UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

DEVELOPMENT OF A NOVEL ENGINE STARTER USING A COMPRESSION SPRING

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Master of Mechanical Engineering (Automotive Engineering)

2017

DEVELOPMENT OF A NOVEL ENGINE STARTER USING A COMPRESSION SPRING

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A Master Project Report submitted
in fulfillment of the requirements for the degree of Master of Mechanical Engineering (Automotive Engineering)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this thesis entitled “Development of a Novel Engine Starter Using a Compression Spring” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

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

Signature : ……

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Date : ……

DEDICATION

Special To

MD FAUZI BIN OTHMAN (My Father), RUSHITA BINTI AZIZ (My Mother) and

NUR IZATUL AMIRA BINTI AZMAN (My Love)

ABSTRACT

Automotive starting system requires an external torque to overcome the cranking resistance in order to initiate the engine operation. Conventionally, this is accomplished by applying an electrical starter motor powered by a lead acid battery. As commonly known, this battery consists of harmful chemical substances which give rise to lots of pollution through explosions, fires, leaks, and poisoning the environment that contaminates and destroys the ecosystem. Alternatively, the spring offers a means for mechanical energy storage in elastic deformation and is a well suited replacement in the engine-starting application due to its ability to provide high power densities and to discharge quickly. Therefore, in this project, the focus is on designing the compression spring that provides sufficient amount of force to rotate the starter shaft by achieving the minimum torque required on the starter pinion. Besides that, the spring is tested through fatigue analysis by using calculations and the *Finite Element Analysis (FEA)* simulation in *ANSYS WORKBENCH*. As a comparison between both results on the spring life, the results of simulation is lower than that from calculations. The analysis offers a life estimation of the mechanical starter where it can be expected to last 317, 960 cycles of the operation before failure. Moreover, the new concept of mechanical spring starter is modelled in *CATIA V5R20* in order to test the physical working of the compression spring as an energy storage device and also to test workings of the other mechanisms such as rotating part, locking mechanism and engagement of pinion. In the end, the results seem very promising.

ABSTRAK

Sistem permulaan dalam automotif memerlukan daya kilas luaran untuk mengatasi rintangan engkol dalaman bagi memulakan operasi enjin. Secara konvensional, hal ini dapat dicapai dengan menggunakan motor penggerak elektrik yang dikuasai oleh bateri asid plumbum. Seperti yang diketahui umum, bateri ini terdiri daripada bahan kimia berbahaya yang menimbulkan banyak kemalangan pencemaran melalui letupan, kebakaran, kebocoran dan keracunan, pencemaran alam sekitar dan merosakkan ekosistem. Sebagai alternatif, spring menawarkan satu cara untuk penyimpanan tenaga mekanikal melalui perubahan bentuk elastik dan merupakan penggantian yang amat sesuai dalam aplikasi permulaan enjin kerana keupayaan membekalkan ketumpatan kuasa yang tinggi dan berupaya untuk melepaskan tenaga dengan cepat. Oleh itu, projek ini memberi tumpuan kepada merekabentuk spring mampatan yang dapat memberikan jumlah tenaga yang cukup untuk memutarkan aci penggerak bagi mencapai daya kilas yang diperlukan oleh gear pinan. Disamping itu, spring diuji melalui analisis lesu berasaskan pengiraan dan simulasi "Analysis Unsur Terhingga" dalam ANSYS WORKBENCH. Sebagai perbandingan antara kedua-dua keputusan berkenaan hayat spring, keputusan daripada simulasi adalah lebih rendah berbanding pengiraan. Analisis ini memberikan anggaran hayat ke atas penggerak mekanikal di mana dapat bertahan sehingga 317 960 kali operasi sebelum mengalami kegagalan. Selain itu juga, konsep baharu penggerak spring mekanikal dimodelkan dalam CATIA V5R20 bagi menguji cara spring mampatan berfungsi sebagai penyimpan tenaga dan juga menguji cara berfungsi bagi mekanisma lain seperti bahagian yang berputar, mekanisma pengunci dan penggerakan gear pinan. Pada akhirnya, keputusan kelihatan sangat menjanjikan.

ACKNOWLEDGEMENTS

In the name of Allah the Most Gracious, Most Merciful

First and foremost, all praises to Allah for all the good things, health and strength throughout this semester for preparing and finishing this Projek Sarjana (PS) thesis with the title of "Development of a Novel Engine Starter Using a Compression Spring" without any problems.

I would like to give my thanks to Universiti Teknikal Malaysia Melaka (UTeM) and Faculty of Mechanical Engineering (FKM) for giving me this opportunity to do work and research on the project that I do. As my supervisor, Dr. Shamsul Anuar Bin Shamsudin, I thank you for all the reprimand and guidance as it is very helpful for me in completing this project. I also want to thank to all lecturers for the guidance, assistance and advice about the project as PS is one of the requirement to graduate. I also would like to extend my thankfulness to the most precious persons in my life, my parent for all their support.

