DEVELOPMENT OF AN AUTOMOTIVE CLUTCH 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)"

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Signature : ………………………
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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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ABSTRACT

Shape Memory Alloy (SMA) is a material that change shape by applying heat. SMA exhibits shape memory effect. In recovering their shape the alloys can produce a displacement or force as a function of temperature. Key features of products that possess this shape memory property include: high force during shape change; large movement with small temperature change; a high permanent strength; simple application, because no special tolls are required; many possible shapes and configurations; and easy to use-just heat. In one well developed application shape memory alloy provide simple and virtually leak proof coupling for pneumatic or hydraulic lines. In this project, the SMA material will be designed and develop to replace the current automotive clutch actuator. Several designs were proposed in this project as the clutch actuator. Problem encounter is to produce the exact time of clutch response and to produce clutch stroke as same as conventional actuator by using SMA wires. To overcome this problem, several designs prototype were build and tested to get its performance data. The data that being recorded are it strokes, response times and bias times and also the voltage of the wire. The method use is by recorded the time by using stopwatch and recorded the stroke produce by using a ruler. From the result, one design was selected as the SMA clutch actuator but it still needs to be improve in the future.

ABSTRAK

Shape Memory Alloy (SMA) adalah sejenis bahan yang berubah bentuk apabila dikenakan haba. SMA mampu mengingat bentuk asal sebelum ia dikenakan daya. Semasa SMA kembali kepada bentuk asal ketika dikenakan haba, SMA menghasilkan sesaran ataupun daya. Antara kesan lain SMA ialah: daya yang tinggi ketika perubahan bentuk; sesaran yg besar hanya dengan haba yang kecil; daya kekal yang tinggi; aplikasi yang mudah dimana tiada peralatan istimewa diperlukan; banyak bentuk yang boleh dihasilkan dan mudah digunakan, hanya menggunakan haba. Dalam projek ini, SMA direkabentuk dan dibina untuk menggantikan aktuator klac yang terdapat pada kereta iaitu aktuator hidraulik. Beberapa rekaan dihasilkan untuk menggantikan aktuator klac hidraulik. Masalah yang dihadapi adalah untuk menghasilkan masa yang tepat untuk tindak balas klac dan sesaran klac yang mencukupi. Untuk mengatasi masalah ini, beberapa prototaip dihasilkan dan prestasi setiap prototaip itu direkodkan untuk dibandingkan. Data yang direkod adalah sesaran aktuator, masa tindak balas, masa ia kembali ke bentuk asal dan voltan wayar SMA. Masa diambil menggunakan jam randik dan jarak sesaran diambil menggunakan pembaris. Daripada keputusan yang diperolehi, satu rekaan diambil sebagai aktuator untuk menggantikan aktuator klac konvensional tetapi masih memerlukan beberapa penambahbaikan di masa hadapan.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Getting power from the engine to the wheels of an automobile has provided a seemingly endless challenge for rear-wheel-drive, front-wheel-drive, 4-wheel-drive, front-engine, rear-engine, and mid-engine cars, longitudinal, transverse, vertical, slant, and flat engines, plus an amazing array of hardware in between. George Selden's notorious 1877 patent was for a front-drive carriage with a transverse 3-cylinder engine, anticipating the Chevy/Suzuki Sprint by over a century. When it comes to car designs, there are very few new ideas, just progressively successful adaptations of old concepts.

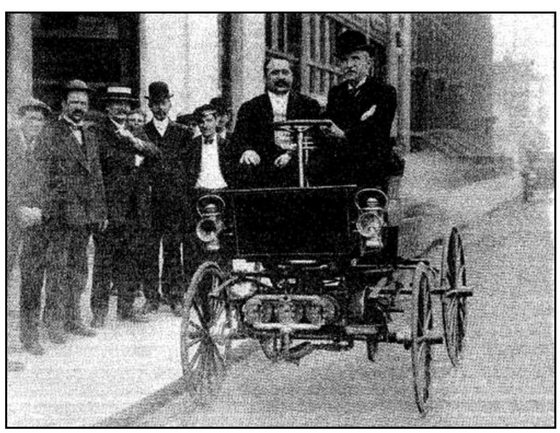

Figure 1.1: George B. Selden, In Car Powered By His Original Engine Built In 1877 (Source:www.corbisimages.com/Enlargement/PG10039C.html)

The heart of the drive train is the transmission. Because gasoline engines develop their torque over a very narrow speed range, several gears are needed to reach useful road speeds.

