DEVELOPMENT OF AUTOMOTIVE LOUVER ACTUATOR USING SHAPE MEMORY ALLOY (SMA) MATERIAL

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of
Bachelor of Mechanical Engineering (Automotive)"

Signature : …………………………
Supervisor I : …………………………
Date : …………………………

Signature : …………………………
Supervisor II : …………………………
Date : …………………………

DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

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Author:	……………….
Date:	……………….

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ABSTRACT

Shape Memory Alloy (SMA) is a special alloy that can change its shape due to temperature that imposed to the alloy. This phenomenon can be applied by using current voltage as exchange for the temperature. The unique behavior of SMA makes it suitable as an actuator. Its small size allows it to compete with other actuators such as pneumatic actuator, hydraulic actuator, and motor actuator. SMA actuators nowadays are widely used especially in robotic field, medical field, also have been applied in aircraft industry. SMA also applicable in automotive industry, it can be used in many parts in the vehicle that are need to using actuator or can replace the existing actuator with the SMA actuator. For the automotive louver, the application of it is by using finger and some more advances are made by using motor actuator to adjusting the louver. In this project, an invention is applied by changing the mechanism by using a button to adjusting the position of the aircond louver, and the result is satisfied. According to SMA's size, it can suit with the louver to create the SMA louver actuator. This great combination may be a new invention, but researches have been made before and the suitability is infallibility. Many design of SMA louver actuator have been made, and the best design is defined based on the value of advantages among all designs.

ABSTRAK

Shape Memory Alloy (SMA) adalah gabungan aloi khusus yang dapat mengubah bentuk akibat suhu yang dikenakan kepada aloi tersebut. Fenomena ini boleh disamaertikan dengan menggunakan voltan daripada arus elektrik sebagai pengganti suhu. Kebolehan unik SMA membuatkannya sesuai sebagai aktuator. Saiznya yang kecil membolehkan ia bersaing dengan aktuator lain seperti aktuator pneumatik, aktuator hidrolik, dan juga aktuator motor. SMA aktuator pada masa kini banyak digunakan terutama dalam bidang robotik, bidang perubatan, dan juga dilaksanakan dalam bidang pesawat terbang. SMA juga boleh digunakan dalam bidang automotif, seperti digunakan di bahagian dalam kenderaan yang perlu menggunakan aktuator atau menukar aktuator sedia ada dengan aktuator SMA. Untuk Louver automotif, aplikasinya sehingga kini adalah dengan menggunakan jari dan terdapat kemajuan dilihat dengan menggunakan aktuator motor untuk menyelaraskan Louver tersebut. Dalam projek ini, sebuah penemuan diterapkan dengan menukar mekanisme dengan menggunakan suis butang untuk melaraskan kedudukan louver, dan hasilnya memuaskan hati. Berdasarkan saiz SMA yang kecil, ianya sesuai digunakan untuk mencipta aktuator Louver SMA. Kombinasi kedua-dua bahan ini mungkin satu inovasi baru Akan tetapi beberapa kajian telah dilakukan sebelum ini dan didapati ianya sangat sesuai dan baik sekali. Beberapa konsep aktuator Louver SMA telah dibuat, dan konsep terbaik ditentukan berdasarkan kelebihan berbanding kelemahan di antara kesemua konsep aktuator yang dibuat.

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LIST OF SYMBOLS

Au-Cd	=	Gold-Cadmium
Cu-Zn	=	Cuprum-Zinc
As	=	Austenite start temperature
Af	=	Austenite finish temperature
Ms	=	Martensite start temperature
Mf	=	Martensite finish temperature
h	=	Hysteresis
σ	=	Maximum shear stress allowed
F	=	Required operating force
Acs	=	Cross sectional area
π	=	Constant value
d	=	Diameter
L	=	Length
S	=	Stroke Parameter
$\Delta\ \varepsilon$	=	Difference in strain between the low and high operating temperatures
ε h	=	Young Modulus
Fr	=	Bias Force
ρ	=	Resistivity
V	=	Voltage
R	=	Resistivity
W	=	Power
I	=	Current
° C	=	Celcius

LIST OF SYMBOLS

m	=	Mass
g	=	Gravitational Force
Sn	=	Stroke needed
%ε	=	Percentage recovery strain
R	=	Resistance
V	=	Voltage