Thanks to all friends that help me with the idea about this project. They were very helpful. Last but not least, thank to all who had helped me to do this project, directly or indirectly to complete this project successfully. Thank you for the support and encouragement.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

An internal combustion engine requires an external source to turn the crankshaft during initiating process. Nowadays, the electric motors are applied in almost all transportation vehicles but in the early days, vehicle engine was started by using hand cranks that were stressful and dangerous to operate. The shortfall was when the failed cranking of the engine due to insufficient amount of force applied. This might have resulted in many injuries to the operators (Antony, 2012 and Lauden, 2013). In order to solve this issue, the electric self-starter was invented by Charles Kettering of Dayton, Ohio which was a considerable step forward in the development of automotive industry (Jeffries, 1960).

Despite the fact that the electric starter is ubiquitous and affordable, the dead battery and electrical issues gave a negative impact on the automobile. Moreover, some application may not be easily, practically and safely used in operating the electric starter, such as for large marine diesel engines and huge generators because of more electric power needed to turn the electric motor (Lauden, 2013). Therefore, the application of spring starter already commercialized by a few manufacturers. In mechanical spring starter, the external power system such as electric, pneumatic or hydraulic are not necessary. Besides that, the external energy source like a battery, hydraulic fluid, gas or pressurized air are also not required (Kineteco, 2013).

The application of spring starters can reduce the use of harmful heavy metals that may be released into the environment upon scrapping the lead-acid batteries. The amount of lead released into the environment was over 40,000 metric tons annually from non-recycled lead-acid car batteries (Schubert, 2012 and Lauden, 2013). Additionally, the spring starter gives the space and weight saving due to the compartment of batteries that can be shrunk or eliminated. This may result in less than fifty percent the weight of a conventional electric starter. The use of a spring starter also offers higher safety compare with old mechanical hand cranks starter where the crank handle will not kick back and fly off during cranking (Startwell, 2013).

1.2 Problem Statement

Most modern machineries which use engines that require ignition starter for them to run from a dead halt. There are two types of commonly-known starters which are mechanical and electrical type of starters. For mechanical type, there are three different mechanism used, which are hand crank, spring-powered, and gun-powdered types of starters. On the other hand, electrical types consist of the Bendix drive and DELCO electric starter. Nowadays, most vehicle engines rarely use mechanical type starters since the age of going towards fully electrical is much more prominent. However, there are still quite a few faults that needed to be addressed when using electrical type starters.

Relating to the usage of battery for electrical starter, if the battery is flat or there is no current passing through, there is absolutely no way for the engine to start other than recharging the battery with an external source such as a portable car jumper. Due to this nature, it can be very troublesome for the user to start the engine when the battery no longer has charge in it and no spare is lying around. Even when the engine has a working alternator to charge the battery back to full capacity, if the initial starting point of charging

the battery cannot be done, then the process of charging the battery is very much hampered. Hence, the need for a fully functioning battery to operate an electrical starter is essential and can be a major problem if the main source of energy is depleted.

Aside from the electrical issues needed for the starter motor to run, a key opposing feature in using a standard battery is that it is not that environmentally-friendly. Most of the commercially available batteries are lead-acid based which contain harmful chemicals that have severe potential to be hazardous to the health and environment. The batteries usually contains traces amount of lead which is a highly toxic metal, and also sulfuric acid that is a corrosive electrolyte solution. The presence of both of these chemicals means it is imperative that the batteries would need to be handled with care to avoid any damage to the environment. Hence, using an electrical starter with the aid of the battery indirectly translate into unsafe effects to health and environment.

Speaking on just about the electrical starter, the mechanical starter is also without no faults. The original mechanical starter which uses a hand-crank method was the common mechanism to start the engine. However, it was very impractical, unsafe, and tough for making it to function properly. This is because of the unpredictability of the engine behaviour during the starting process. Sometimes, the engine can kick back during the crank which can cause a sudden reverse rotation. In the event of this happening, the opposite rotation could suddenly engage the starter, causing the crank to aggressively jerk and possibly injuring the user. This problem was very evident due to lack of a locking mechanism to store the rotational energy before transferring it to the engine flywheel.

Hence, from the problems arising with the mechanical and electrical starters mentioned, it is important that a new kind of engine starting mechanism to be developed in order to overcome the complications of both types of the common starters. Hence in this work, a new conceptual design of the mechanical starter was developed to solve the

problems and relevant analyses were done on the starter spring to determine the amount of energy that can be stored and torque transferred to the start the engine.

