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DEVELOPMENT OF CAR WIPER LIFTER USING SHAPE MEMORY ALLOY (SMA) MATERIAL

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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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ABSTRACT

People normally put up their windshield wiper when their car is parked under the sun. As the windshield wiper is moved back and forth across the windshield surface, the dust particles are tending to scratch the windshield surface. In addition, the windshield is susceptible to the heat build-up which is brought about by the sunlight, especially in the hot summer. The windshield wiper blade is therefore vulnerable to deformation which is caused by the hot of the windshield. Lifting the wiper manually is not practical nowadays as people use technology to ease thier everyday life. There a lot of actuator that can be used in the automotive industry. In modern day technology people would use simple and less components devices to reduce cost and maintenance. By using shape memory alloys (SMA) as an actuator, windshield wiper can be lifted automatically. This new generation of actuator can be used as a simple mechanism that can reduce the space and noise. The design of the wiper lifter is developed and the performance are tested using 12V and 6V battery. Results show that the higher the voltage, the faster the actuation time. 12V batteries have the best actuation time.

ABSTRAK

Kebiasaannya orang akan mengangkat wiper ketika kereta mereka diletakkan di bawah cahaya matahari. Sebagai wiper yang sentiasa digerakkan berulang-alik melintasi permukaan kaca hadapan kereta, terdapat zarah-zarah debu yang cenderung untuk menggores permukaan kaca. Selain itu, kaca hadapan kereta terdedah kepada panas yang terhasil dibawah sinaran matahari, terutama di musim panas. Oleh kerana itu, bilah wiper terdedah kepada deformasi yang disebabkan oleh panas dari kaca hadapan kereta. Mengangkat wiper secara manual adalah tidak praktikal dimana pada masa ini orang menggunakan teknologi untuk memudahkan kehidupan sehari-hari mereka. Banyak jenis actuator yang boleh digunakan dalam industri automotif. Pada zaman moden ini, manusia akan menggunakan teknologi yang mudah dan kurang alat peranti untuk menjimatkan kos dan penyelenggaraan. Dengan menggunakan *Shape Memory Alloy* (SMA) sebagai aktuator, wiper boleh di angkat secara automatik. Generasi baru aktuator ini boleh digunakan sebagai mekanisme ringkas yang dapat mengurangkan ruang dan bunyi. Rekabentuk pengangkat wiper dibangunkan dan prestasi diuji menggunakan bateri 12V dan 6V. Keputusan kajian menunjukkan bahawa semakin tinggi voltan, semakin cepat waktu aktuasi. Bateri 12V mempunya waktu aktuasi paling terbaik.

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FIGURE	TITLE	PAGE

LIST OF SYMBOL

A_s	=	Austenite start temperature
A_f	=	Austenite finish temperature
M_s	=	Martensite start temperature
M_f	=	Martensite finish temperature
NiTi	=	Nickel Titanium
CuZnAl	=	Copper Zinc Aluminium
CuAlNi	=	Copper Aluminium Nickel
FeMn	=	Ferum Manganase
MnCu	=	Manganes Copper
SMA	=	Shape Memory Alloy
R	=	Resistance
V	=	Voltage
I	=	Current
P	=	Power
Ω	=	Ohm
m	=	Meter
W	=	Watt

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

Nowadays, actuator is an important component in automotive industry. It is used in car door lock, brake, wiper and many more. Actuator is a mechanical device that modifies the mechanical states to control mechanism in a system which is coupled (Jose L. Pons, 2005). There are many types of actuators such as hydraulic, pneumatic, DC motor, shape memory alloy, ultrasonic motor and piezoeffect actuator. From such types of actuator, there are many advantages and disadvantages from different type of actuators. A good actuator design needs to have simple system, components and yet cost effective.