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

As the technology become advance now days, automotive technology also not lagged. Every system which at the transmission, chassis, and body structure, electrical circuit, are improved everyday. Louver of car air conditioner has improved its design, and its shape. We can see at different brand of car are have different pattern of their louver. Some has circle shape, square shape and some have rectangular shape. Basically there are 4 four louver in a car which is one at the right and left of the dashboard, and two at the middle of the dashboard. In a conventional vehicle air conditioner, a right center louver on a right-seat side of the vehicle and a left center louver on a left-seat side of the vehicle are disposed in right and left center face air outlet; respectively, to be swung in a horizontal direction. The right and left center louvers are controlled to swing in the same direction in the horizontal direction. Further the right center louver is controlled to swing in a wide swing range from a right front seat to a left front seat, and the left center louver is controlled to swing in a wide swing range from the left front seat to the right front seat. Thus, the temperature of air blown into a passenger compartment is made uniform. (Y.Ichisi, et. al., 2002)

They are three common actuator that are use widely in automotive field, which are pneumatic actuator, hydraulic actuator and motor actuator. New technology currently used widely in robotic field which is Shape Memory Alloy (SMA) actuator. This unique actuator is newly discovered and not very popular in automotive field.

1.1 Problem Statement

This research is about to create a new invention on the existing car air conditioning lover. To design the futuristic louver actuator as the technology become advance day by day, and also to make a simple and reliable of the louver actuator for automotive by using a switch button to adjust the louver compared by using finger in the conventional system of the louver.

Although automotive field has become advanced recently, the design of the louver is only change in term of it shape, and the mechanism is still using finger to adjust the vent in order to adjust the flow of aircond in our desire way. This research is to make an innovation using Shape Memory Alloy (SMA) actuator. We can adjust the vent position only by using the button that linked to the SMA actuator.

1.2 Scope

They are three scopes based on this research, firstly is to study the mechanical behavior of shape memory alloy (SMA) for actuator application. Secondly, is to design and develop a prototype of automotive louver actuator using SMA material. Lastly is to study the performance of the prototype.

We study the mechanical behavior of the SMA about how it react with temperature and relation it between electric current. The design and development of the prototype of louver SMA actuator is done after research about the suitable SMA actuator

at the market and its delivery. The prototype then been tested and recorded the performance in further project in the next semester.

1.3 Objective

In this research, the core intention of this research is to design and develop automotive louver actuator using shape memory alloy material. The main focus is on the designation of the mechanism of SMA actuator and combines it with existing car aircond louver. Certain criteria such as space requirement and type of actuator are set to be important things before installation.

CHAPTER 2

LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 History of the Shape Memory Alloy

Shape Memory Alloy (SMA) is materials which have the ability to remember its shape even after large deformations. When the SMA is heated above its characteristic transition temperature, it will return to its original shape. Below transformation temperature SMA has very low yield strength and can be deformed easily into any new shape, which it can retain. This special phenomenon makes the SMA often called as a smart material. Shape memory effect firstly discovered in the 1930s, by A. Olander when he discovered the pseudoelastic behavior of the Au-Cd alloy in 1932. Then, Greninger and Mooradian in 1938 observed the formation and disappearance of a martensitic phase by increasing and decreasing the temperature of a Cu-Zn alloy. A decade later, the basic phenomenon of the shape memory effect governed by thermoelastic behavior of the martensite phase was widely reported by Kurdjumov and Khandros in 1949 and also by Chang and Read (1951). In the early 1960s, Buehler and his co-workers at the U.S. Naval Ordnance Laboratory discovered the shape memory effect in an equiatomic alloy of nickel and titanium, which can be considered a break trough in the field of shape memory materials. This alloy then was named as Nitinol (Nickel-Titanium Naval Ordnance Laboratory).