1.3 Objectives

The objectives of this research conducted are as follows.

i. To design the compression spring that provides sufficient force to rotate the starter shaft in order to achieve minimum torque required on starter pinion.

ii. To study the spring behaviour in terms of deformation, stress and fatique life by using static structure analysis in ANSYS WORKBENCH.

iii. To propose a new concept of mechanical spring starter by modelling in the CATIA environment.

1.4 Scope of Project

The scopes of this project are list below.

i. Design the compression spring by using the calculation based on the specification of engine, flywheel and pinion that was selected.

ii. Perform simulation by using ANSYS WORKBENCH package to analyse the deformation, stresses, strain and fatique life cycle of designed compression spring.

iii. Implement the CAD drawing by using CATIA V5 software to models the compression spring and whole part of mechanical spring starter.

iv. Develop only a full concept of the mechanical spring starter model in order to introduce the operational way of the compression spring.

1.5 Expected Result

The expected results of this project are as follows.

i. The length of spring deflection that has been decided will give the same result as spring simulation in ANSYS software.

ii. The fatique life of designed spring that calculated by using a calculation and simulation will give similar results.

iii. Complete system of mechanical spring engine starter concept will be modelled in CATIA V5.

1.6 Dissertation Outline

This thesis consists of five chapters that explain in the detail of the entire project in order to provide the understanding of the whole project. Chapter 1 introduces the background of the research, the problem statement, objective, scope and expected result of the project. Chapter 2 covers the theory and working principal of the previous and current engine starter. Besides that, the requirement of starting system and overview on starter motor fault was studies in this chapter. Next in Chapter 3, the data collections are used to design spring parameter and analyse spring behaviour. Moreover, the new concept of spring starter is models in CAD drawing. Discussions of the result of spring parameter designed, spring analysis and the model of spring starter are presented in Chapter 4. Lastly, Chapter 5 will be concluding the results and followed the suggestions for future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this research, the main priority was given to develop a conceptual mechanical starter that uses a spring mechanism which may hypothetically be more efficient than the standard electric starter. Therefore, this chapter will explore the basic mechanisms of engine starter in the early days until current automobiles, the requirements of the starting systems, overview of the starter motor faults, and assessment of lead-acid batteries. Based on green technology ideals that prefer a continuously generating energy to non-toxic cleaning products, the application of engine starter that is fully mechanical should be explored extensively.

2.2 History of Engine Starter

Internal combustion engine needs external device to initiate the engine's operation in order to overcome the cranking resistance to reciprocating the piston. The inertia produced after the engine is started, is used to initiate from each cycle to the next cycle. As known about the four-stroke engine, the third stroke (power stroke) is generated by the very high combustion pressure and enthalpy values. It strongly forces the piston back toward the bottom dead centre (BDC) and produces the power output to initiate the fourth stroke (exhaust) and also the first two stroke (intake and compression). At the beginning of any particular session, the first two (intake and compression) stroke needs to be assisted by the external power before arriving at the power stroke (Willard, 2014). Therefore, the

engine starter is designed for this purpose in order to produce the required torque for the crankshaft to reciprocate the engine. Once the engine starts running and can be operated at certain speed where the feedback loop become self-sustaining, the assistance by engine starter is not required anymore.

The engine starting was performed by using fully mechanical and a combination of mechanical and electrical. The fully mechanical method is seldom used because it is inconvenient and somewhat dangerous like in the hand crank starter, spring-powered starter and gunpowder starter. Therefore, the electrical starter motor is commonplace in order to provide high level of safety to users and it is very easy to operate.

Consequently, this chapter dedicates to study the history of engine starters from beginning with hand cranking until what is currently used like the starter motors in order to contribute more knowledge about the working principles for each type. All of this information is useful in designing a new concept of a starter that is fully mechanical.

2.2.1 Early Engine Starting Mechanism

Modern internal combustion engine have no different with the first automobile engine where they lack the ability to initiate the engine running as self-start. The engine needs external power to overcome the crank resistance in order to start engine. In early automobiles, a few starting techniques was applied in the starting system which included the hand cranks, wind-up spring devices, and the gunpowder cylinders (Laukkonen, 2013).

a) Hand Cranks

The techniques of hand crack were normally used as engine starter in the early days of the automobile where basically crank handles are temporarily coupled to engine crankshaft. The operation of this technique carried out by turning crank handles which directly to turn the crankshaft of engine in repeatedly (Larry, 2009). The crank handles could be removed after the engine capable to run on its own. The location of crank handles to start the car engine shown in Figure 2.1.