1.2 PROBLEM STATEMENT

The windshield wiper arm is provided with a wiper blade of rubber and it is likely to scrape water from a windshield. The wiper blade of the windshield wiper arm is always in contact with the windshield time after time. As the windshield wiper is moved back and forth across the windshield surface, the dust particles are tending to scratch the windshield surface. In addition, the windshield is susceptible to the heat build-up which is brought about by the sunlight, especially in the hot summer.

The windshield wiper or blade is therefore vulnerable to deformation which is caused by the hot of the windshield.

1.3 OBJECTIVE

The primary objective of the present invention is to provide a windshield wiper with an automatic device capable of moving extendly the windshield wiper away from the windshield of motor vehicle at the time when the car is not in operation. As the car is in operation again, the windshield wiper is retracted in place.

The features and the advantages of the present invention will be readily understood upon a thoughtful deliberation of the following detailed description of the invention with reference to the accompanying drawings.

1.4 SCOPE

- To study mechanical behavior of shape memory alloy (SMA) for actuator application.
- To design and develop a prototype of car wiper lifter actuator using SMA material.
- To study the performance of the prototype.

CHAPTER II

LITERATURE REVIEW

2.1 INTRODUCTION

Shape memory alloys (SMA) are a type of metallic alloy that had several unique characteristics including shape memory effect, superelastic properties, modulus of elasticity/temperature relationships, high damping characteristics, and large recoverable strains. This research is intended to take advantage of the unique characteristics of shape memory alloys in order to provide a moment resisting connection with recentering capabilities. The following chapter gives an introduction to the material properties of shape memory alloys focusing on Nitinol, the material that will be used in this study. There are many types of shape memory alloys (SMAs) such as NiTi, CuZnAl, CuAlNi, FeMn, MnCu, and NiTiNb. It was concluded that NiTi, or Nitinol, exhibited the most optimal properties because it has superelasticity, large recoverable strains and excellent corrosion resistance.

2.2 HISTORY OF SHAPE MEMORY ALLOY

In 1932 Olander made the first observations of shape memory alloy in his study of “rubber like effect” in the gold-cadmium system and by Greniger and Mooradian in 1938 in their study of brass alloys. After many years later, Chang and Read reported the term “shape recovery” while working on gold-cadmium alloy. In

1962, William J. Buehler discovered shape memory effect in an alloy of nickel and titanium. The discovery of the effect in the nickel titanium alloys made a kick start interest in shape memory applications.

The methods of harnessing thermal memory effects are divided into three categories by Duerig. First category is free recovery that is an alloy is apparently permanently strained and on the application of heat recovers its original shape and maintain during subsequent cooling. The motion or strain was caused by the function of the alloy. Second category is constrained recovery that an alloy is prevented from full shape recovery thus generate stress on the constraining element. Last category of the thermal memory effect is the actuation recovery. The alloy is able to recover its shape but operates against applied stress, resulting in work production. Superelastic recovery applications are also considers by Duerig. The only isothermal application of the memory effect, pseudoelasticty or superelastic recovery involves the storage of potential energy through large but recovery strains.

The first efforts to exploit the potential of NiTi as an implant material were made by Johnson and Alicandri in 1968. The use of NiTi for medical applications was first reported in the 1970s. In the early 1980s the idea attained more support, and some orthodontic and mainly experimental orthopedic applications were released. It was only in the mid-1990s, however, that the first widespread commercial stent applications made their breakthrough in medicine. The use of NiTi as a biomaterial is fascinating because of its superelasticity and shape memory effect, which are completely new properties compared to the conventional metal alloys. (K. Worden, W. A. Bullough 2003)

2.3 DEFINITION OF SHAPE MEMORY ALLOY

Shape Memory Alloys (SMAs) refer to a group of materials which have the ability to return to a predetermined shape when heated. The shape memory effect is caused by a temperature dependent crystal structure. When an SMA is below its phase transformation temperature, it possesses a low yield strength crystallography referred to as Martensite. While in this state, the material can be deformed into other shapes with relatively little force. The new shape is retained provided the material is kept below its transformation temperature. When heated above this temperature, the material reverts to its parent structure known as Austenite causing it to return to its original shape. This phenomenon can be harnessed to provide a unique and powerful actuator.

