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Design, Fabrication and Intelligent Control of the Gripper Based on SMA Actuators

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This paper presents the designing, simulation, fabrication and control of a gripper actuated by Shape Memory Alloy (SMA) wire. The presented gripper has the advantage of the small linear displacement of the slider connected to the SMA wire, and can convert the linear displacement into angular movement of the gripper fingers. In this study, design and simulation processes have been done by two powerful CAD and quasi-real dynamic simulation software; DS.CATIA and MSC.ADAMS respectively. Then, a gripper that actuated by SMA wire has been fabricated and the physical prototype and its mechanical and electrical properties have been presented. Finally, several experiments have been designed and performed, and the results for tip displacement of the fingers are presented and discussed. The results show that the prototyped gripper is performing to a satisfactory extent; as the fingers have been returned to their initial positions with a proper accuracy and also without any feedback control. To compensate the hysteresis phenomenon derived from SMAs wire, self-tuning fuzzy PID method was used to control the force. At first, this method has been applied on the model of the gripper by co-simulation of MATLAB and MSC.ADAMS. After that, the presented controller has been developed on the physical prototype of the gripper and its efficiency has been investigated. The experimental results demonstrate good performance of the designed controller for the tracking of the gripping force.

Keywords: Gripper, shape memory alloy (SMA), fuzzy-PID, controller, fabrication.

1 Introduction

The robotic gripper is the end-effector of a robot system which is usually installed on a robot arm [1]. Since the gripper is the executor unit of a robot, it plays an important role in the application of robots. Technologies used in the grippers have been developed over the years for consumer products and specialized applications such as electronics, fields related to medicine and biology like drug production and invasive surgery, abdominal surgery and eye -

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surgery. Although the grippers are well-known in robotic systems, their actuation principles are still an important challenge in robotic systems. The actuation of a gripper in a small size can be done with mini electric motors, hydraulic pistons, piezoelectric actuators and SMA actuators. SMA has the benefits of a higher power to weight ratio and corrosion resistance [2]. Additionally, SMA has low cost and does not require further processing as it can just be cut and used [3]. SMA constitutes a group of metallic materials with the ability of recovering a previously defined length or shape when stands under a thermodynamic process. The transition from one form of crystalline structure to another creates a mechanism by which the shape change occurs in SMAs. This change involves transitioning from a monoclinic crystal form (Martensite) to an ordered cubic crystal form (Austenite). The Austenite phase is stable at high temperature, and the Martensite is stable at lower temperatures. The phase transformation between the two phases, Martensite and Austenite, is accompanied by variations in SMA resistivity [4].

One of the first SMA gripper has been designed and fabricated by Lee et al. which was made of Ni-Ti-Cu SMA films. The gripper has large gripping force and is actuated at relatively low actuation temperatures [5]. Mertmann and Hornbogen presented two structures for a gripper using Ni-Ti spring and wire. In their study, the use of flexure hinges has proved to be suitable for the application in such grippers [6]. In another study, a SMA actuator presented and aimed to be integrated in the phalanx of a dexterous micro gripper [7]. Kohl et al. designed and fabricated a gripper device consisting of thin SMA sheet. Closing and opening in gripper are performed by two integrated actuators, which form an antagonistic pair. The motion of the gripping jaws is transmitted by an integrated gearing mechanism into a linear motion of an integrated optical slit, which is detected by change of optical transmission [8]. Also, a gripper made of a thin SMA film was presented by Roch et al. They presented the fabrication process of the thin SMA film in both monolithic and hybrid configurations [9]. A gripper using long length SMA wire presented in [10] that is suitable for laparoscopic operations. Also, the designs of several miniature grippers have been presented and compared. The selected final design from all of the presented grippers is the one actuated by SMA wire. The selected design is compact and gripping forces are in accordance with the specifications. For a gripper in such small size, a spring was fitted for closing the jaws [10]. In another study, detailed design of 5 innovative surgical grippers with SMA wire as actuator has been presented. The presented grippers are suitable to be used as end-effector for MIS laparotomic robotic operations.

The SMA wire is configured helicoidally in the gripping device [11]. Zhong and Yeong presented a gripper using SMA wire driven by a specialized electronic circuit. The small part of SMA wire was excited to create a pulling effect, enabling the closing of the gripper jaws. Tests conducted on the gripper prototype showed convincing results in terms of its consistency and reliability [12]. In later work, Zhong and Chan investigated a gripper actuated by SMA wire with simple actuation mechanism and working principle of the gripping device. A SMA wire was used to close the gripper during operation and a torsion spring was integrated to open the gripper jaw when the SMA wire relaxed [13]. A gripper with a pair of differential SMA springs was presented in [14]. In the gripper, two fingers are driven by a differential SMA actuator through a six-bar linkage to realize their opening and closing motion. The SMA actuator consists of two SMA coil springs and a slider. Later, Yang and Wang presented the designing, driving and controlling process of an SMA-actuated flexible humanoid gripper [15]. In their study, aside from designing the structure of the human hand, also a novel robot finger consists of multi-component was proposed. The finger has two flexible rods with embedded SMA wires and one shorter rod as a connecting part. The results show that the humanoid gripper is bent and returns to its default position when a current is applied to some part of the SMA wires.

