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A Review of Shape Memory Alloys and its Applications

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Abstract

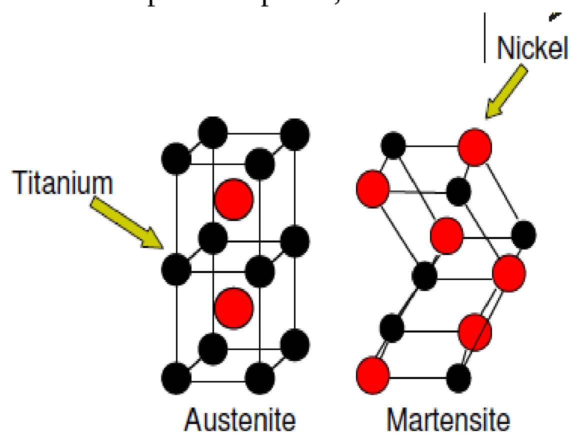
We now need certain "intelligent" or "smart" materials in the production industry that can modify their properties according to our needs. Shape Memory Alloys (SMA) are intelligent materials that can recall their shape. Smart materials are one of kind materials, and they all have one thing in common: their behaviour or significant property may be changed, reversed, or controlled under the impact of an external stimulus. Self-adaptability, self-sensing, and self-healing in response to any environmental stimuli are characteristics of their intelligence. Shape memory alloys are materials that, when exposed to external stimuli such as stress, temperature, electric field, or magnetic field, reverts to their original shape. These materials have attracted a lot of attention from academics and scientists because of their unusual and exceptional mechanical qualities, which has led to widespread commercial use. The

purpose of this study is to summarize the fundamental principles of SMA, applications as well as recent breakthroughs. Future application possibilities and recommendations are also depicted.

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 thelow-temperature phase, called martensite.



Shape Memory Alloy

Shape-memory alloys are metals that, even if they become deformed at below a given temperature, they will return to their original shape before deformation simply by being heated. Alloys with this unusual characteristic are used as functional materials in temperature sensors, actuators, and clamping fixtures.

These metals also have a quality called superelasticity; like rubber, when it is bent or stretched, it will return to its original shape when the deforming force is removed. This characteristic of recovering shape despite substantial deformation is exploited

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in applications in products for daily life, in electrical and electronic appliances, and in the medical field.

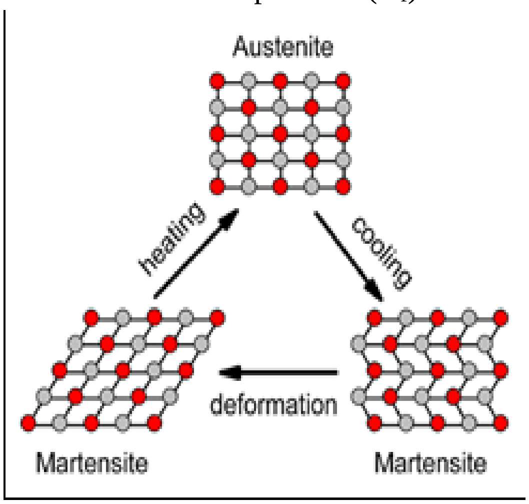
There currently are several dozen types of alloys with such shape-memory properties and superelasticity, but Ni-Ti alloys have the best shape-recovery performance, durability, andcorrosion-resistance.Born of our wealth of titanium and titanium alloy melting and fabrication technology, KTS-SM alloy is one of the most reliable of the Ni-Ti alloys of this type of shape-memory and superelastic alloys.

Phases of SMA

Martensite. This is the low temperature phase.

Austenite. This is the high temperature phase

Transformation temperature. This is the temperature at which the phase changes between austenite and martensite. Actually, the temperature is a range and depends on whether you are heating or cooling, so there is a martensite start temperature (M_s), martensite finish temperature (M_f), austenite start temperature (A_s), and austenite finish temperature (A_f).



Types of SMA

There are two types of shape memory alloys

(i)One-way shape memory alloy

(ii)Two-way shape memory alloy

A material which exhibits shape memory effect only upon heating is known as one-way shape memory.

A material which shows a shape memory effect during both heating and cooling is called two-way shape memory.

Examples of shape memory alloys

Generally, shape memory alloys are intermetallic compounds having super lattice structures and metallic-ionic-covalent characteristics.Thus, they have the properties of both metals and ceramics.