Shape Memory Alloys (SMAs) are a unique class of metal alloys that can recover apparent permanent strains when they are heated above a certain temperature. The SMAs have two stable phases the high-temperature phase, called austenite and the low-temperature phase, called martensite. In addition, the martensite can be in one of two forms: twinned and detwinned. A phase transformation which occurs between these two phases upon heating or cooling is the basis for the unique properties of the SMAs. The key effects of SMAs associated with the phase transformation are pseudoelasticity and shape memory effect.

2.4 A MICROSCOPIC PERSPECTIVE OF MARTENSITE

Shape Memory Alloys can exist in a two different temperature dependent crystal structures called martensite phase (lower temperature) and austenite phase or parent phase (higher temperature). Typically mechanical properties of austenitic Ni–Ti are different to the same properties in martensitic NiTi as shown in Table 2.1. For this reason, SMA in austenite and in martensite can be consider as two different materials. Besides, in Table 2.2 shows a summary of comparison of Ni–Ti with properties of stainless steel, for better understanding the greatest employment in various fields of SMAs.

Table 2.1: NiTi Mechanical Properties

(Source: A. Falvo, (2005))

	Austenite	Martensite
Youngs 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

Table 2.2: Comparison of Nitinol With That of Stainless Steel

(Source: A. Falvo, (2005))

Property	NiTi	Stainless Steel
Recovered Elongation	8 %	0.8 %
Biocompatibility	Excellent	Fair
Torqueability	Excellent	Poor
Density	6.45 g/cm^3	8.03 g/cm^3
Magnetic	No	Yes
Resistively	80 to 100 micro-ohm*cm	72 micro-ohm*cm

However, the martensite crystal is produced from parent crystal without diffusion. Diffusionless transformations are those in which the new phase can only be formed by moving atoms random over relatively short distances (where short distance means moving atoms are less than the interatomic distance).

The austenite is characterized by a Body Centered Cubic structure (BCC), where there is a Nickel atom at the center of the crystallographic cube and a Titanium atom at each of the cubes eight corners, the austenitic phase is microstructurally symmetric. The ordered BCC structures are usually B2 type. This is the phase which plays an important role in the martensitic transformation and the associated shape memory effects. Tipically, under solution-treated conditions, a near-equiatomic NiTi alloys exhibit a trasformation between a high temperature B2 phase, known also as the parent phase, and a low temperature B19’monoclinic phase, known as the martensite. The martensite phase of Ni–Ti is less symmetric and its lattice structure consists of a rhombus alignment with an atom at each of the rhombus corners. Fig. 2.1 shows two Ni–Ti crystals in the austenite (B2 phase) are microstructurally ordined and martensite phases (B19') that is less symetric.

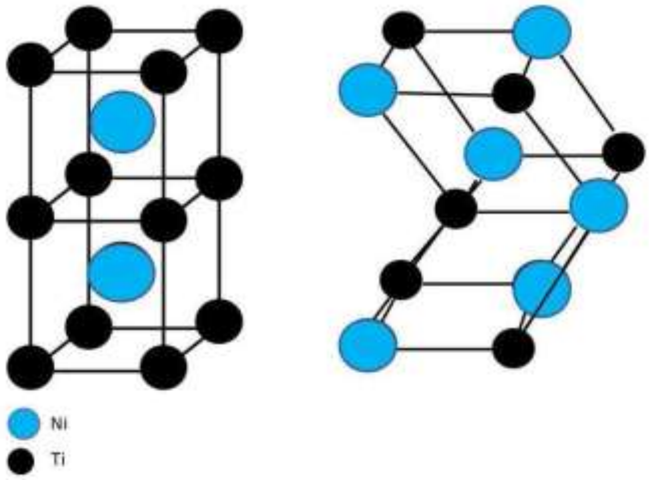

Figure 2.1: Crystallography

(Source: http://www.sma-inc.com/NiTiProperties.html)

However, under certain circumstance, such as cold working, thermal cycling, heat-treatment or chemical composition,an intermediate phase, known as rhombohedral phase or the R-phase, may appear between the austenite and the martensite, causing a two-stage transformation behavior as shown in Figure 2.2.