In (2014), a SMA actuated, miniaturized, origami-enabled, parallel structure was presented as a versatile module for novel robotic tool in minimally invasive surgery. The parallel structure has been combined with a twisting module and a gripper obtaining a 4-DOFs on board actuated end-effector [16]. Accurate force control in a miniature gripper with a single SMA wire was done by Rezaeian and Yousefi-Koma. In their study, a fuzzy PID controller was developed to control the force produced by the gripper [17].
The objective of this study is to investigate the use of SMA wires as an actuator in design, simulation, fabrication and control of a novel three-finger gripper. One basic challenge in gripper-assemblies is the demand for very high accuracy over a large range of motion. So, one of the features of the presented gripper in this study is that the gripper has the advantage of small linear movement of the slider-connected to the SMA wire-and can convert that linear movement into a much bigger angular movement of the gripping jaws. Therefore, the gripper can handle objects with various diameters over a large range of motion with high accuracy using small linear movement of the slider.
In this paper, in accordance with designing objectives, the structure of the gripper is presented in DS.CATIA. Afterwards, the system is simulated in MSC.ADAMS by considering system parameters and applied loads. Then, the kinematic and kinetic behaviors of the gripper are analyzed by simulation. According to the designing objectives, the physical prototype and its mechanical and electrical properties are presented and the experimental results for tip displacement of the fingers are discussed. Then, a self-tuning fuzzy PID controller is presented for the gripper to control the gripping force. The controller is designed in MATLAB and tested on the simulated gripper in MSC.ADAMS and finally the output of the system is evaluated. After that, an experimental setup is designed for implementation of the controller on the physical-mockup of the gripper. At the end, the performance of the designed experimental setup is measured and the recorded results are investigated.

2 Design of the three-fingers gripper

One of the simple design methods of the robotic grippers is the application of the parallel jaws that are used in the industrial applications. Good contact between work-piece and gripper finger is essential for having a safe gripping operation at minimum force. Form-fit and force-fit gripping are two basic principles of gripping with more than one contact surface. Combination of these two were applied in this study, and has been used frequently by other [18]. As shown in figure (1), the griping jaws of the gripper have been designed in a way so that they can be fitted for gripping cylinders with defined range of diameters (10-45mm).

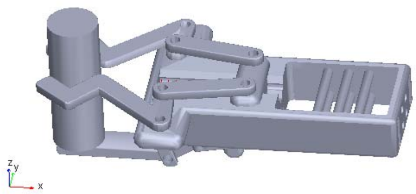
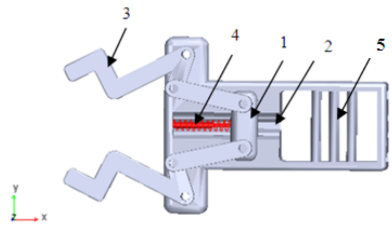
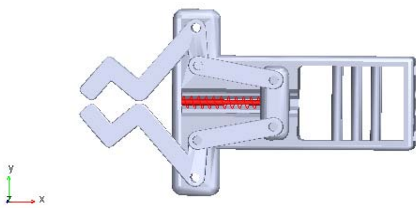


Figure 1 The isometric view of gripper while gripping a cylinder.

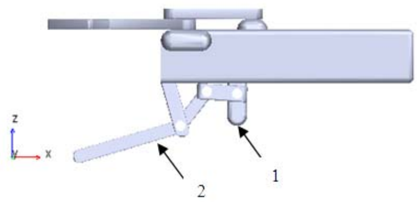


(a)

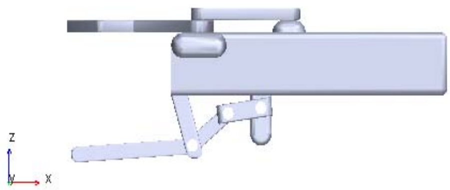


(b)

Figure 2 (a) Opening state of the gripper; (b) Closing state of gripper jaws.



(a)



(b)

Figure 3 (a) The gripper bottom view when voltage is not applied,
(b) The gripper bottom view when voltage is applied.

The elements of the gripper have been shown in figure (2a); Part 1 is the slider, part 2 shows the groove, part 3 is the gripper finger, part 4 is the translational spring that returns the slider to its primary position and part 5 shows some axles so that SMA wires can be screwed around them. By applying a voltage the wire length will decrease and the gripper fingers will close (figure (2b)). As it can be seen in figure (3), this scenario will be repeated for the bottom part of the gripper and will move the leverage finger up.

2.1 Simulation of the Three-Fingers Grippers in MSC.ADAMS

In this section, the simulation of the gripper with SMA actuator is presented. At first, the designed model in CATIA is exported into MSC.ADAMS. Then, thermodynamic properties of SMA actuators that include heat transfer, constitutive and phase transformation models are applied in MSC.ADAMS.

The first derivative of strain for SMA wire, as refer to strain-rate, is calculated by (1). Where $\dot{x}_i$ is the linear velocity of ith slider and l_{wi} is the initial length of SMA wire.

$$\dot{\varepsilon}_i = \frac{-\dot{x}}{l_{wi}} \qquad i = 1, 2 \tag{1}$$

The heat transfer model of SMA wire is the equation that calculates the heating and cooling rate of the SMA wire. The free convection heat transfer from the wire to the surrounding air is defined by Eq. (2) [2]:

$$m_{wi}.c_p.\frac{dT_i}{dt} = \frac{V_i^2}{R_i} - (h_0 + h_2 T_i^2) A_{li} \left(T_i - T_\infty\right) \qquad i = 1, 2 \tag{2}$$

In above equation, m_{wi} is the ith wire mass, V_i is the induced voltage to the ith wire, c_p is the specific heat [2], h_0 and h_2 are the heat convection coefficients, T_i is the ith SMA wire temperature, A_{li} is the lateral area of the ith wire and T_∞ is the ambient temperature that is equal to 25 ºC. The following Table (1) shows the SMA wire properties and the heat transfer model parameters used in this model [2].