The modern transmission was introduced by a pair of Frenchmen, Louis-Rene Panhard and Emile Levassor in 1894. The engineers had invited the press to a demonstration of "the most revolutionary advancement to date in the brief history of the motor car industry." Unfortunately, the engine in their demo vehicle died, and they were reduced to giving a chalk talk on multi-geared transmission theory to a bored press corps.

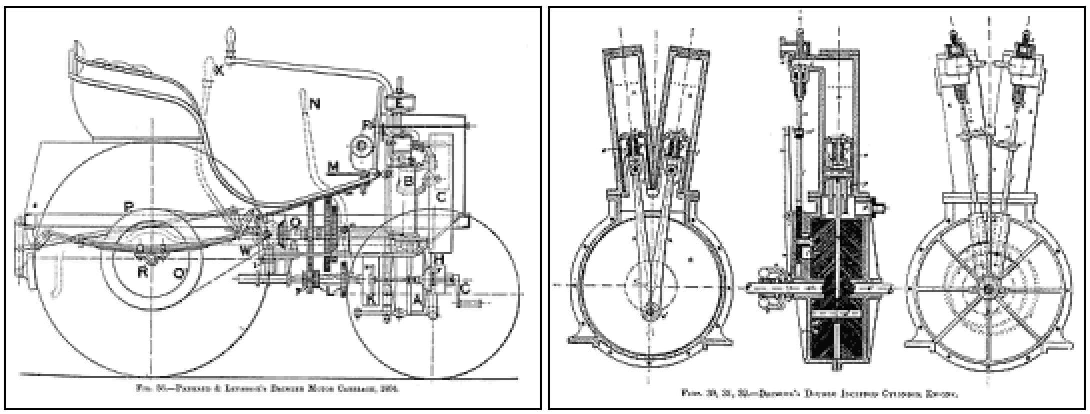

Figure 1.2: Panhard & Levassor first design
(Source: www.jalopyjournal.com)

Cars of the time transmitted engine power to the wheels in a simple fashion that was easy for non-engineers to visualize. The engine drove a set of bevel reduction gears that drove a shaft and pulley. Leather belts extended between the pulley and geared wheels on an axle. One wheel, the small one, got the car going by meshing with a ring gear on one of the driving wheels. The big wheel then took over to get the car to hustle along at a top speed of 20 mph. If the car encountered a hill that it did not have the power to climb, the driver would come to a dead stop so he could engage the small wheel.

Thus, British auto pioneer F. W. Lanchester describes the transmissions in his cars: "One belt-driven HIGH gear that will go over everything and one belt-driven LOW gear in case the car had to climb a tree."

It was not until a year after their disastrous news conference that Panhard and Levassor regained their reputations. At this time, they had their first car ready for the press to drive. With it, they changed a lot of minds.

Figure 1.3: Celebrities rolled into Panhard et Levassor
Louis Pasteur left (car 1899) and Claude Monet right (car 1901)
(Source: www.svvs.org/help01.shtml)

That 1895 Panhard-Levassor was revolutionary not the transmission alone, but the whole drivetrain layout. In fact, it has served as the prototype for most vehicles built in the 90 years since then. Unlike other cars of that day, it possessed a vertically mounted engine in the front of the vehicle that drove the rear wheels through a clutch, 3-speed sliding gear transmission and chain-driven axle. The only modern features missing from the setup were a differential rear axle and driveshaft. These came along three years later, in 1898, when millionaire-turned-auto-hobbyist Louis Renault connected a vertical engine with transmission to a "live" rear axle by means of a metal shaft.

The live rear axle which Renault adapted from an idea developed in 1893 by an American, C. E. Duryea was called the differential rear axle. It used a number of gears to overcome the problem of rapid tire wear, which resulted on turns with the "dead" axles used by all other carmakers. "Differential" referred to the ability of the unit to turn the outer driving wheel faster than the inner driving wheel, eliminating tire scuffing in turns.

By 1904, the Panhard-Levassor sliding gear manual transmission had been adopted by most carmakers. In one form or another, it has remained in use until recent times. Obviously, there have been improvements, the most significant being the invention of a synchronizing system that permits drive and driven gears to be brought into mesh with each other smoothly without gear clashing. This system allows both sets of gears to reach the same speed before they are engaged. The first of these synchromesh transmissions was introduced by Cadillac in 1928. An improvement to the design patented by Porsche is widely used today.

Between the time the sliding gear-transmission was introduced and the perfection of the synchromesh, there were other attempts at making it easier for the driver to shift gears. One was the planetary transmission in the 1908 Model T Ford. It had a central gear, called the "sun" gear, surrounded by three "planet" gears. Today, planetary gears are more widely used in automatic transmissions than in manual.

