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DEVELOPING A GRIPPER USING SHAPE MEMORY ALLOY (SMA)

Mustafa Soylak

Mechatronics Laboratory, Faculty of Aeronautics and Astronautics, Erciyes University, Kayseri, Turkey. Email: soylakm@erciyes.edu.tr

Corresponding Author: Mustafa Soylak, Mechatronics Laboratory, Faculty of Aeronautics and Astronautics, Erciyes University, Kayseri, Turkey. E-mail: soylakm@erciyes.edu.tr,

ABSTRACT

Developing technology has accompanied the need for different working equipments and the discovery of these accordingly. One of these working equipments is shape memory alloys (SMA), which experience phase change when heat is applied and return to the volume and shape in its memory during this phase change. In case of giving the necessary heat for shape change, energy is obtained with high power / weight ratio. It has been observed that there are products in which these systems are used in many areas such as industrial, aviation, medicine, etc.. Within the scope of the study, a gripper has been developed for robotic and automation applications with the use of SMA. It has been observed that the developed holder provides solutions for handling and moving. In addition, with the evaluation of the energy provided by the SMA's with high power / weight ratio in the right designs, it was determined that it will provide much more advanced solutions in the following stage.

Keywords: Shape memory alloy, Gripper, Mechatronic, Robotic.

I. INTRODUCTION

Regardless of the current shape, if the heat is applied, the materials that return to their shape and properties defined with their geometric and volumetric properties are called shape memory materials [1]. The shape memory feature gained the current technology in a process. Chang and Read were the first to find the shape memory transformation in their research on gold-cadmium (Au-Cd) alloys in 1932. The detection of the shape memory feature in brass materials coincides with the year 1938. In 1962, it was determined that Nickel and Titanium alloy (50% Ni-50% Ti) had shape memory properties. Buehler and his colleagues, who conducted a series of researches using Nickel and Titanium alloys within the United States Naval Army Laboratory and detected the shape memory effect, found an alloy under the name of NiTiNOL. This nomenclature was created by quoting the words Ni (Nickel), Ti (Titanium) and NOL (Naval Ordnance Laboratory) [2-3]. Some properties of Nitinol make it different from other SMAs. These features are; more ductility, more recoverable movement, excellent corrosion resistance, stable conversion temperatures, high biocompatibility, electrical current heating and low production costs [4]. The gains obtained after this invention increased the usage areas and commercialization potential of shape memory alloys. However, SMA-based business elements have some disadvantages, such as low speeds, nonlinear and delayed behavior, and modeling complexity. Parameter uncertainty and difficulty in measuring their current status can be added to these disadvantages. These shortcomings have limited the development of SMA-based systems, and SMA elements are generally used only for work in simple on / off mode [5-7].Also, simultaneous sensing and operation using a SMA-based system cannot be obtained with sufficient accuracy due to such delays [8]. Table 1 gives the information of the existing shape memory alloys.

Table 1. Alloys with shape memory [9]

Alloy	Composition	Range of transformation temperatures (A_s) °C	Transformation hysteresis, °C
AgCd	44 ~49 at %Cd	-190 ~50	~15
AuCd	46.5~50 at %Cd	30~100	~15
CuAlNi	14~14.5 wt %Al 3~4.5 wt % Ni	-140~100	~35
CuSn	~15 at % X	-120~30	
CuZn	38.5~41.5 wt % Zn	-180~-10	~10
CuZn X (X=Si,Sn,Al)	small wt % X	-180~200	~10
InTl	18~23 at %Tl	60~100	~4
NiAl	36~38 at % Al	-180~100	~10
TiNi	46.2~51 at % Ti	-50~110	~30
TiNi X (X=Pd,Pt)	50 at % Ni+X 5~ 50 at % X	-200~700	~100
TiNiCu	~15 at % Cu	-150~100	~50
TiNiNb	~15 at % Nb	-200~50	~125
TiNiAu	50 at % Ni+Au	20~610	
TiPd X (X=Cr,Fe)	50 at % Pd+X ~15 at% X	0~600	~50
MnCu	5~35 at % Cu	-250~180	~25
FeMnSi	32 wt%Mn, 6wt%Si	-200~150	~100
FePt	~25 at % Pt	~-130	~4
FePd	~30 at % Pd	~50	
FeNi X (X=C,Co,Cr)	small wt% X		

In the development of shape memory alloys, the process of change and transformation that took place with the transition from martensitic phase to austenitic phase was used. The material, which is at low temperature while in the martensitic phase and changes shape with external force very easily, changes the phase with the help of the applied heat, passes to the austenitic phase and converts to whatever shape that is placed in its memory by a series of processes at the initial stage. Here, the austenitic phase is the high temperature phase and the martensitic phase is the low temperature phase [2,10,11]. In Figure 1, the repetition cycle of martensite-austenite transformation is given in shape memory alloys, and this transformation takes place at different temperatures for each alloy. When the shape memory alloys are heated, the crystal structure of the alloy turns from martensite to austenite at a certain temperature. This temperature value at which austenite conversion takes place is called the austenite start temperature (AS), and the temperature at which the conversion ends is called austenite end temperature (AF). If the austenitic shape memory alloys are cooled, the crystal structure of the material will turn into martensite structure. The temperature at which this conversion takes place is called the martensite start temperature (MS) and the temperature at which the conversion ends is called the martensite end temperature (MF). Shape memory alloys have a mixed order of martensite and austenite between AS and AF, and MS and MF temperatures [11-13].

