iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 **Issue:** V **Month of publication:** May 2019

DOI: https://doi.org/10.22214/ijraset.2019.5134

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.177
Volume 7 Issue V, May 2019- Available at www.ijraset.com

Shape Memory Alloy Actuators: A Review

Shrikant K. Yadav[1], Rupesh S. Bobade[2]
[1, 2]*School of Mechanical Engineering, MIT World Peace University, Pune, India*

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].

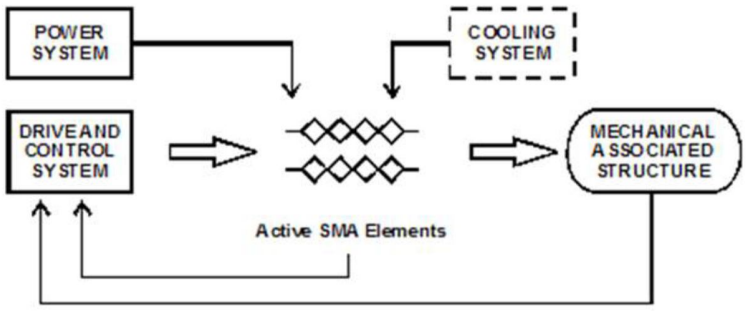


Figure 1: Structure Of Sma Actuators [5, 30]

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	- Titanium Nickel (Ti Ni) - Diaphragms type - Thermal actuator	Micropumps in drug delivery system, fuel injection system etc.	[10, 32]
2.	Servo Actuator	- 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	- 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	- SMA helical springs - One way actuator - Bias mechanism	Active bending system and gripping system, active hand prosthesis, Pipe Robot	[5, 11, 38]
		- NiTiCu Spring - Actuation Gas Temperature viewed	Fire check Valve in industries	[7]
		- NiTi washers used - Ni-Ti TVR spring in pressure sensing device	Gearbox, jet engine oil filters	[16]
		- SMA binary actuator	Automotive tumble flaps	[19, 36]
6.	Strip Actuator	- SMA strip and springs used to achieve output - Planetary system - automatically driven	Colonoscope robotic arm	[6]
		- NiTiCu element - Fluid temperature is actuation parameter	Domestic safety devices	[7]
7.	Ferromagnetic SMA	- Magnetic force actuation - rapid actuation motion	Actuator, Valves, Biomedical Applications, Hydraulic Pumps	[12,13,14]
8.	Disc actuators	- bimetallic actuators can be used	current interrupt mechanism in batteries	[7]
9.	SMA Dampers	- 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].