Figure 2.1: Hand Cranks Starter on Ford Model T (Larry, 2009)

Even though this technique looks like simple and reliable but many users suffered engine kicks back during cranking process. Aside from that, if the handle of cranks continued to turn after the engine started running, this situation may cause an injury. Another problem of this technique is the required higher strength in order to take a certain degree of physical effort to operate this starter. This was a hindrance to users who lacked the required skill and physical strength (Laukkonen, 2013).

b) Gunpowder Starters

The method for the starter to initiate the engine is by exploding a pocket-size cordite charge inside a combustion chamber. Cordite as shown in Figure 2.2 is a smokeless powder composed of saltpetre, sulphur, and charcoal and pressed into cords shape (Bluck, 2008). This operation are effectively powered the piston to move downward in order to provide the inertia of crankshaft in reciprocating motion. In this result, one of the other pistons will pushed upward and makes the air fuel mixture ignited in combustion chamber before the engine begins to operate under its own power.

Figure 2.2: Cordite (Bluck, 2008)

This starter also known as Coffman engine starter or shotgun starter mostly applied in aircraft and armoured vehicle around 1930s to 1940s. Type of this starter had several advantages over starting system in currently used. Electric motor starters need larger compartment, heavy, and carry batteries on board. Inertia starter required a heavy flywheel; usual material is brass which works with cranking by hand crank or electric motor in order to start the engine. Hence, the Coffman system provides lightweight solution and compact than the inertial starter and also it did not need any particular auxiliary equipment (Laukkonen, 2013). Nevertheless, the many cartridges used for starting the engine was the primary weakness of this starter, users need to keep stock of cartridges around.

c) Spring Starters

The operation of spring-powered starter was a like to hand crank starter in that it necessitated to charge the rotational motion of crankshaft through a winding action. Type of spring used in this starter was extension spring where the spring store energy in extension state and then used to initiate the engine. Nevertheless, after electric starter was introduced and applied in automotive industry, the spring-powered starter fell out of use. However, the application of the spring as engine starter still prevail till today and called the recoil starter and it is applied on small machines such as lawn mowers, chainsaws and portable engine generators. Besides that, some small vehicle such as minibike, small ATVs and go-karts also used recoil starter to start the engine. This starter used a rope to spin the crankshaft by pulling the rope's grip. In recoil starter, it consists of a few main parts which are housing, rope, reel, coil spring, ratchet, and plate friction as shown in Figure 2.3.

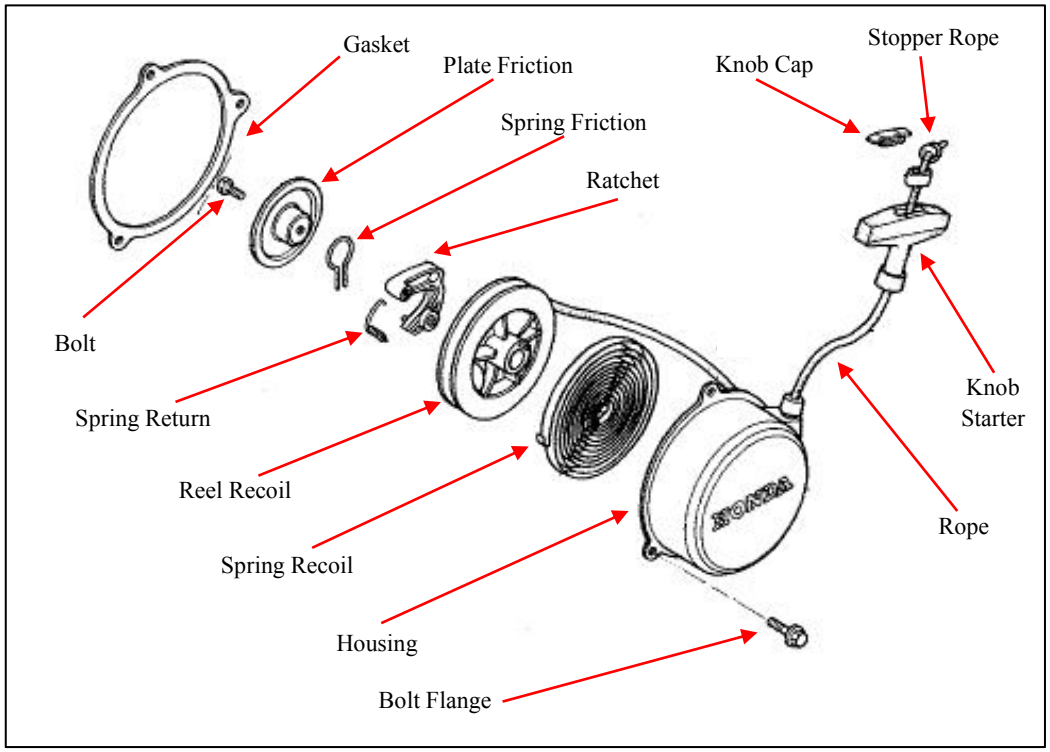

Figure 2.3: Schematic diagram of recoil starter with part name (Jianbo, 2016).