that a system undergoes from one equilibrium state to another is called a ***process***, and the series of states through which a system passes during a process is called the ***path*** of the process.
- To describe a process completely, one should specify the initial and final states of the process, as well as the path it follows, and the interactions with the surroundings.
- There are infinite ways for a system to change from one state to another state.

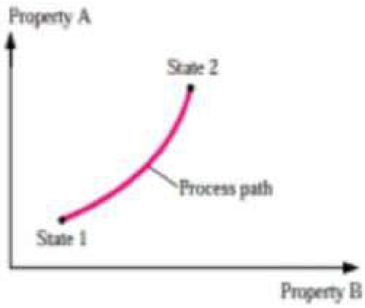

Fig. 1.7 A process between states 1 and 2 and a process path

Cycle

- When a system in a given initial state goes through a number of different changes of state or processes and finally returns to its initial state, the system has undergone a **cycle**. Thus for a cycle the initial and final states are identical.
- **Example:** Steam (water) that circulates through a steam power plant undergoes a cycle.

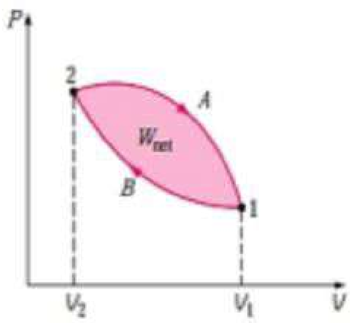

Fig. 1.8 Cycle of operations

Point Function

- When two properties locate a point on the graph (Co-ordinate axis) then those properties are called as Point Function.
- Examples: Pressure, Volume, Temperature, etc.
- It can be represented by an exact differential. i.e. $\int_1^2 dV = V_2 - V_1$

Path Function

- There are certain quantities which cannot be located on a graph (Co-ordinate axis) by a point but are given by the area or so, on that graph.
- In that case, the area on the graph, pertaining to the particular process, is a function of the path of the process, such quantities are called Path Functions.
- **Examples:** Heat, Work, etc.
- It can be represented by an inexact differential. Their change can not be written as difference between their end states.
- Thus,

$$\int_1^2 \delta W \neq W_2 - W_1 \text{ and is shown as } W_{1-2}$$

$$\int_1^2 \delta Q \neq Q_2 - Q_1 \text{ and is shown as } Q_{1-2}$$

> ❖ **Note:**
> The operator δ is used to denote inexact differentials and d is used to denote exact differentials.

1.5 Thermodynamic Equilibrium

- A system is said to be in a state of thermodynamic equilibrium, if the conditions for the following three types of equilibrium are satisfied simultaneously:
  - ✓ **Mechanical Equilibrium:** There are no unbalanced forces within the system or between the surroundings. The pressure in the system is same at all points and does not change with respect to time.
  - ✓ **Thermal Equilibrium:** The temperature of the system does not change with time and has same value at all points of the system.
  - ✓ **Chemical Equilibrium:** No chemical reaction takes place in the system and the chemical composition which is same throughout the system does not vary with time.
- A system in thermodynamic equilibrium does not deliver anything.

1.6 Quasi-Static Process *OR* Quasi-Equilibrium Process

- ***"Quasi"*** means Almost slow or Infinitely slow.
- Consider a system of gas contained in a cylinder fitted with a piston upon which many very small pieces of weights are placed as shown in Fig.1.9(a).
- The upward force exerted by the gas just balances the weights on the piston and the system is initially in equilibrium state identified by pressure P_1, volume V_1 and temperature T_1.

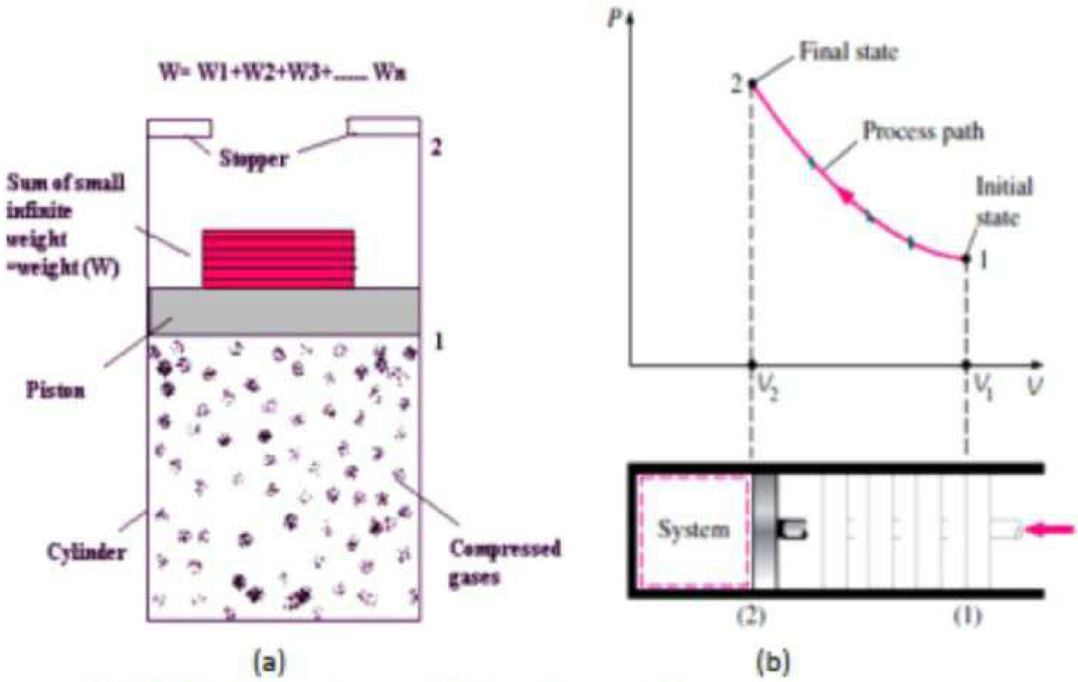

Fig. 1.9 (a) Quasi-Static Process (b) p-v diagram of a compression process

- When these weights are removed slowly, one at a time, the unbalanced potential is infinitesimally small.
- The piston will slowly move upwards and at any particular instant of piston travel, the system would be almost close to state of equilibrium.
- Every state passed by the system will be an equilibrium state.
- ***The locus of a series of such equilibrium states is called a "Quasi-Static or Quasi-Equilibrium process."***
- It should be pointed out that a quasi-equilibrium process is an idealized process and is not a true representation of an actual process. But many actual processes closely approximate it, and they can be modeled as quasi-equilibrium with negligible error.
- Engineers are interested in quasi-equilibrium processes for two reasons. First, they are easy to analyze; second, work-producing devices deliver the most work when they operate on quasi-equilibrium processes. Therefore, quasi-equilibrium processes serve as standards to which actual processes can be compared.
- Fig. 1.9(b) shows the p-v diagram of a compression process of a gas.
- A quasi-static process is also called a reversible process. This process is a succession of equilibrium states and ***infinite slowness*** is its characteristic feature.