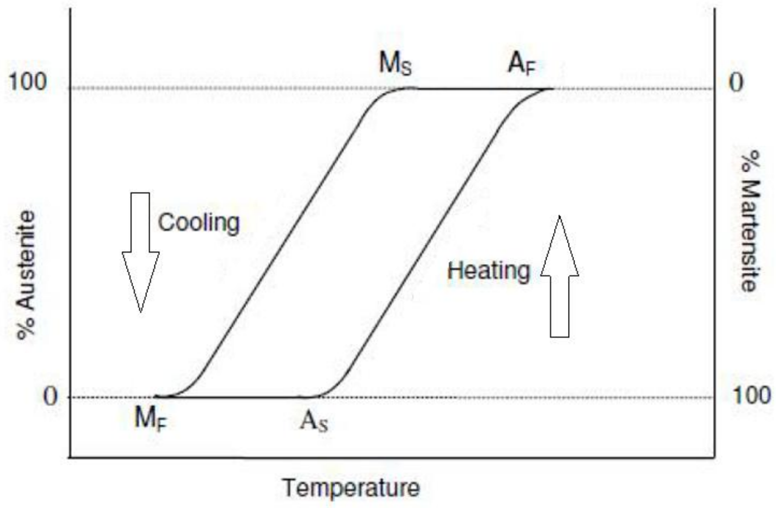

Figure 1. Temperature changes of SMA and hysteresis curve [3,11]

In these systems, in which the least amount of energy is spent to take the initial form of the alloy, when the power it generates during the return to the shape in its memory is examined, the high value and performance that the power / weight ratio has compared to almost all systems appear. In the literature, there are many studies that are carried out to use the advantages of SMAs in different systems (aviation, robotics, medicine, industry, etc.). Andrianesis K., et al. studied about a new prosthetic hand design working with the SMA, analytically explained the system and conducted an experimental examination on one finger.They explained the contribution of SMAs to prosthetic hand applications [14]. Gabriel, K.J. et al. fixed two 100 µm diameter shape memory alloy (Nitinol) wires under the torsional strain in the form of a thin rod, and were used as a micro working element of less than 0.04 cm^3 in volume. Electric current was applied by touching the center and the two halves of the wire could be heated differently. Thus, repeatable, continuous and directional angular bends were obtained around the longitudinal axis of the wire [15]. Haga, Y., et al. explored catheters and endoscopes, one of the medical applications of the SMA microcomponent. Within the scope of the research, endoscopes with imager were examined at the end of the bending mechanism [16].

In this study, a gripper design and prototype production, which is widely used in all automation applications, especially robotic applications, has been realized. The usability of this holder in the transportation and positioning of materials with different physical properties has been determined.

II. MATERIAL AND METHOD

As a final processor in robotic systems; hand, torch, holder, spray gun, cutting unit are used. If the system and the units that need to work in coordination with this system are not designed and manufactured with due diligence; It will cause loss of work done by a robotic system with advanced features running in the background. In flexible production and automation applications, which are widely used in robotic systems, the importance of post processors and carrier mechanisms has been understood and different solution suggestions have been developed by scientists..Martínez, Á. It examines the gripper classification in 4 different categories according to the way it holds. These; 1. Pressure grippers; They comprehend and carry objects with pressure, membrane type grippers are examples of this type. 2. Grasping type holders; These are the holders used by the gripper to position large pieces that perform multi-point clutch. 3.Vacuum type holders; they are often used to hold non-ferrous and low specific gravity objects. They use vacuum containers, also known as suction cups, as gripping devices. They are efficient if the objects to be moved are smooth, flat and clean. It has only one surface to hold objects. Not suitable for carrying porous objects, 4.Electromagnetic Holders; They are used to transport magnetizable metal materials (Figure 2).

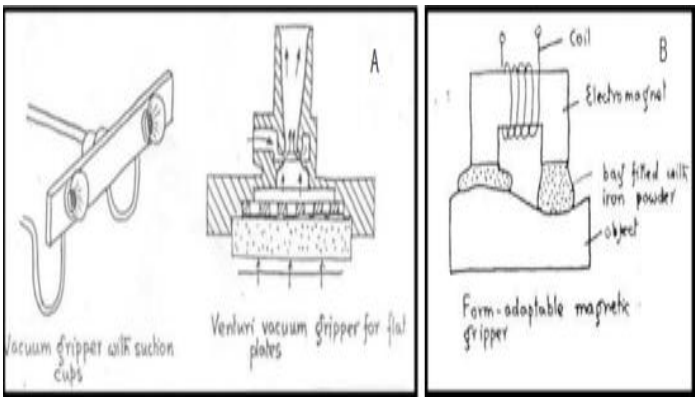

Figure 2. Holder Examples (A: Vacuum, B: Magnetic) [17]

In the study carried out by Kahya, E., a scissors-type gripper design and prototype were produced that carried out with image processing equipment and experimentally examined in kiwi harvest application [18]. Adldoost, H. proposed a new type of micro holder that can use a longer SMA cable in a spiral sheath inside the coating tube, take the form of memory with less electrical current, and presented its design and simulation [19]. The gripper designed in this study is shown in Figure 3 and the gripper image developed as a prototype is shown in Figure 4.

