4.2 SHAPE MEMORY ALLOYS

Shape memory alloys (SMA) *are the alloys which change its shape from its original shape to new shape and while heating /cooling it will return to its original shape.*

Transformation temperature

In SMA, the shape recovery process occurs not at a single temperature rather it occurs over a range of temperature [may be few degrees].

Thus, the range of temperature at which the SMA switches from new shape to its original shape is called ***transformation temperature (or) memory transfer temperature.***

Below the transformation temperature the SMA can be bent into various shapes. Above

the transformation temperature the SMA returns to its original shape. This change in shape was mainly caused due to the change in crystal structure (phase) within the materials, due to the rearrangement of atoms within itself.

PHASES (STRUCTURES) OF SMA

In general the SMA has two phases (crystal structures) viz.,

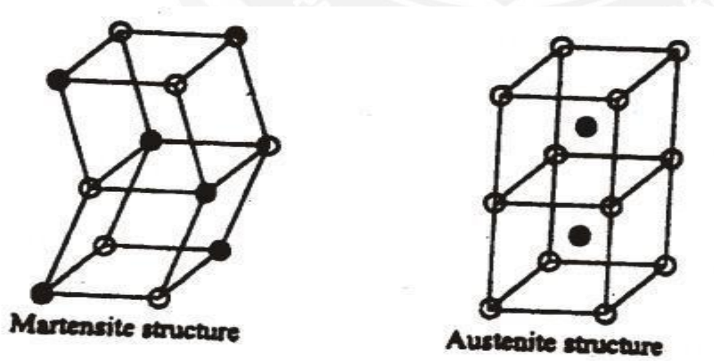

Fig:4.2.1- Two phases of SMA

(i) Martensite

Martensite is an interstitial super solution of carbon in γ-iron and it crystallizes into **twinned structure** as shown in fig. 4.2.1. The SMA will have this structure generally at lower temperatures and it is soft in this phase.

(ii) Austenite

Austenite is the solid solution of carbon and other alloying elements in γ-iron and it crystallizes into **cubic structure** as shown in fig4.2.1. The SMA will attain this structure at higher temperatures and it is hard in this phase.

PROCESSING OF SMA

Shape memory effect

It is very clear that at lower temperature the SMA will be in martensite structure and when it is heated then it will change its shape to austenite structure and while cooling it will again return to martensite form. This effect is called ***shape memory effect.***

Let us consider a shape memory alloy, for which the temperature decreased. Due to decrease in temperature, phase transformation take place from austenite to twinned martensite as shown in fig

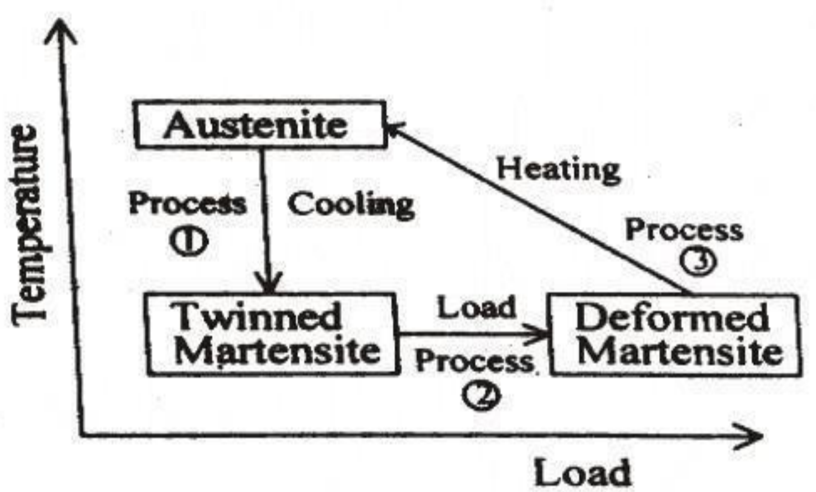

Fig 4.2.2 [Process 1] i.e., a micro constituent transformation takes place from the platelet structure (Austenite) to needle like structure (martensite).

During this state the twinned martensite phase will have same size as that of austenite phase as shown (Macroscopic view). Hence macroscopically if we see, no change in size (or) shape is visible between the Austenite phase and twinned Martensite phase of the SMA.It is found that the transformation from austenite to martensite takes place not only at a single temperature, but over a range of temperatures.