Since that time, intensive investigations have been made to reveal the mechanics of its basic behaviour. The use of Nitinol as is fascinating because of its special functional behaviour, which is completely new compared to the conventional metal alloys. (A. Falvo, 2005)

2.2 Martensite - Austenite phase transformation

NiTi shape memory alloys can exist in a two different temperature-dependent crystal structures that are called martensite (which is lower temperature) and austenite (which is higher temperature or parent phase). The process is crystallographic reversible and these two phases have the same chemical composition but different crystallographic structures, and thus, different thermal, mechanical and electrical properties. (S.M. Mahfuzur Rahman, K. Kwang Ahn, 2008)

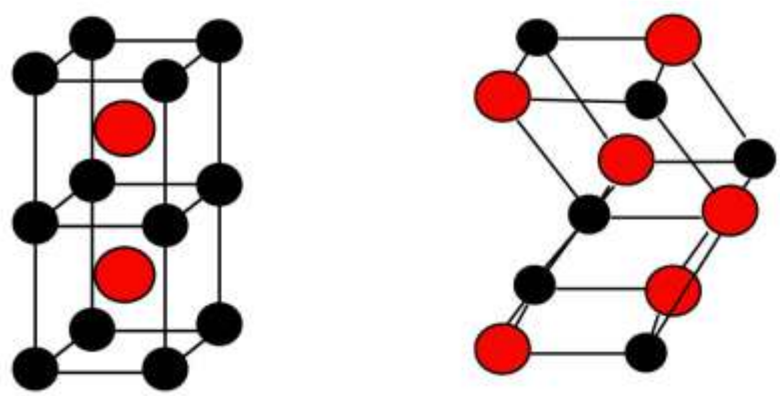

Figure 2.2(1) (a) Austenite and (b) Martensite lattice structures

(Source: A. Falvo, (2005))

Figure 2.2(1) (a) and (b) shows the molecule structure of the austenite and martensite. The martensite will transforms into austenite through either increasing in the temperature or by removing the applied stress. This shows that mechanical loading and thermal loading have opposite effects on NiTi alloys. When austenite is cooled, it begins to change into martensite. The temperature at which this phenomenon starts is called martensite start temperature (Ms), while the temperature at which martensite is again completely reverted is called martensite finish temperature (Mf). When martensite is heated, it begins to change into austenite. The temperature at which this phenomenon starts is called austenite start temperature (As), while the temperature at which this phenomenon is complete is called austenite finish temperature (Af). (J. R. Santiago, 2002). Figure 2.2(2) below shows the graph of the relationship between changes in length of the SMA with the temperature.

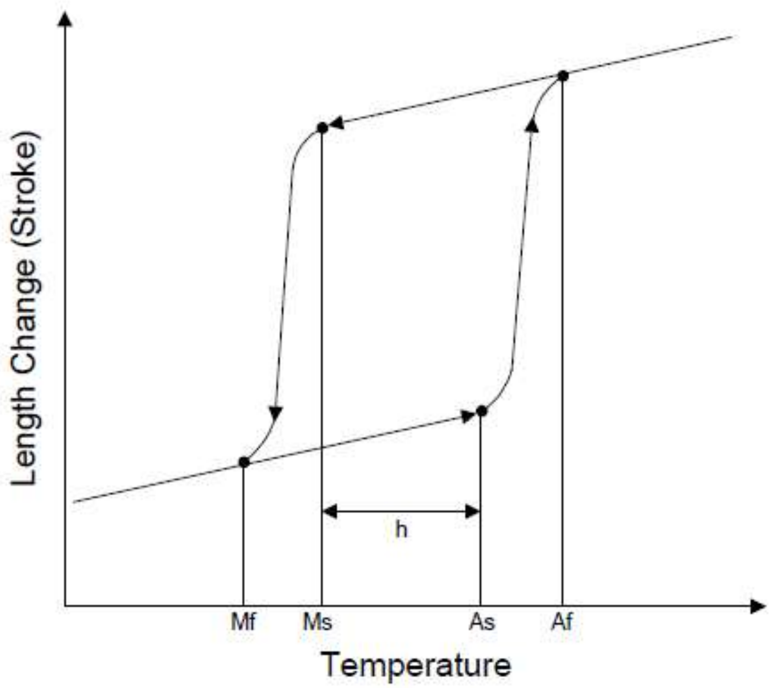

Figure 2.2(2) SMA Length vs. Temperature Schematic.

(Source: J.R. Santiago, (2002))

Another important factor to notice is that shape memory alloy will have a temperature hysteresis between its martensite and austenite states. Due to this hysteresis, the transformation from martensite to austenite will not coincide with that from austenite to martensite. The difference between the temperature where the austenite transform to martensite and the temperature where the martensite transform back to austenite is known as hysteresis. (K. Battacharya, 2003).

