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A Review on Load Positioning Application of Shape Memory Alloy

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Abstract: **Shape Memory Alloy (SMA) is a special material, which have the ability to return to its original shape when it is heated. SMA is different from other materials due to its two unique properties- Shape Memory Effect (SME) and Superelasticity. When there is a limitation of shape recovery, these alloys promote high restitution forces. Because of these properties, there is a great technological interest in the use of SMA for different applications[6]. This paper focuses on the brief review on applications of SMA in different fields. They have applications in aircraft and spacecraft, civil structures, robotics, automotive, telecommunication, piping, medicine, optometry etc.**

***Keywords*- Hysterisis, MSMA, actuator, generalized Prandtl-Ishlinskii model (GPIM).**

I. INTRODUCTION

Shape Memory Alloy (SMA) is an advanced engineering material. It is also known as smart materials as well as known as memory alloys. Alloys are prepared to enhance its property and to gain more industrial application. Normal alloys when they are heated they change their shape and when they are cooled they will not gain any original shape, instead they appear to come in a new form. Whereas SMA when subjected to thermal procedures they regain their original shapes. They have got wide range of application. There are two types of SMA: i) One way SMA, ii) Two way SMA. One way SMA regains its shape only on heating. Whereas two way SMA regains its shape both on heating and cooling process. NiTi (nitinol, Mix of 50% nickel and 50% titanium) based SMAs are preferable for most applications due to their stability, practicability and superior thermo-mechanic performance and also in commercial applications because they combine good mechanical properties with shape memory. SMA is mainly found in two state phase: i) Austenite, ii) Martensite. Austenite is called the parent phase, from which a transformation process occurs into the softer product phase called Martensite. When some material undergoes Austenite phase, that is when the temperature increases, the material goes into a stronger phase. In martensite phase the temperature is very low and the material is soft and deformable. Both can change their state by heating and cooling and that is the extraordinary property of Shape Memory Alloy.

There are three important properties of SMA: i) Shape Memory Effect (SME), ii) Superelasticity iii) Hysterisis. Shape Memory Effect (SME) is the very important property of SMA. If some material like NiTi is subjected to room temperature, the material will be in martensite state, which is known as twinned state. Next by applying some load the material will change into another form of martensite state known as deformed martensite state. When heating this deformed martensite state, the material will be converted into austenite state. Again when this state is cooled the material will be regained into martensite state. Figure 1 shows the graph of SME process, that is what happens to SMA when temperature changes.

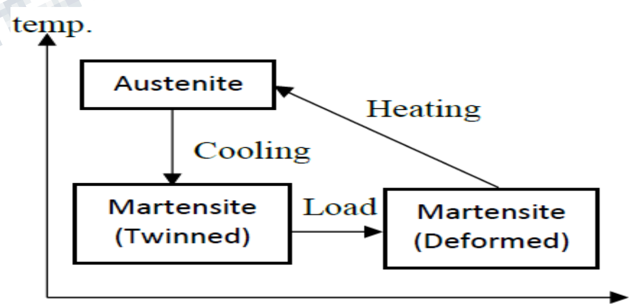

Figure 1: Shape Memory Effect

Next property of SMA is Superelasticity, which is also known as pseudoelasticity. Where, Pseudo means false and elasticity means a material which will regain its shape when load is applied or removed. Usually, SMA changes its state when the temperature is increased or decreased. But in superelasticity no temperature change is necessary. The transformation occurs by applying load to the austenite state (temperature will be constant). The austenite state will be converted into martensite state by applying load, and when the load is removed, the material will be converted back into austenite state. Figure 2 shows the superelasticity process with constant temperature[5].

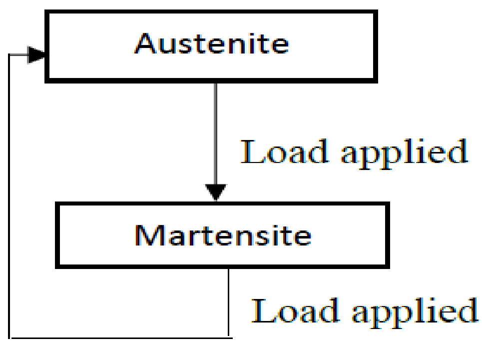

Figure 2: Superelasticity

Third property of SMA is hysteresis. The wide range transformation or temperature change will result in the overlapping of transformation.

1.1 Magnetic Shape Memory Alloy:

Magnetic-field induced reorientation, or the magnetic shape memory alloy (MSMA), is defined as, the magnetic field induced rearrangement of (ferromagnetic) twinned martensite microstructure along with a large macroscopic deformation.

1.1.1 Properties of MSMA:

i) Magnetic shape memory effect of up toM6% elongation in a magnetic field. ii) It exhibits inverse magnetostrictive effect or Villari iii) It shows shape memory alloy effect with a shape change caused by applying a magnetic field as well as a shape change is caused by temperature. iv) If the element is completely compressed or elongated, a change in resistance occurs. v) Exhibits controlled spring properties.

II. REVIEW

A review on some new techniques of SMA in some of the applications is discussed in this paper.

2.1 Shape Memory Alloy (SMA) in LoadPositioning Application:

Although SMA changes the material shape during its phase transformation, there are many other physical and chemical properties that will be altered during its transformation. The change in electrical resistivity is most relevant one, because it enables the SMA to be used not only as an actuator, but also as strain or even temperature sensor. In this way SMA becomes an actuator with position self-sensing capabilities, which can be employed in many sensor-less motion control applications. The issue in SMA based position sensing is its non-linear and hysteretic behavior of stress versus strain characteristic and its dependence on applied mechanical load, which makes the design non trivial and limits its operating range. This issue can be overcome by using two antagonistic SMA actuators that work alternatively as active and passive elements.

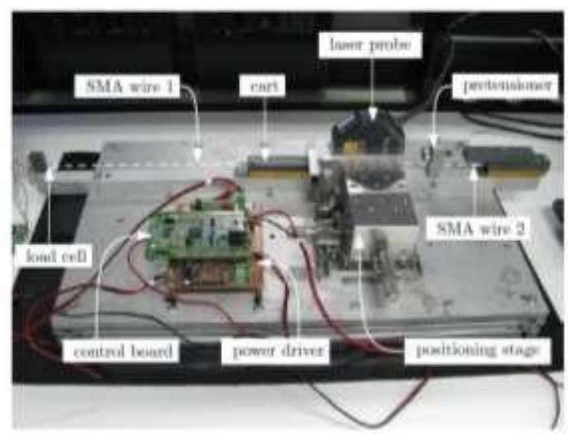

Figure 3: Testing platform used for the experimental activity [1]

A mathematical model to predict the pseudo-static response of the system under different driving conditions for the two wires are considered. Then the special test bench and actuation system have been experimentally tested[1]. The testing platform used for the testing of actuation principle based on opposite SMA elements is shown in Figure 3.

2.2 Magnetic Shape Memory Alloy (MSMA) in Hysterisis Modeling and Position Control of Actuator:

MSMAs belongs to a group called smart materials, which changes its properties under external stimulus. Magnetic shape memory alloys combine good dynamics, similar to magnetostrictive materials such as terfenol D. And deformations range similar to thermally activated SMAs. These properties make it suitable for positioning systems, but before engineering applications it should be well tested. The biggest disadvantage of MSMAs is wide, asymmetric, saturated hysteresis curve. Reason for that is internal friction located on twin boundaries in crystal lattice. These non-linearities have negative influence on control quality in open and closed loop control systems. It can be limited by compensation based on hysteresis modeling techniques by using generalized Prandtl- Ishlinskii model (GPIM) and its analytical inversion. GPIM is phenomenological model where hysteresis can be expressed as a sum of weighted play operators[2]. Figure 4 shows the test setup that is specially designed for MSMAs examinations. Base of this rig is thick steel plate which ensures high stiffness. Next to this plate are connected actuator and displacement measuring system. Application of positioning stages with regulation screw provide precision micro-adjustment of used equipment.

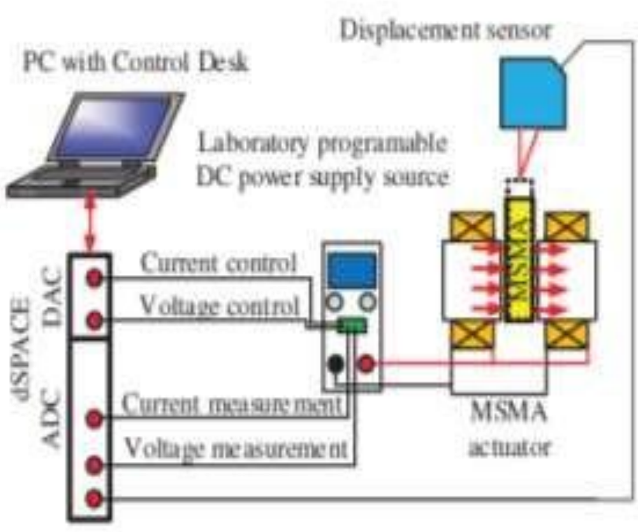

Figure 4: Schematic diagram of test stand for MSMA actuator examinations [2]

DSpace system was used for data acquisition and control tasks, made in cooperation with Matlab/Simulink and Control Desk software. Coils in actuator were energized by programmable DC power supply[2].

III.OTHER APPLICATIONS OF SMA

SMA have wide range of applications in industrial and medical field. Industrial applications include Cryofit hydraulic tube coupling, temperature control system, force actuators. Medical applications include Blood clot filters, eye frame glasses, tumour identification, catheters, bone plate, hip joint materials etc. [3][4]

IV. CONCLUSION

In this paper, a brief introduction of SMA is given and in addition to introducing some new features and phenomena developed in shape memory alloy in recent years, we also present a number of interesting applications of shape memory alloy.

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