As it can be seen in (3), the SMA constitutive model is a linear mathematical relationship among the first order derivative of stress, strain, temperature, and phase transition coefficient. In this equation, $\dot{\sigma}_i$ means the ith wire stress, $\dot{\varepsilon}$ means the strain of the wire, ξ means the SMA wire phase transition coefficient, D is the Young's modulus, Θ_T is the thermal expansion factor, and Ω_i is the phase transformation contribution factor of wire i [2].

$$\dot{\sigma}_i = D\dot{\varepsilon} + \Theta_T \dot{T}_i + \Omega_i \dot{\xi}_i \qquad i = 1, 2 \tag{3}$$

The SMA phase transition is called the SMA phase transition model which is calculated through (4). a_A, b_A show the effect of stress on the reverse transformation temperatures. They are extracted from [2]. Also, A_s is the initial temperature of austenite phase transition [2].

$$\xi_i = \frac{1}{2}\left[\cos\left[a_a\left(T_T - A_S\right) + b_A \sigma_i\right] + 1\right] \qquad i = 1, 2 \tag{4}$$

From the Eq. (3), the SMA wire stress is calculated. By using (5), the created force in the SMA wire can be calculated too. In this equation, σ_i is the wire stress and A_i is the initial cross section of wire.

$$F_w = \sigma_i . A_i \qquad i = 1, 2 \tag{5}$$

Table 1 SMA wire and heat transfer model parameters

Wire	r_{wi}(m)	l_{wi}(m)	m_{wi}(kg)	Initial Strain	h_0	h_2	R_{wi}(Ω)
1	7.62e-5	1	1.628-4	0	70	1.0e-3	50
2	7.62e-5	0.54	8.795e-5	0	70	1.0e-3	27.63

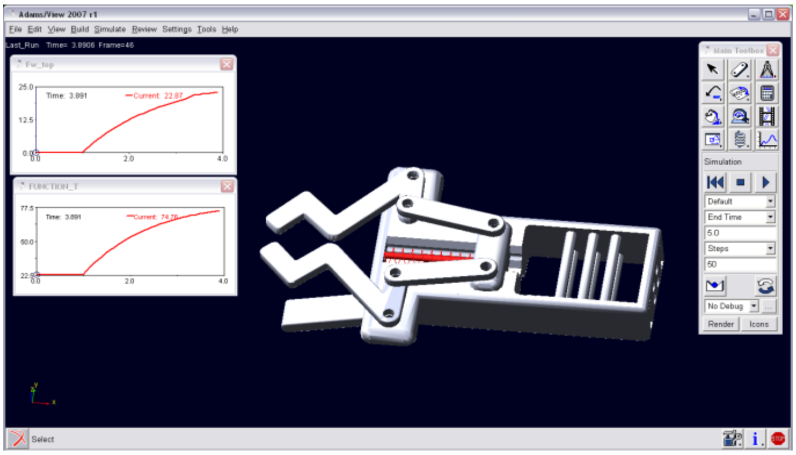


Figure 4 The simulated gripper in MSC.ADAMS.

The simulated gripper in MSC.ADAMS software is illustrated in figure (4).

3.1 Fabrication of the Three-Fingers Gripper

A physical mock-up, as in figure (5), has been created to verify the operating principle of the gripper. The frame, jaws and the sliders have been made by Plexy-glass [19]. The part that the grooves are embedded in it, has been made of PTFE. The device is powered by 0.15 mm diameter SMA wires. At the top and the bottom of the gripper, according to the model, two springs have been located inside of the grooves with 319 N/m and 75 N/m stiffness. These values are fully in accordance with the parameters of the simulated model. At the end-part of the frame, 6 pulleys are embedded so that the SMA wires can move easily on them.

Actuation in gripper is provided by two piece of SMA wire (1 m long in the top of the gripper and 0.54 m in the bottom of the gripper) with both ends kept fixed by a pair of bolts and nuts (figure (6)). The SMA wire forms a loop around a protruding part attached to the sliding unit so that it pulls the jaws to close simultaneously when the SMA wire is activated. The diameter of the SMA wire used in gripper has been selected as 0.15 mm.

Figure 5 The fabricated gripper.

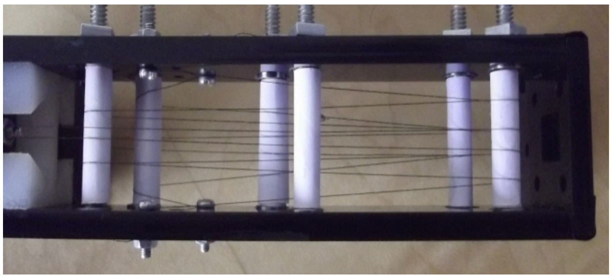


Figure 6 The actuation unit of gripper.

Figure 7 The spring embedded into the groove.

Two biased springs have been mounted at the back of the top and bottom of the sliders to open the gripper when the SMA wire is deactivated. The part made of PTFE has grooves to accommodate the placement of the springs. The sliders have been guided along their directions to slide through the grooves. The springs have been added at the back of the sliding units to ease its recovery motion and effectively prevent it from getting jammed in the grooves (figure (7)).

3 Performance of simulated and fabricated gripper

As said before, applying voltage causes an increase in the SMA wire temperature and therefore decreases its length. Thus, the connected slider, moves through the groove and causes angular motion in the fingers of gripper. The operation of the gripper is as follow: 1) SMA length shortening, which is because of applying voltage, causes the fingers of the gripper to close. 2) By disconnecting voltage, SMA wire returns to its original length, and by using spring embedded into the groove and connected to the slider, jaws of the gripper will return to their initial locations and the gripper goes to its open state. 3) By applying voltage, the SMA wire will be shortened at the bottom segment of the gripper. So, the slider will move towards the right and the leverage finger will go up.

3.1 Tip Displacement Measurement Test

The aim of this test is to determine displacement of the fingers with respect to the SMA wire excitation voltage. For each level of voltage excitation, the stroke of the fingers is measured. In this test, the voltage level is changed in the range of 1.25-12.5 V at the upper wire of the gripper. Then the stroke of the fingers at the top of the gripper is measured and the results are shown in figure (8).