2.3 Mechanical properties of Nitinol

A relatively large number of researchers have been interested in exploring the mechanical characteristics of NiTi in its two phases. Researchers are interested in studying and specifying the properties of NiTi materials under various types of thermo mechanical loadings. Several experimental studies have been conducted to specify the mechanical properties of SMA. The outcomes of experimental research in the past two decades assisted in developing a range for the mechanical parameters that would be expected from NiTi in its austenite and martensite phases. Table 2.3 presents a summary of the mechanical properties for NiTi. As explained in the following, mechanical properties could be due to several factors such as alloys composition, manufacturing process, strain rate and cyclic loading.

Table 2.3: Summary of NiTinol mechanical properties

	Austenite	**Martensite**
Young's modulus	*30-83 GPa*	*20-45 GPa*
Ultimate Tensile Strength	*800-1900 MPa*	*800-1900 MPa*
Elongation at Failure	*20-25%*	*20-25%*
Recoverable strain	*8-10 %*	*8-10 %*
Poisson Ratio	*0.33*	*0.33*

(Source: A. Falvo, (2005))

2.4 Shape memory alloy material

There a numerous alloys that exhibit shape memory but overall there are two which are commercially available due in part for their proven ability to excel in some design aspects like maximum strain achievable, biocompatibility, lifespan and others. Table 2.4 shows the different kinds of alloys and their commercial availability.

Table 2.4: Shape Memory Alloy materials.

Alloy	Commercially Available
Au-Zd	No
Cu-Zn	No
Ln-Ti	No
Ni-Ti	Yes
Cu-Zn-Al	Yes
Ti-Nb	No
Au-Cu-Zn	No
Cu-Zn-Sn	No
Cu-Zn-Si	No
Cu-Al-Ni	Yes
Ag-Cd	No
Cu-Sn	No
Cu-Zn-Ga	No
Ni-Al	No
Fe-Pt	No
U-Nb	No
Tl-Pd-Ni	No
Fe-Mn-Si	No

(Source: J.R. Santiago, (2002))

2.4.1 Ni-Ti (Nitinol)

Nitinol takes its name from Nickel-Titanium for its composition and NOL from Naval Ordinance Laboratory, which is the place where they first discovered its shape memory aspects. (D. Stoeckel, 1992). Today Ni-Ti is the most common commercially available shape memory alloy and for good reason. The maximum strain that can be obtained from this kind of alloy reaches 8%. This is a high number under SMA standards since most of the alloys only achieve between 2 to 4% strain. Its biocompatibility makes them suitable for medical applications. The only drawback lies on its cost, which is substantially higher than its peers.

2.4.2 Ni-Ti-Cu

Ni-Ti shape memory alloys, the most common standard is available, but some of its features might not be involved in the design of specific learning. Therefore, extensive research has been done to improve some of its mechanical properties. Like, adding an item like ternary element to Ni-Ti as the method. Cu is added to Ni-Ti will lower the martensite phase of its yield strength and reduces the temperature lower hysteresis when compared to Ni-Ti. Low yield strength of martensite phase, so that requires a higher net output power, giving a tendency to deform the SMA element is to reduce the amount of force. Lower temperature hysteresis actuation offers fast cycle times or the rate of actuator can also be made more suitable for thermal actuation.

2.5 Shape memory alloy calculation (Drawn wire shape)

Wire is the most common form of shape memory alloy. When compared to other forms it provides the maximum amount of force per cross sectional area, matched only by strip or ribbon form. Waram assumes a linear stress strain behavior of the alloy in the operational temperature range (Mf – Af). (T.C. Waram, 1993). Another assumption is that the given design parameters are only force and stroke. The actuator force and diameter are related by the stress:

$$\sigma = \frac{F}{A_{cs}} \qquad (1.1)$$

Where σ represents the maximum shear stress allowed and F is the required operating force. The maximum stress value is related to the lifespan of the memory element or the number of cycles the actuator can perform. This parameter if chosen conservatively and can provide to hundreds of thousands of cycles. The designer can obtain an approximate value for the maximum high temperature shear stress from the manufacturer according to the desired life of the actuator. For a wire, the cross sectional area becomes:

$$A_{cs} = \frac{\pi \cdot d^2}{4} \qquad (1.2)$$

Substituting 2 into 1 and solving for the wire diameter (d) we have: