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Shape Memory Alloy Actuators: A Review

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Abstract: The Shape memory alloys (SMAs) comes under special class of materials which possesses ability to recover their original shape at some temperatures characteristics. The SMAs are being used in different field in variety of applications. This ability of SMA can be viewed under high applied loads and elastic deformations. In this review paper, the SMA actuators and their applications are discussed.

Keywords: SMA, Types of SMA, actuator.

I. INTRODUCTION

The term ‘‘smart alloy’’ was introduced in 1932 and the nomenclature ‘‘shape-memory’’ was given in 1941 for polymeric dental material [1, 2, 3]. Shape memory alloys (SMAs) are a unique type of material contains the ability to recover their shape at certain temperature characteristics. These materials are able to regain their original shape, even after reaching large inelastic deformations (near 10%) [1].

The demand for SMAs for engineering applications has been increasing in different fields; such as in industrial applications, automobile industries, aerospace applications, structures and composites, robotics and biomedical applications [4, 5]. Different SMA actuators like wire, compression / tension springs and cantilever had been used in thermal and electrical actuation systems [7, 33]. In this paper, a review on different applications of SMA actuators is presented.

II. SMA ACTUATOR

The SMA material can be used as actuators as well as sensors. There are different applications of shape memory alloys like free recovery, constrained recovery, superelastic applications and actuator applications. The two-way SMA can remember the low and high temperature austenite shape whereas one-way SMA can only remember high temperature shapes. The one way SMA have different types of actuators namely one way actuator, biased actuator and two way actuator. The SMA can be actuated by different ways like changes in atmospheric temperature, passing electric current through SMA, exposing to thermal radiation. Figure 1 shows structure of shape memory alloy actuator [4,5,7, 30].

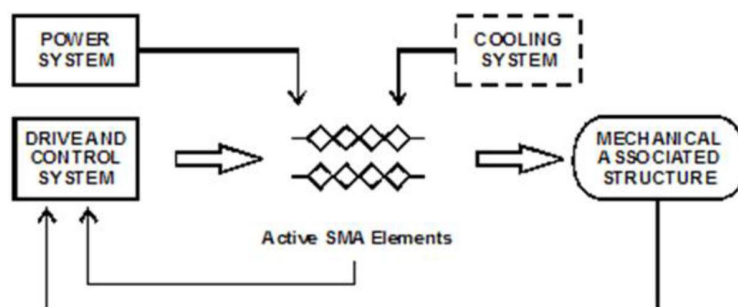


Figure 1: Structure Of Sma Actuators [5, 30]

A. Advantages of SMA Actuators

- 1) Small in size
- 2) Light weight
- 3) Low complexity and high power to weight ratio
- 4) Smooth, silent operation, long life and precise controllability.

The SMA actuators can be used to develop self opening door of oven, design hot water self opening / closing valve for sink, design industrial fire check valve, design current interrupt mechanism for battery etc [7]. Due to poor stability, slow response and controllability, SMA wire actuator cannot be used directly. The response speed for thin SMA wires is faster, but for environment temperature variation they are more sensitive. By using control strategy SMA actuators can be used for active shape control of inflatable space structures [8].

The applications of SMA actuators in biomedical field are: arterial clips, aids for disabled, contraceptive devices, eyeglass frames, graft stents, minim invasive surgery (MIS) instruments, intraocular lens mount, penile implants, intervertebral artificial joints, scoliosis correction devices, drug delivery systems, orthopedic implants, stents etc.

The SMA actuator can be used in micro robotic arm used in colonoscopy. The endoscopic actuator can be used to achieve 180° movement at the end. By using SMA servo actuator the multiple degrees of freedom can be achieved [4,6]. The SMA servo actuator can be used to drive active endoscope to achieve multiple degree of freedom which can be driven through electric resistance feedback [9].

In automobile sector, the demand of SMA actuator is increasing [27]. Radiator, fan clutch, engine, battery, brakes, headlight, sunroof, wipers, mirror, dashboard, airbags, pedestrian safety etc. are some applications of SMA actuators in automobile [25, 28, 29, 34, 35, 36]. It can be used in aerospace domain at wings, stabilizer, flap edge, inlet, nozzle, rotor, hydraulic lines, landing gear etc. [17, 18, 24].

There are following shapes of an actuator which are generally used. [16, 22, 37]

- a) Straight tensile wires (to achieve small motion with high force)
- b) Wave-washer springs (to achieve small motion with high force)
- c) Helical compression springs (to achieve large motion with less force)
- d) Cantilever springs (to achieve bending)
- e) Disc springs (to achieve small motion with high force)

The following table 1 describes different types of SMA actuators

Table 1: Types of SMA Actuator.

Sr no	Type of SMA actuator	Working principle	Application	Reference number
1.	Thin Film Actuator	<ul style="list-style-type: none"> - Titanium Nickel (Ti Ni) - Diaphragms type - Thermal actuator 	Micropumps in drug delivery system, fuel injection system etc.	[10, 32]
2.	Servo Actuator	<ul style="list-style-type: none"> - Titanium Nickel (Ti Ni) with Ti-50.2 at % of Ni. - Microcomputer controlled - electric resistance feedback control system 	Active Endoscope (Medical Robot)	[9]
3.	Wire Actuator	<ul style="list-style-type: none"> - Thermal actuator - Control strategy for adjusting wire temp. quickly. - composites 	Active shape control of Inflatable space structures, Automobile safety system, Automobile mirrors, Adaptive control, Mobile micro-robots, actuation of aircraft flight surfaces, robot arms and grippers, artificial muscles.	[8, 18, 21, 15, 23, 25, 26, 35]
4.	Spring Actuator	<ul style="list-style-type: none"> - SMA helical springs - One way actuator - Bias mechanism 	Active bending system and gripping system, active hand prosthesis, Pipe Robot	[5, 11, 38]
		<ul style="list-style-type: none"> - NiTiCu Spring - Actuation Gas Temperature viewed 	Fire check Valve in industries	[7]
		<ul style="list-style-type: none"> - NiTi washers used - Ni-Ti TVR spring in pressure sensing device 	Gearbox, jet engine oil filters	[16]
		<ul style="list-style-type: none"> - SMA binary actuator 	Automotive tumble flaps	[19, 36]
6.	Strip Actuator	<ul style="list-style-type: none"> - SMA strip and springs used to achieve output - Planetary system - automatically driven 	Colonoscope robotic arm	[6]
		<ul style="list-style-type: none"> - NiTiCu element - Fluid temperature is actuation parameter 	Domestic safety devices	[7]
7.	Ferromagnetic SMA	<ul style="list-style-type: none"> - Magnetic force actuation - rapid actuation motion 	Actuator, Valves, Biomedical Applications, Hydraulic Pumps	[12,13,14]
8.	Disc actuators	<ul style="list-style-type: none"> - bimetallic actuators can be used 	current interrupt mechanism in batteries	[7]
9.	SMA Dampers	<ul style="list-style-type: none"> - Noise and vibrations 	Structural supports, Engine mountings	[15,23]

Table 2: Different SMA Actuator Materials [1, 2, 12]

Type	Alloy
Fe-alloys	Fe-28-31-pd, Fe-Pd-Ni, Fe-23-Pt, Fe-Ni-Co-Ti
Heusler	Ni2MnGa
NiTi based alloys	NiTi, NiTiCu, NiTiPd, NiTiFe, NiTiNb, NiTiGa, NiTiCo
Cu based alloys	CuZn, CuZnAl, CuAlNi, CuAlNiMn
Ag based alloys	AgCd
Au based alloys	AuCd
Co based alloys	CoNiAl

The NiTi is best choice to use as SMA actuator and Fe-Pd can be used as ferromagnetic SMA actuator but to improve mechanical properties Pd can be replaced by Pt, Co. [12,15,31].

III. CONCLUSION

The Shape memory alloys (SMAs) are special class of material. The accountable change in the physical properties of material makes them suitable for multiple applications. Literature supports different reviews on SMAs. In this review paper, the used SMA as an actuator and their applications are presented.

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