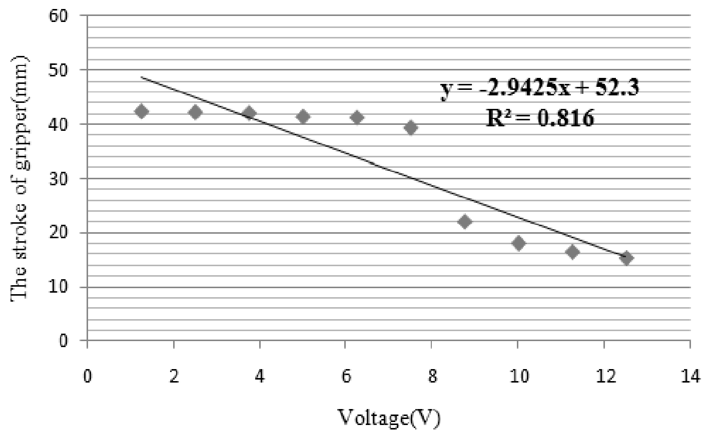


Figure 8 The stroke of the gripper fingers vs. excitation voltage.

Figure (8) shows the voltage-displacement diagram of the fabricated gripper. As it can be seen, no significant displacement is observed at voltage level 8 and less than that. But for values higher than 8 voltages, the gripper displacement behavior is suitable to use for gripping. Furthermore, the obtained correlation coefficient (*R*) is 0.9033, which indicate small values of error. Thus, without any feedback control, error values are relatively small.

4.1 The Generated Displacement Tracking Performance

For an SMA wire excitation in a complete gripping motion, i.e. a closing and an opening movement of the gripper, the 12.5 V and 5.5 V step voltages are applied to the top and the bottom of the system. The SMA wire phase transition and gradual shortening occur due to the applied voltage. This shortening causes the slider to transfer to the right. Then, the fingers of the gripper are closed. When the jaws are in closing phase, an object with a defined diameter can be gripped. Then by disconnecting the voltage, the jaws of the gripper go back to the initial opening state. To complete the gripping cycle, the bottom SMA wire of the gripper also should be actuated. As said before the leverage finger of the gripper moves up and then by removing the voltage, the finger returns to its initial location.

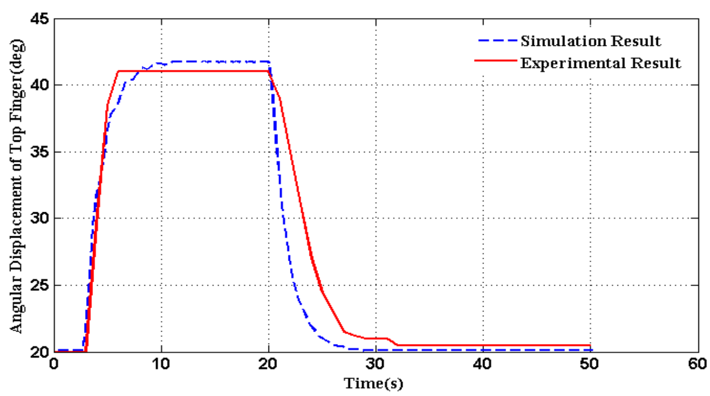


Figure 9 Tip angular displacement under pulse voltage.

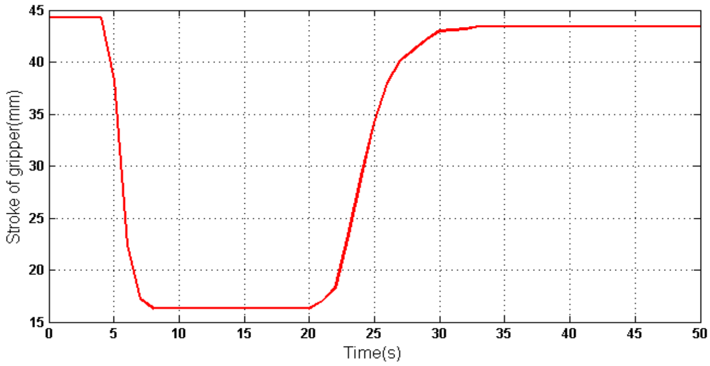


Figure 10 The stroke of jaws for pulse voltage as input.

According to figure (10), the stroke values of the jaws in the top of the gripper show that with a small displacement in the slider, the jaws will move in a large range of motion (28 mm). This feature is very important, because as said before, one basic challenge in gripper-assemblies is the demand for high accuracy over a large range of motion. As most of the similar studies have applied higher values of voltage and also gained less range of motion for the jaws. Therefore, it can be seen that we have achieved high accuracy in the gripper with a less voltage value.

4 Self-tuning fuzzy PID controller for gripping force control

The PID controller is widely used in industry due to its simple control structure and easy design [20]. However, there are certain problems that occur in practical control systems. The parameters of the conventional PID controller are not often properly tuned for the nonlinear systems with unpredictable parameter variations. For this reason, it is necessary to automatically tune the PID Parameters.
Since the fuzzy control provides a formal methodology for representing, manipulating and implementing human's heuristic knowledge about how to control a system [20], we can incorporate the benefits of fuzzy and PID controllers into one controller. The structure of such system is shown in figure (11).

As it can be seen, the controller has the form of PID structure, but the PID parameters are tuned by fuzzy inference, which provides a nonlinear mapping from the error signal $e(t)$ (the difference between reference signal and system output), and derivation of error $de(t)$, to the PID parameters K_p , K_i , and K_d [20]. These parameters are changed within the initial parameter boundaries. The structure of the fuzzy inference block is shown in figure (12).

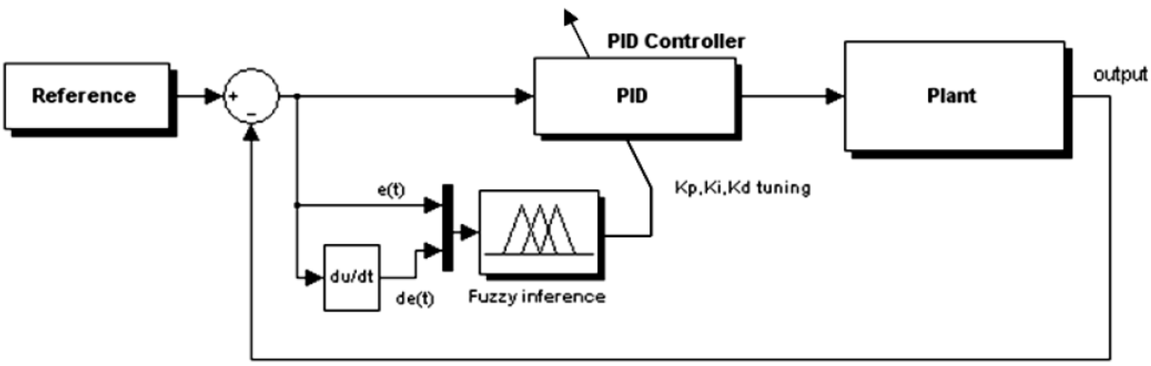


Figure 11 The structure of the system [20].