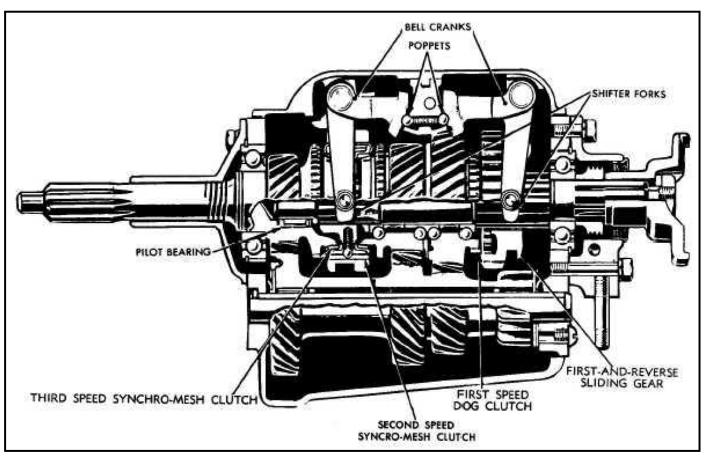

Figure 1.4: Sliding gear transmission
(Source: www.tpub.com/content/engine/14037/css/14037_121.htm)

Some pretty elaborate planetary manual transmissions did evolve, however. One was developed by Walter Wilson and was called the Wilson Preselector. It came along in 1930.

This gear system, which used four individual planetary gear sets, allowed the driver to preselect one gear ratio by moving a small lever on the steering column. the driver could then "order up" the particular preselected gear by depressing a foot pedal. This caused a camshaft to disengage one gear and simultaneously allow the preselected gear set to engage.

All transmission designs since the Panhard-Levassor unit have had one goal in common to make shifting easier. Obviously, the easiest to shift transmission is the automatic. It's strictly an American innovation.

The first automatic was invented in 1904 by the Sturtevant brothers of Boston. It provided two forward speeds that were engaged and disengaged by the action of centrifugal weights without need for a foot-operated clutch. As engine speed increased, the weights swung out to engage bands first the low-gear band and then the high-gear band. The unit failed because the weights often flew apart.

The next significant attempt at an automatic transmission was by Reo in 1934. Called the Reo Self-Shifter, it was actually two transmissions connected in series. For ordinary driving, one unit up shifted itself automatically in relation to car speed through the engagement of a centrifugal multiple-disc clutch much the same idea used by the Sturtevants. The second transmission was shifted manually and was used only when a lower gear was needed.

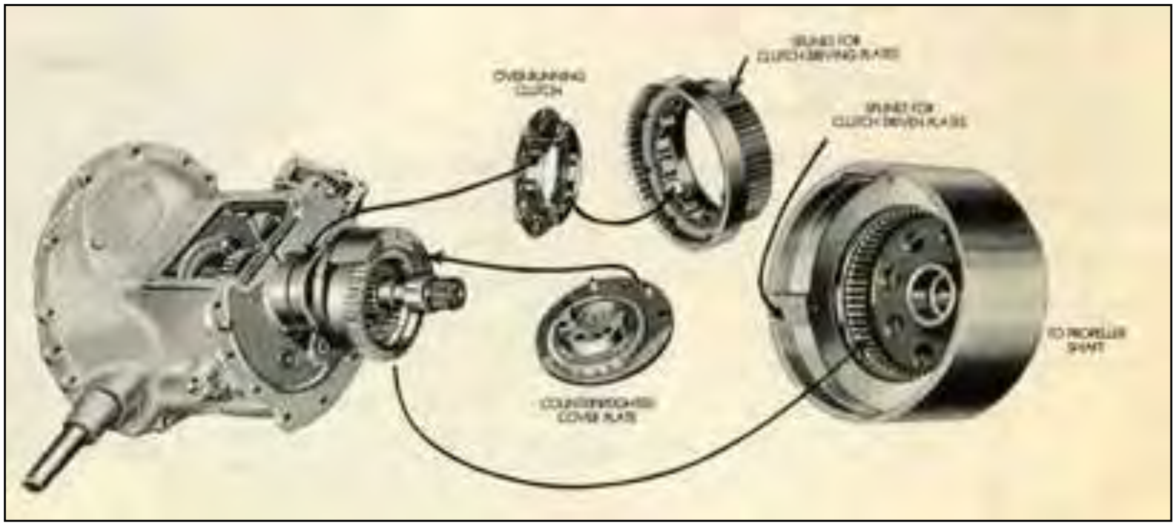

Figure 1.5: Reo Self-Shifter
(Source: www.kitfoster.com/archive/2007_02_01_archive.html)

