Work and heat (part 1)

1.DEFINITION OF WORK

Work is usually defined as a force F acting through a displacement x, where the displacement is in the direction of the force. That is,

$$w = \int_1^2 F\,dx$$

This is a very useful relationship because it enables us to find the work required to raise a weight, to stretch a wire, or to move a charged particle through a magnetic field.

However, when treating thermodynamics from a macroscopic point of view, it is advantageous to tie in the definition of work with the concepts of systems, properties, and processes. We therefore define work as follows: Work is done by a system if the sole effect on the surroundings (everything external to the system) could be the raising of a weight.

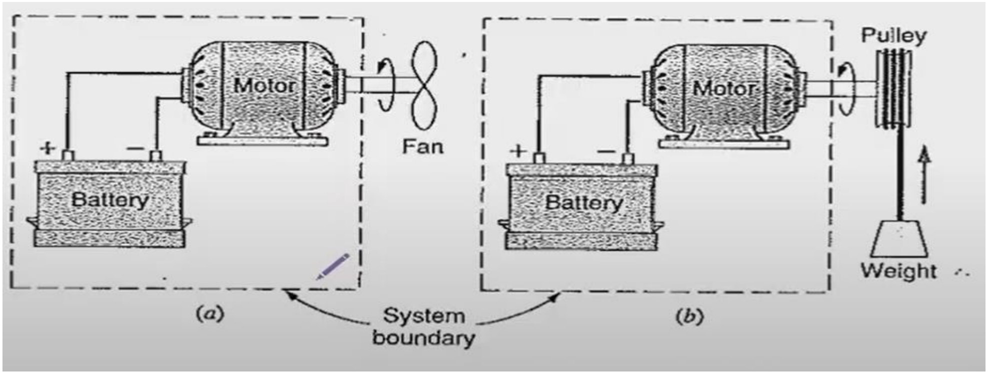

Fig.1 Example of work crossing the boundary of a system

2.UNITS FOR WORK

As already noted, work done by a system, such as that done by a gas expanding against a piston, is positive, and work done on a system, such as that done by a piston compressing a gas, is negative. Thus, positive work means that energy leaves the system, and negative work means that energy is added to the system.

Our definition of work involves raising of a weight, that is, the product of a unit force (one newton) acting through a unit distance (one meter). **This unit for work in SI units is called the joule (J).**

1J=1Nm

<u>Power</u> is the time rate of doing work and is designated by the symbol($\dot{W}$).

$$\dot{W} = \frac{\delta W}{dt}$$

The unit for power is a rate of work of one joule per second, which is a watt (W): $1w = 1\frac{J}{s}$

It is often convenient to speak of **the work per unit mass of the system, often termed "specific work."** This quantity is designated w and is defined.

$$w = \frac{W}{m}$$

3.WORK DONE AT THE MOVING BOUNDARY OF A SIMPLE COMPRESSIBLE SYSTEM

We have already noted that there are a variety of ways in which work can be done on or by a system. These include work done by a rotating shaft, electrical work, and the work done by the movement of the system boundary, such as the work done in moving the piston in a cylinder. In this section we will consider in some detail the work done at the moving boundary of a simple compressible system during a quasi-equilibrium process.

Consider as a system the gas contained in a cylinder and piston, as in Fig. 2. Let one of the small weights be removed from the piston, which will cause the piston to move upward a distance **(dL)**. We can consider this quasi-equilibrium process and calculate the amount of work **W** done by the system during this process. The total force on the piston is **PA**, where **P** is the pressure of the gas and **A** is the area of the piston. Therefore, the work δW is

$$\delta W = PA\, dL$$

But A dL = dV, the change in volume of the gas.

Therefore, $\delta W = P\, dV$

$$W = \int_1^2 P\, dV$$

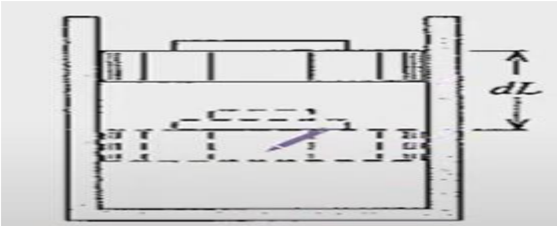

Fig.2. Example of work done at the moving boundary of a system in a quasi- equilibrium process.

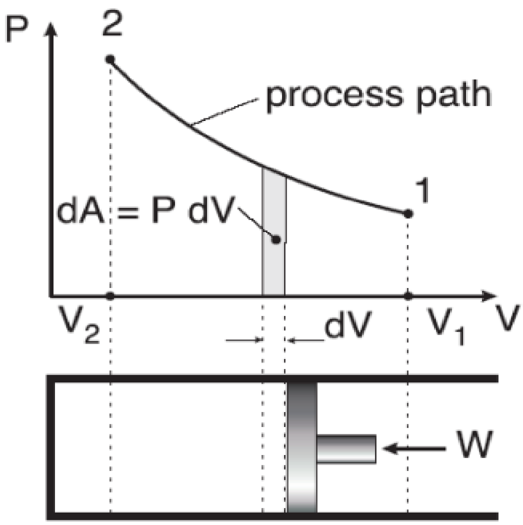

Fig. 3: the area under P-V diagram represents the boundary work.

The quasi-equilibrium expansion process is shown in Fig. 3. On this diagram, the differential area under the process curve in P-V diagram is equal to,, which is the differential work. Note: a gas can follow several different paths from state 1 to 2, and each path will have a different area underneath it (work is path dependent). The net work or cycle work is shown in Fig. 4. In a cycle, the net change for any properties (point functions or exact differentials) is zero. However, the net work and heat transfer depend on the cycle path.

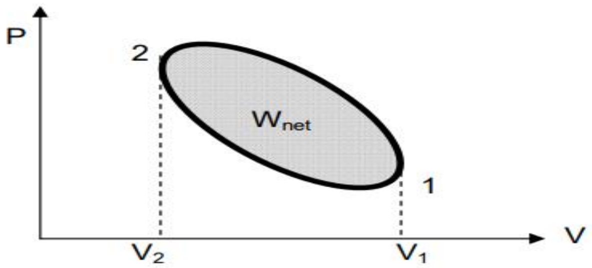

Fig. 4: network done during a cycle.