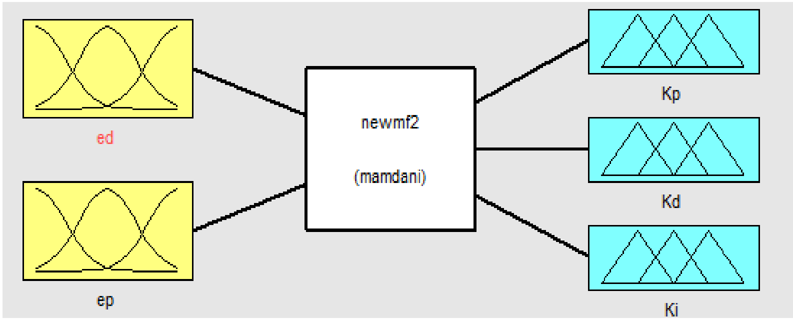
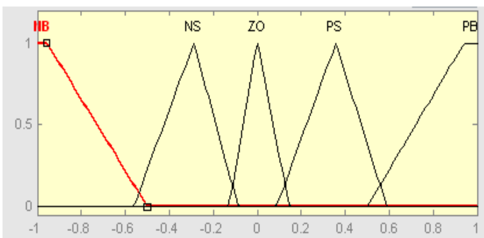


Figure 12 Fuzzy inference block.

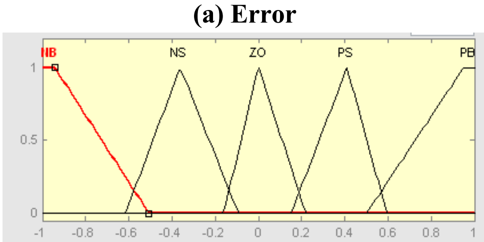
For de-normalization of the PID gains, we assumed that the ranges of K_p, K_i and K_d variable are (K_{pmin}, K_{pmax}), (K_{imin}, K_{imax}) and (K_{dmin}, K_{dmax}), respectively [20]. The range of each PID parameter was experimentally determined as $K_p' \in [1\ 1.5]$, $K_i' \in [0.1\ 2.9]$ and $K_d' \in [0.01\ 0.011]$. To obtain a rule bases with high inference efficiency, the PID parameters must be normalized over the interval [0, 1] as follows:

$$K'_p=(K_p- K_{pmin})/(K_{pmax}- K_{pmin})$$
$$K'_i=(K_i- K_{imin})/(K_{imax}- K_{imin}) \quad (6)$$
$$K'_d=(K_d- K_{dmin})/(K_{dmax}- K_{dmin})$$

In this paper, there are two inputs to the fuzzy inference: error and rate of change of the error signal. Five triangular membership functions are designed for both inputs. The linguistic label of the membership functions are as follows: Negative Big (NB), Negative Small (NS), Zero (ZO), Positive Small (PS) and Positive Big (PB). Also, thirteen membership functions are designed for the three outputs of the fuzzy inference (K_p, K_i and K_d). Their linguistic labels are as follows from the lower level to high level: VL, LVL, L, MLL, ML, MML, M, MHM, MH, HMH, H, VHH and VH. The membership functions of the inputs and outputs are shown in figures (13) and (14).

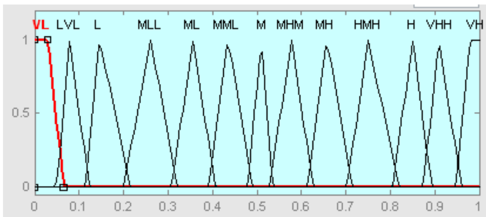


(a) Error

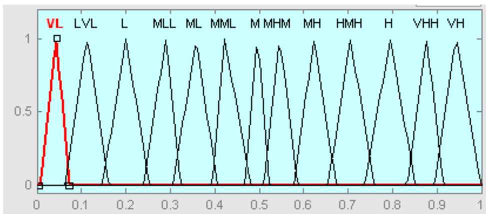


(b) Derivation of error

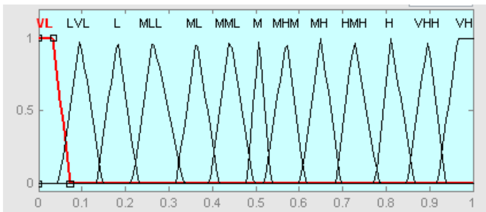
Figure 13 Membership functions of inputs.



(a) K_p



(b) K_i



(c) K_d

Figure 14 Membership functions of outputs.

Considering above fuzzy sets, fuzzy rules are composed based on the characteristics of SMA actuator as follow: the NB error means that the force is more than the reference force, then the applied voltage have to decrease, until the temperature of the wire decreases. Also, the PB error means that force is less than the reference force and the voltage have to increase until the temperature of the SMA wire increase. Table (2) shows the lookup table of fuzzy rules for control of gripping force. Generally, these rules depend on the plant and the type of the controller and can be defined from the practical experience.

In this study, the conventional PID gains are determined from the Ziegler-Nichols method by applying a unit step voltage to the open loop system. The calculated PID gains are shown in Table (3). The structure of the PID segment of controller is shown in figure (15).

Table 2 Look up table of fuzzy rules.

e / de(t)	NB	NS	Z	PS	PB
NB	ML	M	MH	H	VH
NS	MLL	MML	MHM	HMH	VHH
Z	L	ML	M	MH	H
PS	LVL	MLL	MML	MHM	HMH
PB	VL	L	ML	M	MH

Table 3 PID gains.