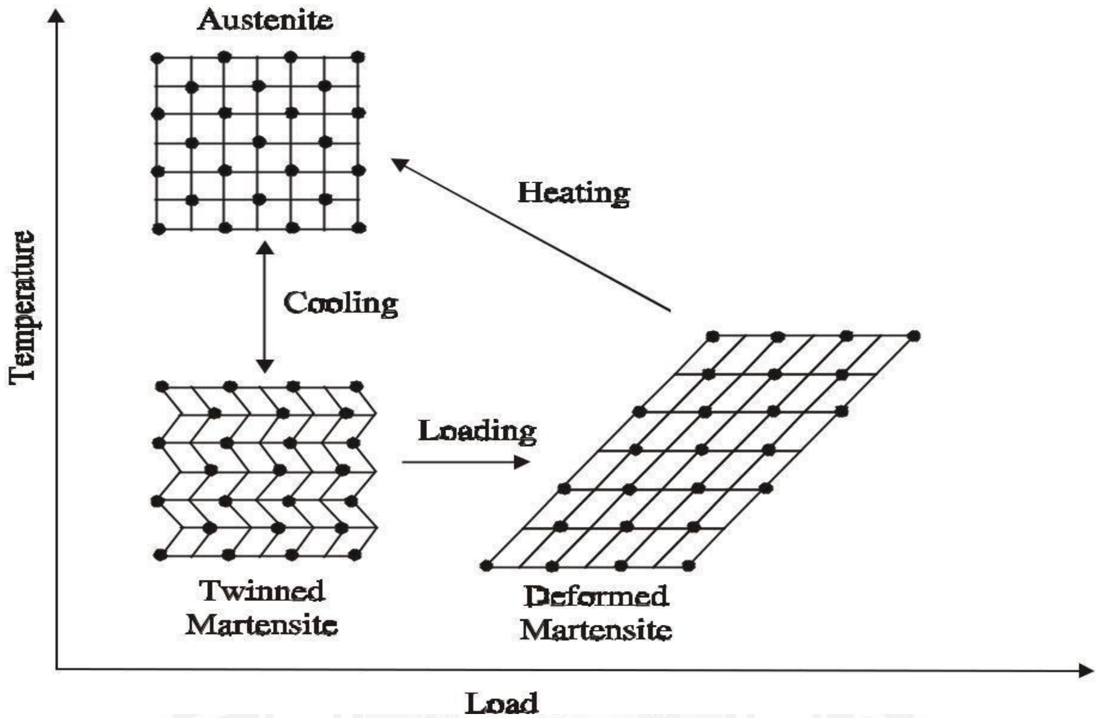

Fig:4.2.3- Transformation from austenite to martensite

Both austenite and twinned martensite is suitable in a particular range of temperature. Now when the twinned martensite is applied a load, it goes to deformed martensite phase as indicated in fig (Process 2). During the transformation from twinned martensite to deformed martensite the change in shape and size occur both microscopically and macroscopically as shown in fig 4.2.3

Now when the material is further heated it will go from deformed martensite to austenite form (Process 3) and the cycle continues as shown in fig 4.2.3

CHARACTERISTICS OF SMA

(i) The transformation occurs not only at a single temperature rather they occur over a range of temperatures.

(ii) **Pseudo – elasticity:** *Pseudo-elasticity occur in some type of SMA in which the change in its shape will occur even without change in its temperature*

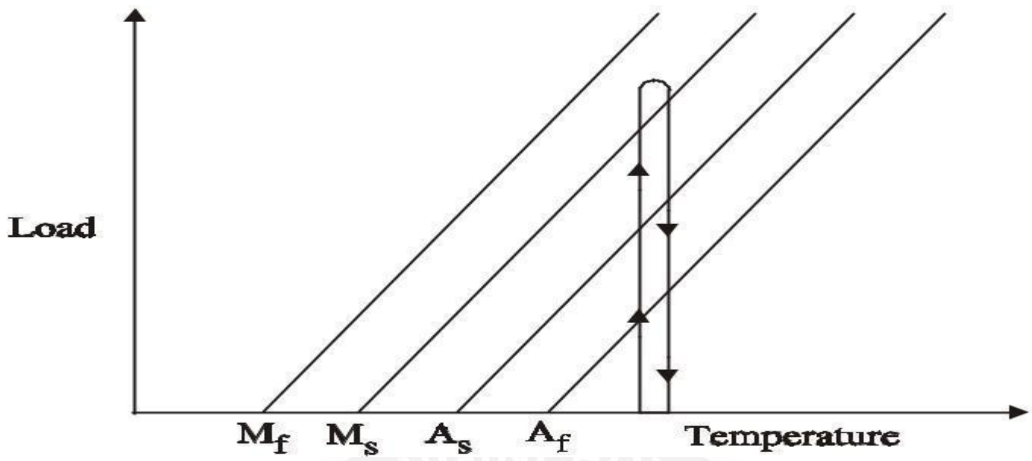

Fig:4.2.4- Transformation over a range of temperatures.