Ni –Ti alloy (Nitinol)

Cu –Al –Ni alloy

Cu –Zn –Al alloy

Au –Cd alloy

Ni –Mn –Ga and Fe based alloys

Characteristics of SMA

Shape memory effect

The change of shape of a material at low temperature by loading and regaining of original shape by heating it, is known as shape memory effect.The shape memory effect occurs in alloys due to the change in their crystalline structure with the change in temperature and stress.While loading, twinned martensite becomes deformed martensite at low temperature.On heating, deformed martensite becomes austenite (shape recovery) and upon cooling it gets transformed to twinned martensite (fig.).

SMAs exhibit changes in electrical resistance, volume and length during the transformation with temperature.

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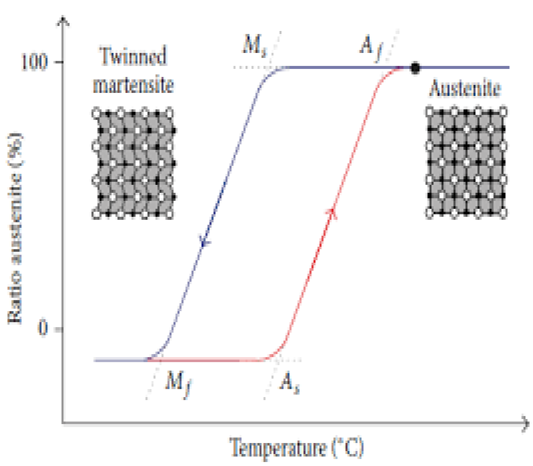
Pseudo-elasticity

Pseudo –elasticity occurs in shape memory alloys when it is completely in austenite phase (temperature is greater than $A_f$austenite finish temperature).Unlike the shape memory effect, Pseudo-elasticity occurs due to stress induced phase transformation without a change in temperature.The load on the shape memory alloy changes austenite phase into martensite.As soon as the loading decreases the martensite begins to transform to austenite.

This phenomenon of deformation of a SMA on application of large stress and regaining of shape on removal of the load is known as pseudo elasticity.This pseudo elasticity is also known as super elasticity.

Hysteresis

The temperature range for the martensite to austenite transformation which takes place upon heating is somewhat higher than that for the reverse transformation upon cooling.The difference between the transition temperature upon heating and cooling is called hysteresis. The difiference of temperature is found to be 20-30^{o}C.



Properties

- The Ni-Ti alloys have greater shape memory strain upto 8.5% tend to be much more thermally stable.
- They have excellent corrosion resistance and susceptibility, and have much higher ductility.
- The material do respond well to abrasive removal such as grinding, and shearing**.**

Applications of SMA

Microvalve

One of the most common applications of SMAs is microvalves. Actuator is a micro sensor that can trigger the operation of a device. The electrical signal initiates an action. When an electrical current of 50 to 150 mA flows in Ni-Ti actuator, it contracts and lifts the poppet from the orifice and opens the valve.

Toys and novelties

Shape memory alloys are used to make toys and ornamental goods.A butterfly using SMA. Moves its wings in response to pulses of electricity.

Medical field Blood clot filters

Blood clot filters are SMAs, properly shaped and inserted in veins to stop the passing blood clots. When the SMA is in contact with the clot at a lower temperature, it expands and stops the clot and blood passes through the veins. They are used in artificial hearts. Orthodontic applications

NiTi wire holds the teeth tight with a constant stress irrespective of the strain produced by the teeth movement. It resists permanent deformation even if it is bent.

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NiTi is non-toxic and non-corrosive with body fluid.

Antenna wires

The flexibility of superelastic Ni –Ti wire makes it ideal for use as retractable antennas.

Stepping motors

Digital SMA stepping motors are used for robotic control. Titanium-aluminium shape memory alloys offer excellent strength with less weight and dominate in the aircraft industry. They are high temperature SMAs, for possible use in aircraft engines and other high temperature environments.

Springs, shock absorbers, and valves

Due to the excellent elastic property of the SMAs, springs can be made which have varied industrial applications. Some of them are listed here.

Engine micro valves
Medical stents
Firesafety valves and
Aerospace latching mechanisms

Eyeglass Frames:

In certain commercials, eyeglass companies demonstrate eyeglass frames that can be bent back and forth, and retain their shape. These frames are made from memory metals as well, and demonstrate super-elasticity.

Conclusions

Following 1969, the demand for SMAs alloy has been steadily expanding. There have been numerous inventions introduced to society, particularly in the bio-medical field. SMA alloys are also being used in biological domains, in addition to industry applications such as aerospace and automotive.

Communities are debating the design of SMA for future applications. New improvements in the production and treatment of SMAs will help designers create more durable applications. Future trends include introducing new design techniques and creative applications, as well as studying computer models of SMA behavior for additional advancements.

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