K_p	K_i	K_d
1.25	1.5	0.0105

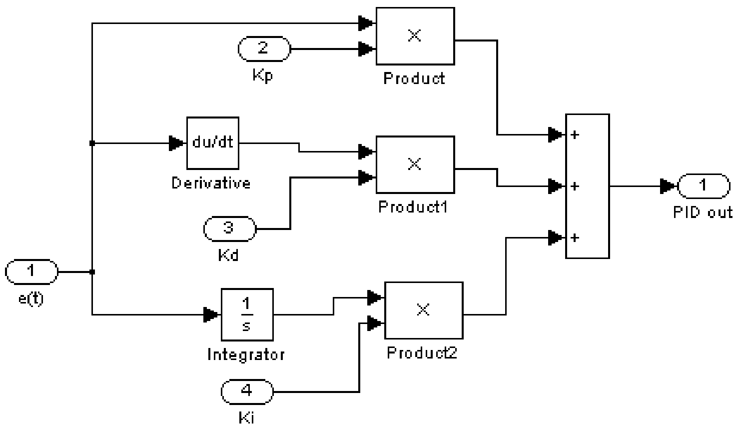


Figure 15 The structure of PID segment

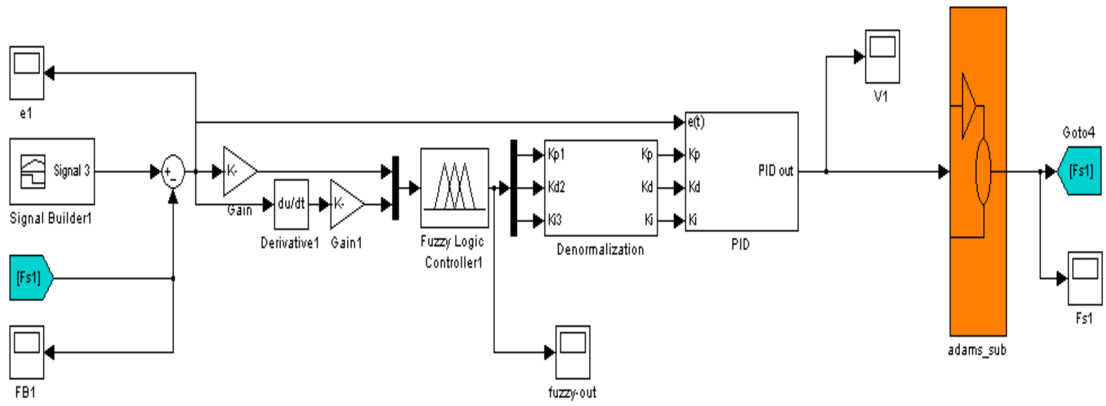
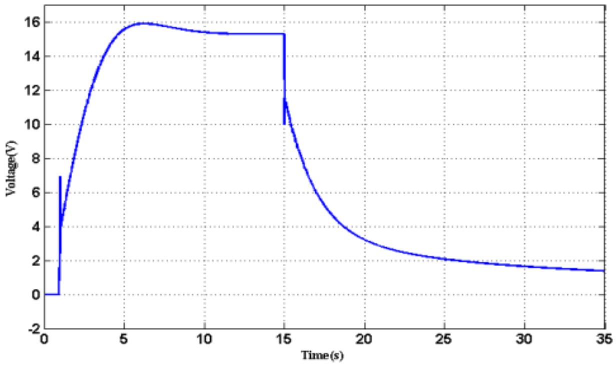


Figure 16 Block diagram of self-tuning fuzzy PID controller

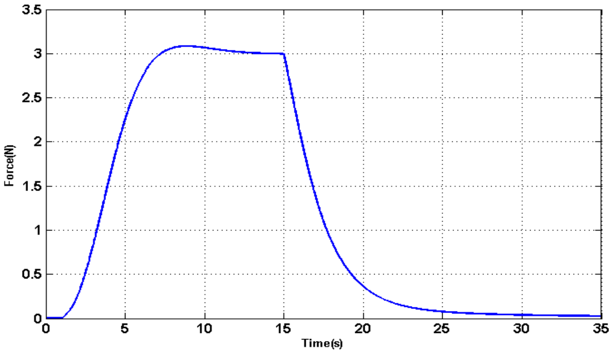
Figure (16) shows the block diagram of the force control system in MATLAB/SIMULINK. Since MATLAB is a powerful tool for applying control commands to the robot and also MSC.ADAMS is a powerful software for modeling the dynamics of the robot, the co-simulation between them is a very efficient tool in simulating the control process of a robot that is modeled in MSC.ADAMS environment [21].

As said before, the dynamic model of the gripper has been modeled in MSC.ADAMS environment. By using the ADAMS/Controls, the control plant of the gripper is exported to MATLAB environment. In MATLAB/SIMULINK environment, this control plant is placed in *adams_sub* block (the orange block in figure (16)).

The input and output of plant are defined in MSC.ADAMS. The input of gripper system is the voltage applied to the wire, and the output of gripper system is the force of SMA wire. Generated force signals for the SMA wire, enable the gripper to track the desired force. The Force tracking diagram of the gripper under 12.5 V pulse input voltage has been shown in figure (17).



(a)



(b)

Figure 17 (a) The output of controller under 12.5 V pulse input voltage, **(b)** The output force of system under pulse voltage.

Table 4 SMA wire and heat transfer model parameters.

Rise time(s)	Overshoot percent	Settling time(s)	Steady state error
3.63	1.76	11.04	0.035

Table (4) shows the performance of the control system over the SMA wire and heat transfer model. It can be seen from the table, given the applied voltage, the gripper showed a good force tracking performance and the steady-state error is around zero.
These results show that the performance of the designed controller is acceptable.