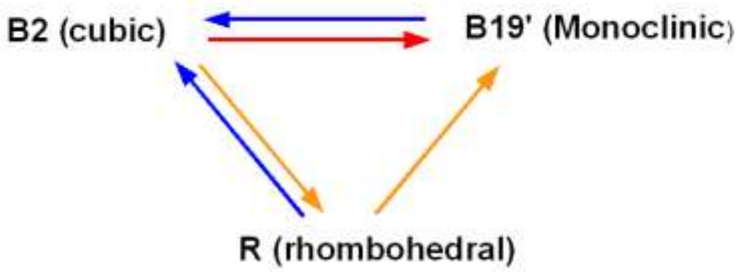

Figure 2.2: Two transformation paths in NiTi alloys

(Source: http://www.sma-inc.com/NiTiProperties.html)

Khalil-Allafi and co-workers investigated the effect of aging as a function of time and temperature, and they suggested that microstructural and chemical heterogeneity also play an important role in the phase transition sequence observed in multi-step transitions. Another way to stabilize the R-phase in binary NiTi alloys is to introduce dislocations, usually by cold working. Only in ternary alloys such as NiTiFe, NiTiAl, or NiTiCo is the R-phase known to occur spontaneously. Thus, the structure determination of the R-phase in binary Ni–Ti is always a challenge because of the presence of other phases, defects, and texture are introduced (Yang H., Voigt A., Liu Y., 2003).

2.5 TEMPERATURE TRANSFORMATION IN SHAPE MEMORY ALLOYS

For almost any use of a Shape Memory Alloy, it is highly desirable knows the Transformation Temperatures of the alloy. The Transformation Temperatures are those temperatures at which the alloy changes from the higher temperature Austenite to the lower temperature Martensite and viceversa. SMAs do not undergo their phase transformation from martensite to austenite or from austenite to martensite at one specific temperature. The transformations begin at one temperature and stop at another. These start and finish temperatures are different depending on the material is heating or cooling.

In order of lowest to highest temperature, are defined:

- Matensite finish (M_f): temperature at which the material is completely twinned martensite which does not entail a change in shape if unloaded
- Martensite start (M_s): temperature at which, when austenite is cooled, it begins to change into martensite
- Austenite start (A_s): temperature at which martensite begins to change in austenite
- Austenite finish (A_f): the temperature at which the change in austenite is complete.

Assume that a strip of SMA begins at an initial temperature where it is completely martensite. Increasing the temperature to A_s will cause the material to start transforming in austenite. Once the temperature reaches A_f, the material is completely in austenite.

Assume that a strip of SMA begins at an initial temperature where it is completely in austenite. Decreasing the temperature to M_s causes the material to start transforming to martensite. Once the temperature is cooled to M_f , the material is completely twinned martensite. Figure 2.3 shows the transformation temperatures and their relation to martensite and austenite in the material.

The percentage of nickel and titanium composition plays an important rule in the transformation temperatures, the transformation temperatures are sensitive to small alloy composition changes, a 1% shift in the amount of either nickel or titanium in the alloy results in a 100◦C change in Af. For this reason, it is necessary to control and known the alloy composition. In commercial NiTi alloys cover an A_f range from approximately 100◦C in Ni50%Ti, -20◦C in a NiTi48.8%. Typical tolerances for A_f are ±3◦C to ±5◦C, while, As is tipically approximately 15◦C to 20◦C lower than A_f, instead, M_f is about 15◦C to 20◦C lower than M_s.