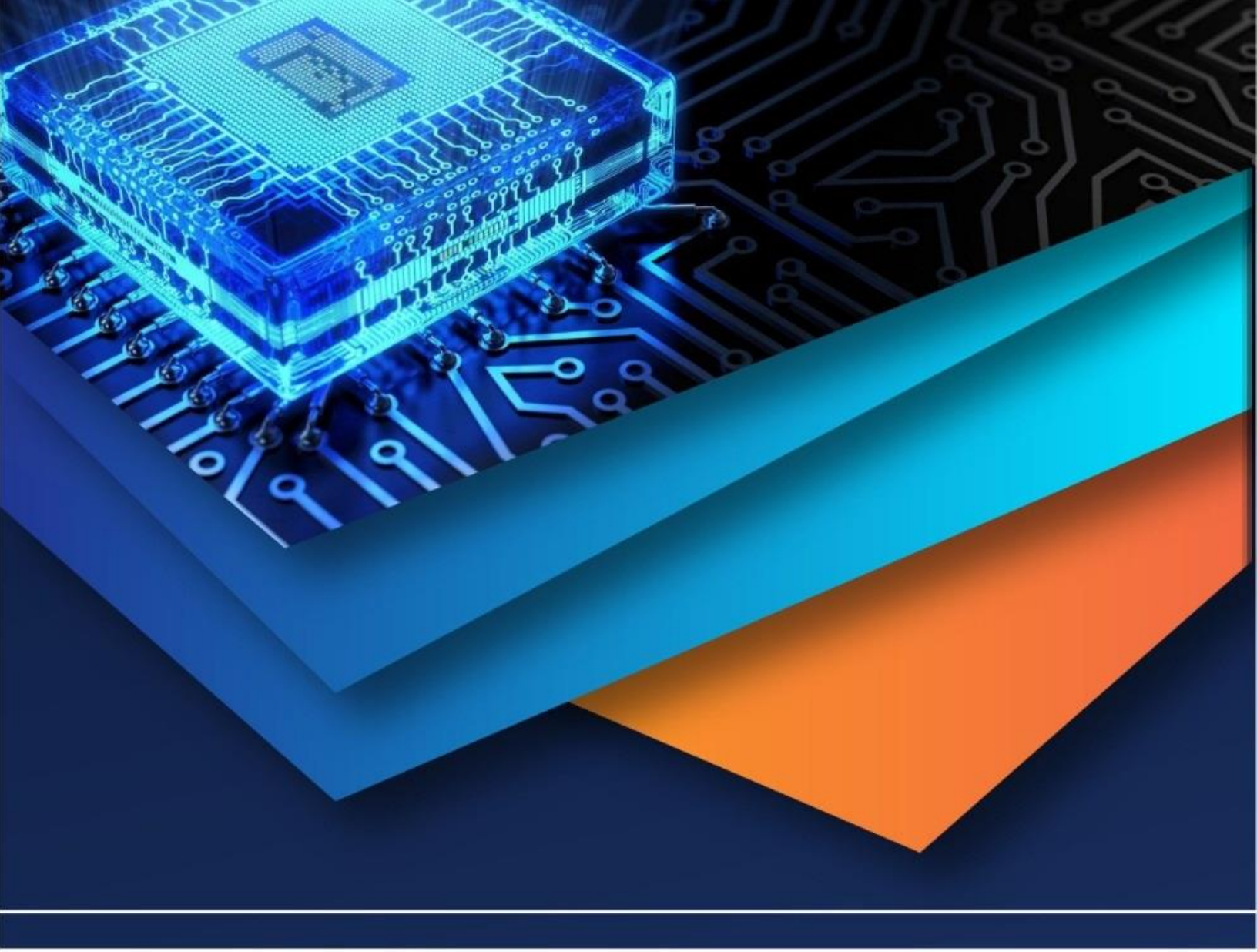
III. CONCLUSION

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.

REFERENCES

[1] Huan W 1998 Shape memory alloys and their application to actuators for deployable structures PhD Thesis Cambridge University.
[2] Ölander A. An electrochemical investigation of solid cadmium-gold alloys. AmChem Soc 1932;54:3819–33.
[3] Vernon LB, Vernon HM. Process of manufacturing articles of thermoplastic synthetic resins. In: US Patent 2234993; 1941.
[4] W. Huang, On the selection of shape memory alloys for actuators, Materials and Design 23, 2002, pp 11-19
[5] Dan Mândru, Ion Lungu, Simona Noveanu, Olimpiu Tătar, "Applications of Shape Memory Alloy Actuators in Biomedical Engineering", Fascicle of Management and Technological Engineering, Volume VII (XVII), 2008, pp 922-927.
[6] Peirs, J. , A micro robotic arm for self propelling colonoscope, Proceedings of the 6th International Conference on New Actuators Actuator 98, 1998, Bremen, pp 576-579.
[7] Ming H. Wu, L. McD. Schetky, Industrial Applications for Shape Memory Alloys, Proceedings of the International Conference on Shape Memory and Superelastic Technolgies, Pacific Grove, California, 2000, P.171-182.
[8] Fujun Peng, Xin-Xiang Jiang, Yan-Ru Hu, Alfred Ng, Application of Shape Memory Alloy Actuators in Active Shape Control of Inflatable Space Structures, IEEE, version 8, 2004, pp 1-10.
[9] Koji Ikut, Masahiro Tsukumoto, Shigeo Hirose, Shape Memory Alloy Servo Actuator System with Electric Resistance Feedback and Application for Active Endoscop, IEEE, 1988.
[10] William L. Benard, Harold Kahn, Arthur H. Heuer, and Michael A. Huff, Thin-Film Shape-Memory Alloy Actuated Micropumps, Journal of Micro Electromechanical Systems, VOL. 7, NO. 2, JUNE 1998, PP 245 - 251
[11] Ľ. Mikova, s. Medvecka - beňova m. Kelemen, f. Trebu ňa, i. Virgala, Application of shape memory alloy (sma) as actuator, metalurgija 54 (2015) 1, pp 169-172.
[12] M. Taya, H. Kato et.all., Development of Ferromagnetic Shape alloys based on FePd Alloy, APCFS & ATEM 01, JSME-MMD, Oct 2001, pp 11-20.
[13] A Novac, R Sprincenatu et.all., Martensitic Transformation in Fe-Pd Ferromagnetic Shape Memory Alloy Wires, 7th International conference on Advanced materials and structures, 2018, pp 1-5.
[14] Tobias Mielke, Jan-Maris W. Gopfert, Hubertus Murrenhoff, Potential of Ferromagnetic Shape Memory Alloys as Power Units in Hydraulic Pumps, IEEE 978-1-5386-4785-1/18.
[15] Jaronie Mohd Jani, Martin Leary, Aleksandar Scbic, Mark A. Gibson, A review of Shape change memory alloy research, applications and opportunities, Elsevier, Journal of materials and design 56, 2014, pp 1078-1113.
[16] Stoeckel D, Waram T. Use of Ni–Ti shape memory alloys for thermal sensor actuators. In: Active and adaptive optical components. San Diego, CA, USA: SPIE; 1992. p. 382–7.
[17] Mohammad T, Jeng-Jong R, Chuh M. Thermal post-buckling and aeroelastic behaviour of shape memory alloy reinforced plates. Smart Mater Struct 2002;11:297.
[18] Balta JA, Simpson J, Michaud V, Månson JAE, Schrooten J. Embedded shape memory alloys confer aerodynamic profile adaptivity. Smart Mater Bull 2001;2001:8–12.
[19] Bellini A, Colli M, Dragoni E. Mechatronic design of a shape memory alloy actuator for automotive tumble flaps: a case study. IEEE Trans Industr Electron 2009;56:2644–56.
[20] Strittmatter J, Gümpel P, Zhigang H. Long-time stability of shape memory actuators for pedestrian safety system. J Achiev Mater Manuf Eng 2009;34:23–30.
[21] Williams EA, Shaw G, Elahinia M. Control of an automotive shape memory alloy mirror actuator. Mechatronics 2010;20:527–34.
[22] D. Stoeckel. "Thcrmovariable Rate Springs - A New Concept For Thennru Sensor·Actuators ", Proceedings Actuator 90, VDINDE, Bremen, 1990, pp. 226-229.