(i) **Super – elasticity:** *The shape memory alloys which have change in its shape at constant temperature are called* ***super-elastic SMAs*** *and that effect is known as super-elasticity.*

Here, at a single temperature, when the load is applied the SMA will have a new shape(deformed Martensite) and if the load is removed it will regain its original shape (Twinned Martensite), similar to pressing a **rubber** (or) **a spring.**

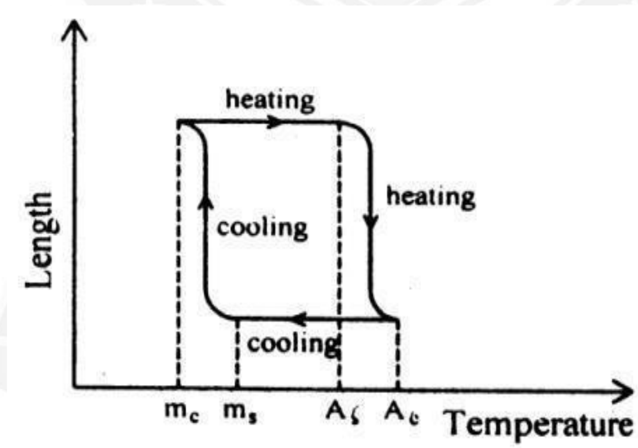

Fig:4.2.5- Cooling & Heating process

(iv) Hysterisis: For an SMA, during cooling process, a martensite starts (ms) and ends(me) and during heating process, austenite starts (As) and ends (Ae).

It is found that they do not overlap with each other and the transformation process exhibits the form of hysterisis curve as shown in fig**.(**4.2.5**)**

iii. Crystallographically the thermo-elastic martensites are reversible.

APPLICATIONS OF SMA

Shape memory alloys have vast applications in our day-to-day life, as follows:

1. We know that the recently manufactured eye glass frames can be bent back and forth, and can retain its original shape within fraction of time. All these materials are made up of Ni-Ti alloys, which can withstand to maximum deformation.
2. We might have seen toys such as butterflies, snakes etc. which are movable and flexible. These materials are made using SMAs.
3. The life time of Helicopter blades depends on vibrations and their return to its original shape. Hence shape memory alloys are used in helicopter blades.
4. The SMA is cooled and sent into vein, due to body temperature it changes its shape and acts as a blood clot filter, by which it controls the blood flow rate.
5. The SMA is mainly used to control and prevent the fire and toxic gases (or) liquids to a large extent. For example, if an SMA is placed in a fire safety valve, when fire occurs, then due to change in temperature the SMA changes its shape and shuts off the fire. Similar principle has been used in the area of leakage in toxic gases (or) liquids.
6. The Ni-Ti spring is used to release the hot milk and the ingredients at certain temperature and to close it after particular time, thereby we can get coffee automatically [coffee makers].
7. SMA is used for cryofit hydraulic couplings i.e., to join the ends of tubes. Here, the SMA material is pasted in between the two tubes to be joint at a particular temperature when the temperature change the SMA expands and thus the two ends are joined.
8. Using SMA the circuit can be connected and disconnected, depending on the variation in temperature. Hence SMA is used as a circuit edge connector.
9. They are used in controlling and preventing cracks.
10. They are used in relays and activators.
11. They are used for steering the small tubes inserted into the human body.
12. They are used to correct the irregularities in teeth.

13. Ni-Ti SMA is also used in artificial hip-joints, bone-plates, pins for healing bones-fractures and also in connecting broken bones.

Advantages

i. SMA is very compact in nature.

ii. It is safe and smart.

iii. They are flexible.

iv They are Non-Corrosive.

Disadvantages

i.Cost is high ii.Efficiency is low.

iii.Transformation occurs over a range of temperatures.

iv.Structural arrangements may sometime get deformed.