In 1937, Oldsmobile came out with a four-speed semi-automatic transmission called the "Automatic Safety Transmission" (AST). The driver depressed the clutch pedal and shifted into reverse or into one of two forward ranges: Low or High. Once in Low, the transmission shifted automatically from first to second; when in High, it shifted from third to fourth. Changes within each range were automatic by way of oil pressure and two hydraulically operated planetary gear sets. The shift points were preset according to the vehicle's speed. This AST transmission was installed on about 28,000 1938 Oldsmobile’s. The "safety" aspect referred to the claim that the driver could keep focused on the road rather than be occupied shifting. The significance of the AST is that it was the forerunner of the GM Hydra-Matic transmission which Oldsmobile introduced in 1939 and made available on the 1940 models. In 1938 Buick introduced a five-speed semi-automatic transmission in the Special, but it was so prone to trouble that it was dropped the following year.

The Hydra-Matic consisted of three planetary gear sets that were operated hydraulically. A fluid coupling was used to connect the engine and transmission. Credit for perfecting the fluid coupling goes to Chrysler, which developed the concept in 1937. However, Chrysler did not make use of it until 1941, when the Chrysler Fluid Drive transmission was introduced. This was not an automatic unit, but a standard transmission with a fluid coupling, not a clutch.

By 1948, the automatic transmission had evolved into the hydraulic torque converter that we know today coupled to a planetary gear train. The first to use the converter was Buick. In 1948 Buick offered the Dynaflow fully automatic transmission on the Roadmaster. Within three years, 85 percent of Buicks had the Dynaflow. The Dynaflow was the model for present-day automatic transmissions. Others soon followed with similar units Chevrolet Powerglide, Fordomatic and Merc-O-Matic in 1950; and the Chrysler M-6 Torque Converter Automatic in 1951.

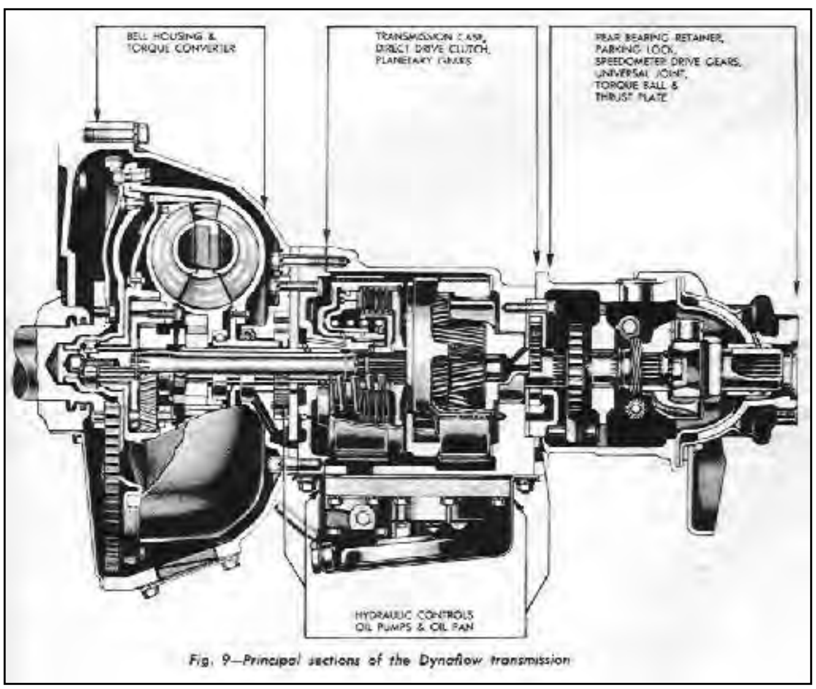

Figure 1.6: Dynaflow
(Source: www.localdreamcars.com/Acars/Transmissions.html)

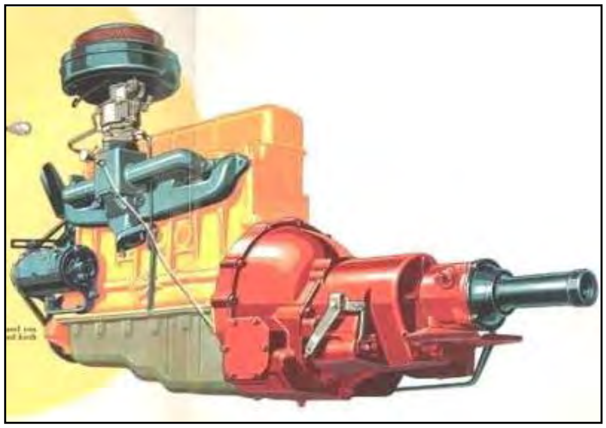

Figure 1.7: Chevrolet Powerglide
(Source: www.51classicchevy.com/1951-six-cylinder-engines.html)