5 Experimental evaluation

A microcontroller (ATMEGA32L) has been used to control the gripping force of the gripper fingers. A PWM unit operated by H-Bridge transistors work as a switch to modulate the voltage applied to the SMA wire actuator. The built-in A/D converter in microcontroller converts analog feedback information from the finger-tip force sensor to a digital form suitable for using by the microcontroller. Also, an FSR sensor has been used for measurement of the tip gripping force of the fingers. This resistive sensor has the advantages such as light weight, proper sensitivity and repeatability [22]. Data in the form of serial configuration sent by a PC with through RS232 port, then processed by the microcontroller's built-in UART. A program running on the host PC has been used for communication with the microcontroller. This program is an interface between SIMULINK and the microcontroller for developing the designed Self-Tuning Fuzzy PID controller on the fabricated gripper.
Figure (18) shows the schematic of the experimental setup for developing the designed controller on the prototyped gripper.

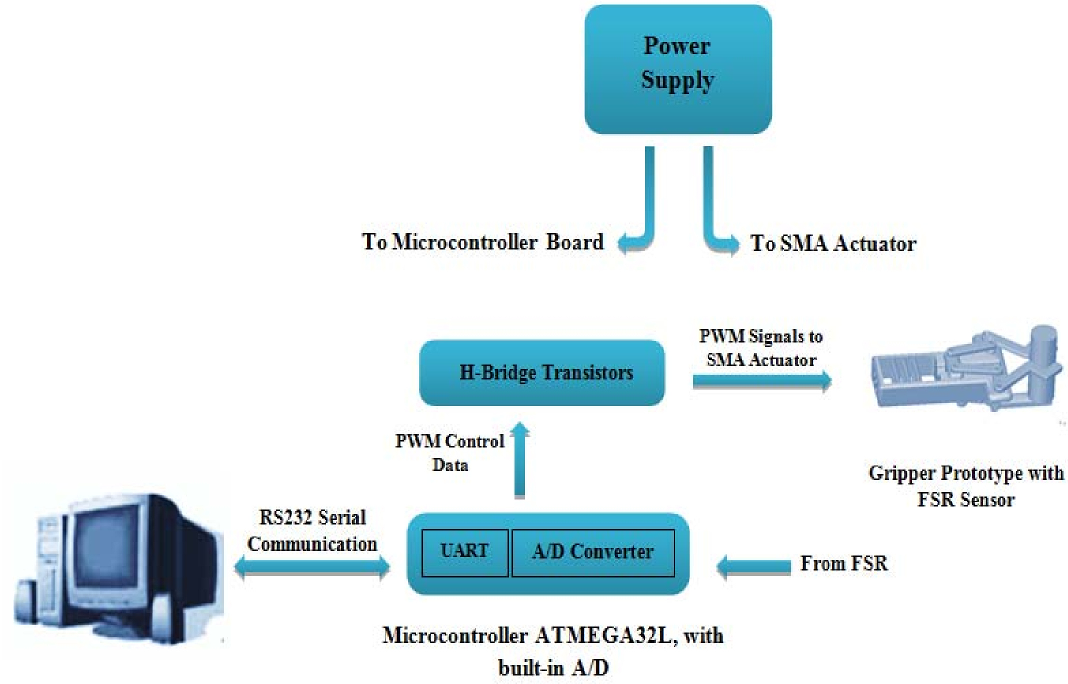


Figure 18 Schematic of experimental setup

Figure (19) shows the experimental setup for developing the designed controller on the fabricated gripper, as shown in the figure (18) schematic.
After running experimental setup, the output force is shown in figure (20).

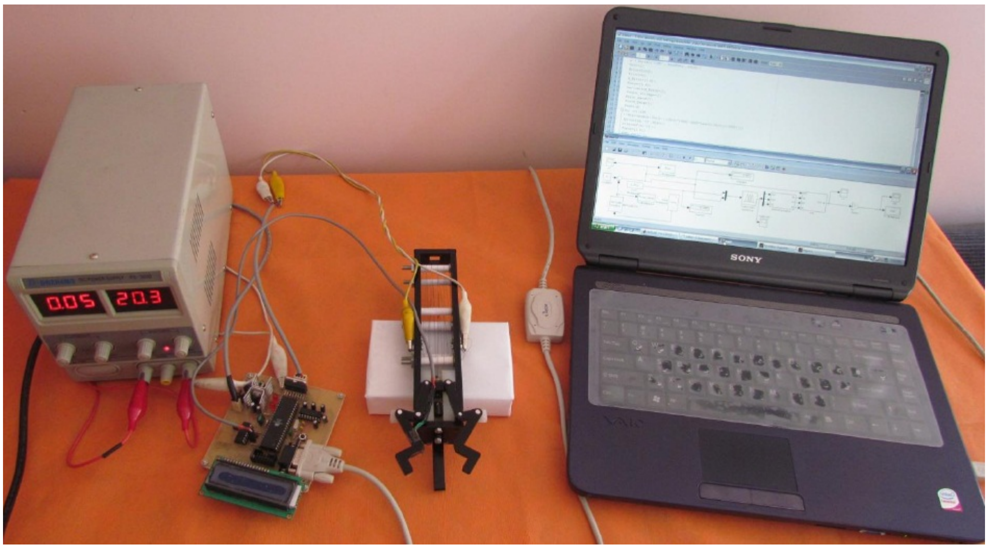
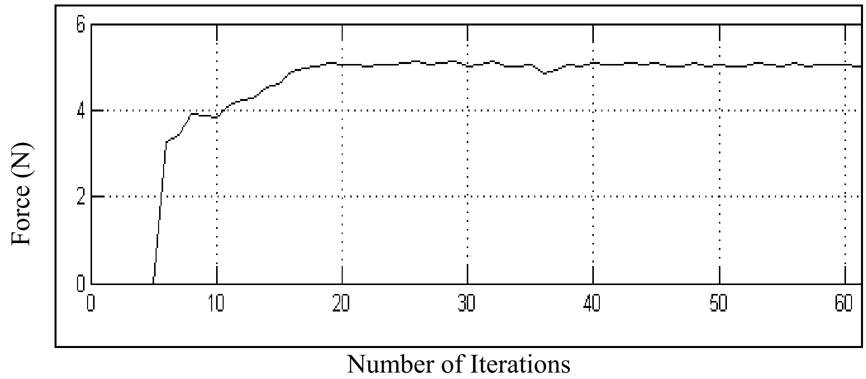
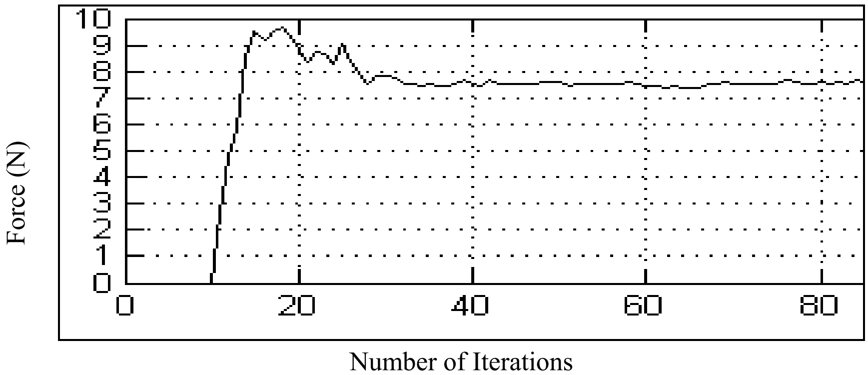