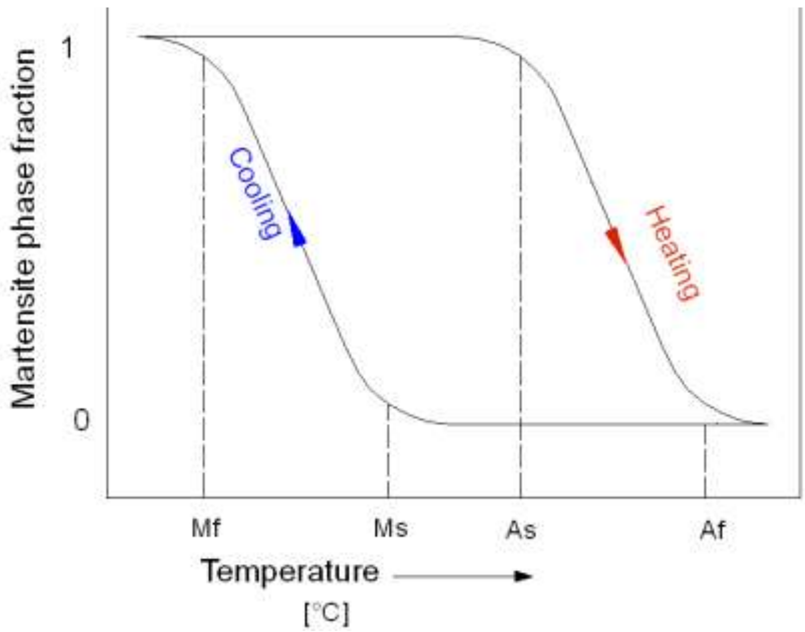

Figure 2.3: Phase Transformation Temperatures of SMA material

(Source: http://en.wikipedia.org/wiki/Shape_memory_alloy)

2.6 MECHANICAL AND FUNCTIONAL PROPERTIES OF NiTi ALLOYS

The mechanical characteristics of NiTi in its two phases are interested by a large number of researchers. Several experimental studies have been conducted to specify the mechanical properties of SMAs and the experimental research developed a range for the mechanical parameters that would be expected from NiTi in its austenite and martensite. Since the SMA stress–strain relationship depends on temperature, the Youngs modulus also depends on temperature. Youngs modulus is the ratio of the applied stress to the resulting strain. Therefore, the mechanical behavior of a NiTi alloy as a function of temperature. At low temperature, so that in martensitic phase, the mechanical behavior of the material is characterized by large inelastic deformation after unloading that could be recovered by heating the alloy. As the multivariant martensitic phase is deformed, a detwinning process takes place, as well as growth of certain favourably oriented martensitic variants at the expense of other variants. The mechanical loading in the martensitic phase induces reorientation of the variants and results in a large inelastic strain, which is not recovered upon unloading. At the end of the deformation, and after unloading, it is possible that only one martensitic variant remains if the end of the stress plateau is reached; otherwise, if the deformation is halted midway, the material will contain several different correspondence variants. During unloading, the detwinned martensite transforms in austenite due to its instability at temperature up than A_f, so that, a lower stress plateau, related to the reverse transformation, appears in the stress–strain–T curve (Superelastic Effect), generally, without inelastic strain.

2.6.1 Shape Memory Effect

Martensite is generally lower symmetry phase than Austenite. So there are several ways in which Martensite can be formed from Austenite. But there is only one path through the formed Martensite will revert back to Austenite. The unique property of NiTi alloys is Shape Memory Effect it can be explained in a very simple manner by a 2D geometrical concept depicted. Upon cooling from Austenite, the self–accommodating variants of Martensite are formed. During the application of stress, the twin boundaries migrate and therefore result in a biased distribution of Martensite variants. It is however important to note that no matter what the