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Shape Memory Alloys

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ABSTRACT
Shape memory alloys (SMAs) are metals that "remember" their original shapes. SMAs are useful for such things as actuators which are materials that "change shape, stiffness, position, natural frequency, and other mechanical characteristics in response to temperature or electromagnetic fields" The potential uses for SMAs especially as actuators have broadened the spectrum of many scientific fields. The study of the history and development of SMAs can provide an insight into a material involved in cutting-edge technology. The diverse applications for these metals have made them increasingly important and visible to the world. This paper presents the working of shape memory alloys , the phenomenon of super-elasticity and applications of these alloys.
Keywords: Austenite, martensite, super-elasticity.

I. INTRODUCTION

Shape Memory Alloys (SMAs) are a unique class of metal alloys that can recover apparent permanent strains when they are heated above a certain temperature. The SMAs have two stable phases - the high-temperature phase, called *austenite* and the low-temperature phase, called *martensite*. In addition, the martensite can be in one of two forms: *twinned* and *detwinned,* as shown in Fig (a). A phase transformation which occurs between these two phases upon heating/cooling is the basis for the unique properties of the SMAs. The key effects of SMAs associated with the phase transformation are *super-elasticity* and shape *memory effect.* Nickel-titanium alloys have been found to be the most useful of all SMAs. The generic name for the family of nickel-titanium alloys is Nitinol.

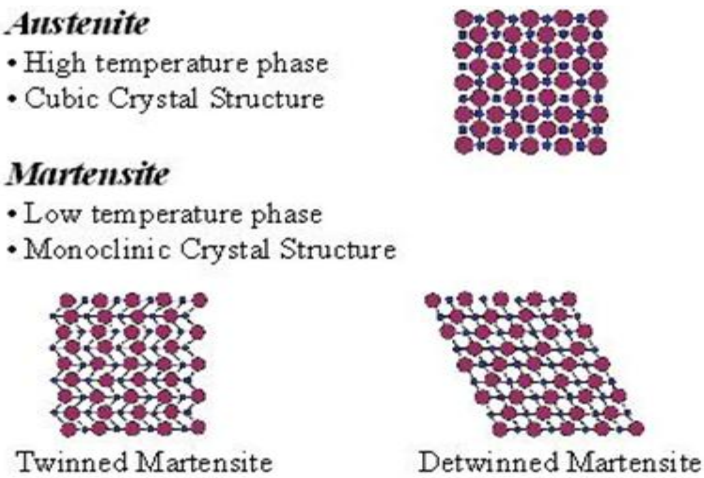


Figure (a)

II. SHAPE MEMORY EFFECT

Temperature and internal stresses determine the phase that the SMA will be at. Martensite exists at lower temperatures, and austenite exists at higher temperatures. When a SMA is in martensite form at lower temperatures, the metal can easily be deformed into any shape. When the alloy is heated, it goes through transformation from martensite to austenite. In the austenite phase, the memory metal "remembers" the shape it had before it was deformed. Here, the main difference between twinned and detwinned martensite is that when mechanical load is applied to the alloy in twinned state, it is possible to detwin the martensite. But upon releasing of the load the material remains deformed. Upon heating the material changes to austenite and reverts to original shape. The above is better understood when we look at Fig.(b).