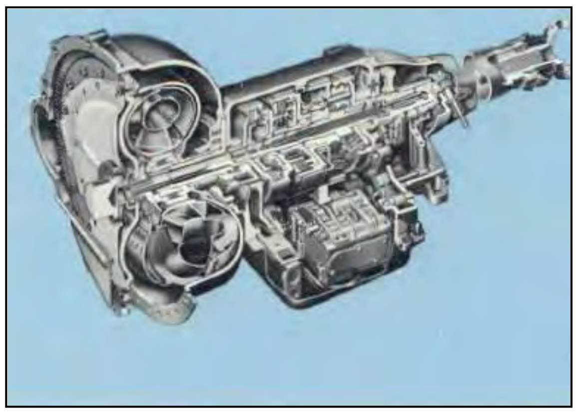

Figure 1.8 : Fordomatic
(Source: www.crankshaftcoalition.com/wiki/Transmission_identification)

These are some other interesting developments in the history of transmissions and drive units.

In the early days of transmissions, leather-lined, multiple-disc, oil-bathed clutches were in common use. Although the first use of a dry single-plate clutch was by Duryea in 1893, it was not until 1921 that a design was developed that would not burn out in a few hundred miles, thanks mainly to Englishman Herbert Frood, who perfected more durable friction materials.

Universal joints were first introduced on the 1902 Peerless. The 1908 Franklin was the first car to use roller-bearing U-joints. The 1930 Hupmobile pioneered needle-bearing U-joints, which is the point where we stand today.

Although differential locks were first used on a steam lorry in 1903 to provide wheel traction on slippery roads, it was not until 1956 that the first production limited-slip differential for a popular car was produced by Studebaker.

In 1906, Otto Zachow and William Besserdich of Clintonville, Wisconsin, built a car with the first successful 4-wheel-drive unit. A year later, they began a company called the Four Wheel Drive Auto Co.

In 1913, Packard made a milestone step in differential development with the introduction of a spiral-bevel ring and pinion set that cut the noise level produced in the rear axle. In 1926, with the introduction by Packard of the hypoid gear rear axle, noise ceased to be a problem altogether, unless the differential was going bad.

In 1934, automatic overdrive was introduced on the Chrysler and DeSoto Airflow.

The latest development in transmission seems to be the continuously variable automatic transmission, or CVT. The CVT is driven by a metal link belt.

1.2 PROBLEM STATEMENT

Many late model vehicles have a hydraulic clutch linkage with a master cylinder attached to the clutch pedal and slave cylinder on the bell housing. The internal piston seals on the master and slave cylinder can develop leaks that allow a loss of pressure when the clutch pedal is depressed. This may prevent the clutch from disengaging or allow it to engage prematurely.

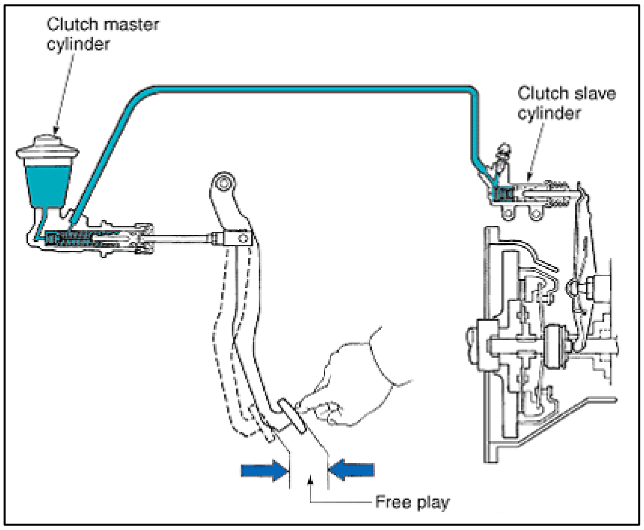

Figure 1.9: Hydraulic Clutch Linkage
(Source: www.autopartslib.com/2010/01/20/car/fiat-uno-hydraulic-clutch-components-assembly-and-parts-diagram)

Shape Memory Alloy was chosen in order to reduce parts and components in automotive clutch to produce a simple clutch actuator that can function well besides reducing the weight of the vehicle to improve power consumption, work density, cost and space constraint.

1.3 OBJECTIVES

To design and develop an automotive clutch actuator using shape memory alloy material.

1.4 SCOPES

a) To study mechanical behavior of shape memory alloy (SMA) for actuator application.
b) To design and develop a prototype of an automotive clutch actuator using SMA material.
c) To study the performance of the prototype.