Figure 19 Experimental setup for developing controller on the fabricated gripper



(a)



(b)

Figure 20 The output force of system from experimental results; (a) Subjected to reference force 5(N), (b) Subjected to reference force 8(N).

As it can be seen from figure (20), control system reaches the desired force in a short time, thus gripper can quickly grab the desired object. Also the uniformity of control signal shows that the system does not show disturbed and fluctuated behavior. Furthermore, control system shows good performance as the steady state error of the controller is low.

6 Conclusion

In this paper, design, simulation, fabrication and control process of a three-finger gripper actuated by the SMA wire was presented. The designed gripper takes the advantage of the small linear displacement of the slider to convert it into the angular motions of the jaws of gripper. Using this set of movements, work pieces with a diameter in the range of 10-45 mm can be gripped. To evaluate the performance of the simulated gripper, some experiments were performed. The simulation results show that the gripper achieving appropriate angles for gripping an object with the defined range of diameters. Moreover, the parameters and performance of fabricated prototype is consistent with the simulated gripper.

Without any feedback control, the errors were relatively small. But, for more accurate results, high-precision force and displacement sensors can be used, and force and displacement feedback control can be implemented. Thus, self-tuning fuzzy PID force controller presented for three finger gripper that actuated by SMA wire. At first, the controller designed in MATLAB, and tested on the model of the gripper in MSC.ADAMS. Then, the controller developed on the physical prototype of the designed gripper. The output of the system showed that the controller has good performance in reducing the maximum overshoot, and also was able to produce reliable outputs with small errors.

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Nomenclature

A	: initial cross section of wire
A_l	: lateral area of the wire
A_s	: initial temperature of austenite phase transition
a_A, b_A	: effect of stress on the reverse transformation temperatures
c_p	: specific heat
D	: Young's modulus
$e(t)$	: error signal
$de(t)$	: derivation of error
h_0 , h_2	: heat convection coefficients
K_p , K_i , and K_d	: PID parameters
l_w	: initial length of wire
m_w	: wire mass
T	: wire temperature
T_∞	: ambient temperature (equal to 25 ºC)
V	: induced voltage to the wire
$\dot{x}$	: linear velocity

Greek Symbols

$\dot{\varepsilon}$	: strain of wire
$\dot{\sigma}$	: wire stress
Θ_T	: thermal expansion factor
ξ	: wire phase transition coefficient
Ω	: phase transformation contribution factor of wire

چکیده

در این مقاله طراحی، شبیه‌سازی، ساخت و کنترل یک گریپر (گیرنده‌ی رباتیک) که با استفاده از سیم‌های آلیاژ حافظه دار حرکت می‌کند ارائه شده است.
ویژگی مهم گریپر ارائه شده اینست که می‌تواند یک جابه‌جایی خطی کوچک در لغزنده‌ی متصل به سیم را به حرکت زاویه‌ای نسبتا زیاد انگشتان گریپر تبدیل کند. در ابتدا، مراحل طراحی و شبیه‌سازی گریپر به ترتیب توسط دو نرم‌افزارکتیا و ادمز انجام شد.
سپس، یک نمونه از گریپر (با عملگرهایی از جنس سیم آلیاژ حافظه دار) ساخته شد و مشخصات فیزیکی، مکانیکی و الکتریکی آن ارائه شد. درنهایت، چند آزمایش طراحی و بر روی گریپر پیاده‌سازی شد و نتایج مربوط به تغییر مکان نوک انگشتان گریپر ارائه و بررسی شدند.
نتایج نشان می‌دهند که گریپر ساخته شده عملکرد بسیار مناسبی داشته است و انگشتان آن با دقتی بسیار بالا و بدون هیچگونه عملیات کنترل بازخوردی به موقعیت اولیه خود بازگشته‌اند. برای جبران پدیده‌ی پسماند (هیسترزیس) موجود در سیم‌های حافظه‌دار، از کنترلر فازی PID با تنظیم‌گر خودکار پارامترهای K_p، K_i و K_d برای کنترل نیروها استفاده شد.
ابتدا سیستم کنترلی پیشنهادی با استفاده از نرم‌افزار متلب بر روی مدل گریپر در نرم‌افزار ادمز اعمال شد. سپس، کنترل‌کننده ارائه شده بر روی نمونه ساخته شده گریپر نیز پیاده‌سازی شد و کارایی آن مورد بررسی قرار گرفت.
نتایج آزمایش نشان‌دهنده عملکرد مناسب کنترل‌کننده برای کنترل نیروی مورد نیاز گریپر می‌باشد.