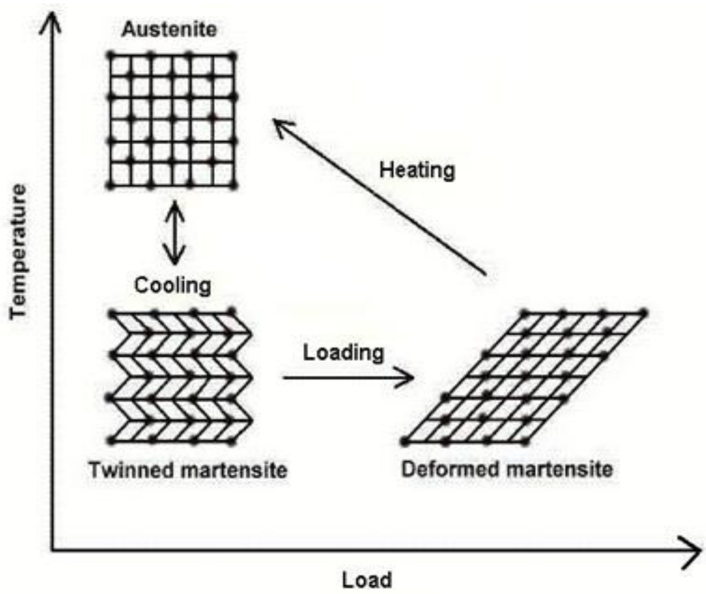
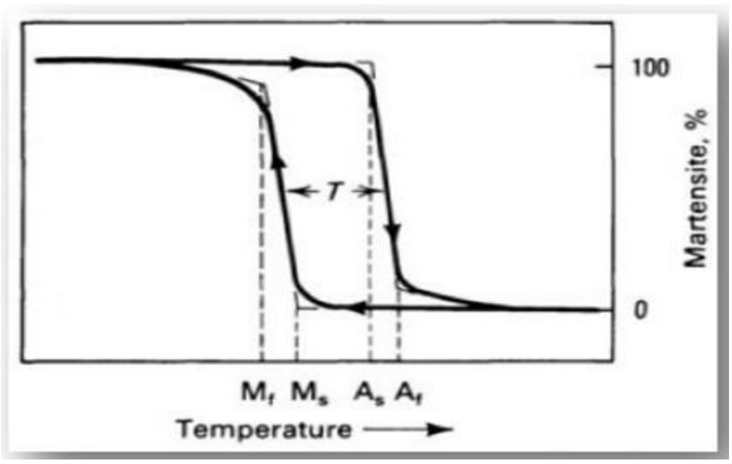


Figure (b)

After looking at the above process we may have a question in mind that what happens if we heat the twinned martensite to austenite form and cool it? Upon cooling in the absence of applied load the material transforms from austenite into twinned martensite. As a result of this phase transformation no observable macroscopic shape change occurs. Upon heating the material in the martensitic phase, a reverse phase transformation takes place and as a result the material transforms to austenite.

Henceforth, the thermal hysteresis can be divided into four temperature points. When we heat the material, the point where the martensite percentage drops is where austenite starts or .The point where austenite is fully formed is point . Similarly, on cooling, when the martensite starts is and where martensite ends is .



Figure(c)

A generally accepted term to describe the temperature at which the austenite phase is formed on heating of martensite form is called as transition temperature.

III. SUPER-ELASTICITY

Super-elasticity is a similar phenomenon except that heat energy is not involved. Instead of transforming between the martensite and austenite phases in response to temperature, this phase transformation can be induced in response to mechanical stress. When shape memory alloys are loaded in the austenite phase, the material will transform to the martensite phase above a critical stress, proportional to the transformation temperatures. Upon continued loading, the twinned martensite will begin to detwin, allowing the material to undergo large deformations. Once the stress is released, the martensite transforms back to austenite, and the material recovers its original shape. As a result, these materials can reversibly deform to very high strains.

IV. APPLICATIONS

This material is a lightweight, solid-state alternative to conventional actuators such as hydraulic, pneumatic, and motor-based systems. Shape-memory allsoys are utilized in robotics and automotive, aerospace and biomedi cal industries.
Eyeglass frames were an early example of a new use of super-elasticity which has grown to be a worldwide product. Cellular phone antennas consume millions of feet of super-elastic wire, and the development of underwire for women's brassieres, formerly limited to Asian market, is now expanding into a worldwide fashion. A new idea of using super-elastic NiTi powder to enforce the resistance of SnPdAg solder against failure induced by thermal stress appears promising. In the automotive sector, European car manufacturers have long been using SMA actuators for transmission fluid control. Now, it is growing with the most recent success in using a NiTiNb plug for sealing high-pressure fuel passages in diesel engine injectors.

V. CONCLUSIONS

Smart materials and adaptive structures are now common terms and large government supported programs are underway to develop and utilize them in aeronautical and space structures. Due to its light weight, the material has varied advantages. A number of international meetings on smart materials take place every year under the aegis of SPIE and ASME. Hence, many uses and applications of shape memory alloys ensure a bright future for these metals.

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