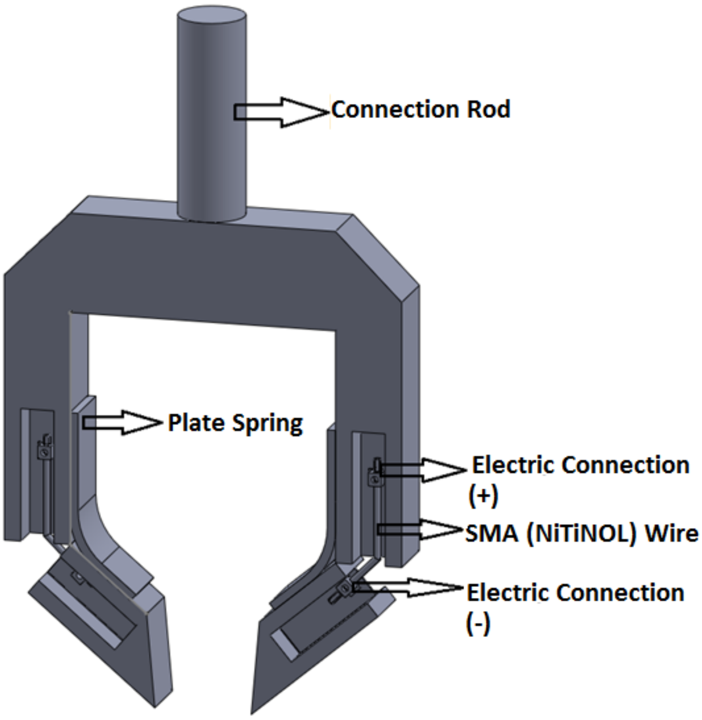

Figure 3. Designed Gripper

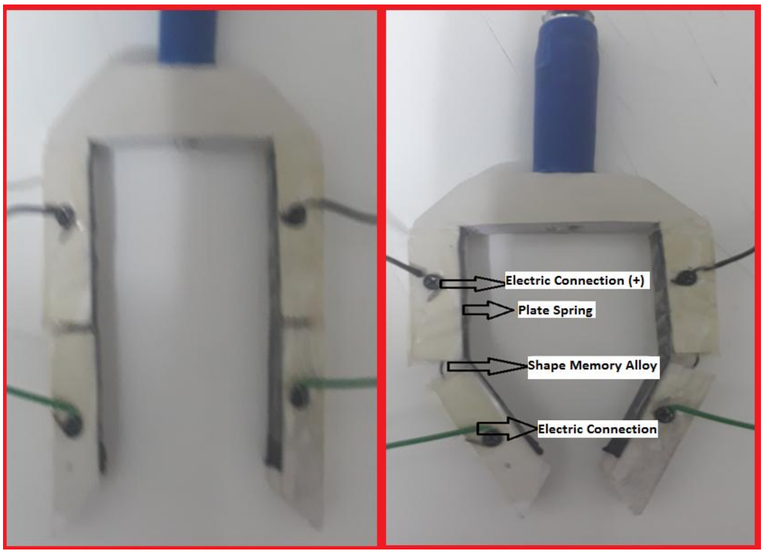

Figure 4. Prototype of the designed gripper.

During the activation of the holder developed within the scope of this study, the SMA is heated by electric current to make the movable arms perform the necessary holding movement. The shape memory wire heated by electric current passes into the austenitic phase, while bending at the defined angle value in its memory. This bending allows the holding arms to take the necessary position for holding and carrying and generate the required force. In the meantime, the plate spring, which is mounted on the inner surface of the arm area, remains under the effect of elastic deformation. The electric current is cut and the shape memory wire cools to release the conveyed material and restore the holder. If the wire cools down, the plate spring is activated and gripper arms return to their former shape. The continuity of the work takes place with the repetition of this movement.

III. RESULTS AND DISCUSSIONS

In this study, a gripper was developed using shape memory alloys. It has been found to be usable for grasping and transporting different products. It is possible to create alternative designs of the developed gripper using shape memory metal technology. Without using complex electromechanical systems, this type of holder, which uses a shape memory alloy with its simple design, will be widely used in industrial applications. This is because the manufacturer will pave the way for produce their own gripper units. After a much more economical and short-term production process, it will be possible to develop a holder for alternative requirements. As in this study; The evaluation of the power produced by shape memory metals in phase transformations with the creation of suitable designs will result in the introduction of much more new products to the technology.

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