[23] Bogue R. Shape-memory materials: a review of technology and applications. Assembly Automation 2009;29:214–9.
[24] Melton KN. General applications of shape memory alloys and smart materials. In: Otsuka K, Wayman CM, editors. Shape memory materials. Cambridge University Press; 1999. p. 220–39.
[25] Luchetti T, Zanella A, Biasiotto M, Saccagno A. Electrically actuated antiglare rear-view mirror based on a shape memory alloy actuator. J Mater Eng Perform 2009;18:717–24.
[26] Manzo J, Garcia E, Wickenheiser A, Horner GC. Design of a shape-memory alloy actuated macro-scale morphing aircraft mechanism. 2005:232–40.
[27] Stoeckel D. Shape memory actuators for automotive applications. Mater Des 1990;11:302–7.
[28] Butera F. Shape memory actuators for automotive applications. Adv Mater Processes 2008;166:37.
[29] Johnson RW, Evans JL, Jacobsen P, Thompson JR, Christopher M. The changing automotive environment: high-temperature electronics. IEEE Trans Electron Pack Manuf 2004; 27 :164–76.
[30] Mândru, D., et al., Actuating Systems in Precision Engineering and Mechatronics Alma Mater, Cluj- Napoca, 2004.
[31] I. W. Hunter, S. Lafontaine, J. M. Hollerbach, and P. J. Hunter, “Fast reversible NiTi fibers for use in microrobotics,” in IEEE Proc. Microelectromech. Syst., 1991, pp. 166–170.
[32] A. D. Johnson, J. D. Busch, C. A. Ray, and C. L. Sloan, “Fabrication of silicon-based shape memory alloy micro actuators”, in Mater. Res. Soc. Symp. Proc., vol. 276, pp. 151–160, 1992.
[33] K.Ikuta, (1987), Study of Servo Actuator using Shape Memory Alloy, Doctoral Dissertation in Tokyo Institute of Technology
[34] J. Strittmatter , P. Gümpel , H. Zhigang , Long-time stability of shape memory actuators for pedestrian safety system, Journal of achievement in materials and manufacturing engineering, volume 34, issue 1, 2009, pp 23-30.
[35] Williams E, Elahinia MH. An automotive SMA mirror actuator: modeling, design and experimental evaluation. J Intell Mater Syst Struct 2008;19(12):1425–34.
[36] M. L. Tharayil and A. G. Alleyne, “Modeling and control for smart mesoflap aeroelastic control,” IEEE/ASME Trans. Mechatronics, vol. 9, no. 1, pp. 30–39, Mar. 2004.
[37] R. Velazquez and E. Pissaloux, “Design of shape memory alloy helical springs using force and time response criteria,” in Proc. Int. Conf. Mechatron. Robot. 2004, Aachen, Germany, Sep. 13–15, 2004.
[38] Roch I, Bidaud Ph, Collard D, Buchaillot L. Fabrication and characterization of an SU-8 gripper actuated by a shape memory alloy thin film. J Micromech Microeng 2003(February).



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY