DESIGN AND DEVELOPMENT OF TIRE NUT REMOVAL

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ABSTRACT

This thesis presented about design and development of tire nut removal based on pitch circle diameter (PCD) 114mm car. Based on the existing model, there have a few improvements to be done. First thing is to reduce the weight of the tire nut removal where appropriate by designing more compact and smaller size of mechanism of tire nut removal but still in PCD 114mm. Secondly, this study also conduct to utilize less expensive materials and production costs in order to access this tire nuts removal into market. Corresponds to the project background and problem statements, it is decided that the objectives of the project are to design, fabricate and assemble the tire nut removal with lighter weight compared with the current design, to utilize less expensive materials and production cost and to design a lower input torque and find the suitable gear system complete with suitable actuator that fulfils the required specification. Study was focused on restructure the tire nuts removal in increasing the torque and produces high speed and select the best option which is capable to be fabricated at UMP. Three different types of gear mechanism have been designed by using Geartrax 2003 and Solidwork 2012. Then, analysed the gear mechanism by Finite Element Analysis: Algor 23.0 software. Three parameters have been set up in choosing the best tire nuts removal to be fabricated which are the weight of tire nuts removal, the torque and speed of tire nuts removal, and the production cost of tire nuts removal.

ABSTRAK

Tesis ini membentangkan tentang reka bentuk dan penciptaan pembuka nut tayar berdasarkan diameter bulatan kereta (PCD) 114mm. Berdasarkan model yang sediaada, terdapat beberapa penambahbaikan yang perlu dilakukan.Perkara pertama adalah untuk mengurangkan berat pembuka nut tayar dengan merekabentuk mekanisme pembuka nut tayar yang lebih padat dan saiz yang lebih kecil tetapi masih dalam PCD 114mm. Kedua, kajian ini juga adalah untuk menggunakan bahan-bahan dan kos pengeluaran yang lebih murah supaya pembuka nut tayar ini dapat ke dalam pasaran. Berdasarkan dengan latar belakang projek dan pernyataan masalah, objektif projek ini telah dibuat iaitu untuk merekabentuk, membina dan memasang pembuka nut tayar dengan lebih ringan berbanding dengan rekabentuk sebelum ini, untuk menggunakan bahan-bahan dan kos pengeluaran yang lebih murah dan merekabentuk tork input yang lebih rendah dan mencari sistem gear yang sesuai serta lengkap dengan system penggerak yang sesuai yang dapat memenuhi spesifikasi yang diperlukan. Kajian tertumpu kepada menyusun semula pembuka nut tayar dalam meningkatkan tork dan menghasilkan kelajuan yang tinggi dan memilih pilihan pembuka nut tayar yang terbaik untuk difabrikasi di UMP. Tiga rangka mekanisme gear yang berbeza telah direka dengan menggunakan Geartrax 2003 dan Solidwork 2012. Kemudian, mekanisme gear dianalisis dengan menggunakan perisian Finite Element Analysis: Algor 23.0. Tiga parameter telah ditetapkan semasa memilih pembuka nut tayar yang terbaik untuk difabrikasi iaitu yang berat pembuka nut tayar, tork dan kelajuan pembuka nut tayar, dan kos pengeluaran pembuka nut tayar.

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LIST OF ABBREVIATIONS

PCD	Pitch Circle Diameter
DC	Direct Current
AC	Alternating Current
BLDC	Brushless Direct Current
BDC	Brush Direct Current
ASME	American Society of Mechanical Engineer
3D	Three-dimensional
ABS	Acrylonitrile Butadiene Styrene
BOM	Bill of Materials
UV	Ultra-violet
CAD	Computer Aided Design
FEA	Finite Element Analysis
FEM	Finite Element Method
STL	Stereolithography
RP	Rapid Prototyping

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW OF THE PROJECT

Vehicle owner always faces a tire broken problem. If the vehicle tires have some problem then the user must remove the tire and fix it. For the car users, it is difficult to remove the tire nuts especially for the women. The obstacles are time consuming and higher ability is needed. The conventional tool method is to remove the nut one by one. In Malaysia automotive market there still no tools that is easy to use to remove the tire nuts. The time to open the car's tire nut is too long and consumes a long time with utilization of high force or energy. This is too hard especially for women. To reduce the time consumed and force needed, a tool has been designed to remove four tire nuts in one time with lower force required.

The tire nut removal has been designed with 114 mm pitch circle diameter (PCD) for the last project. This tool can open four nuts in one time and the force utilization has been reduced. This tire nut removal is operated by applying gear system to reduce the force needed to straightly remove all four nuts in one time. For this thesis there have some improvement on running the gear system using a DC motor located outside the box of tire nut removal. This project maybe has solves the four nut removal problem and force usage utilization. This tire nut removal with 114 mm PCD has some potential in automotive industry in Malaysia. This project is quite successful but the tool also has some problems.

For this final year project, the tire nut removal with 114 mm PCD is chosen to be improved and reduced the errors. This tire nut removal has been designed to remove four nuts in one time and decrease the required force. This project will improve and reduce the errors and also decrease the lack of tire nut removal 114 mm PCD in the last project.

1.2 PROBLEM STATEMENT

From the introduction, the tire nut removal has been explained. This tire nut removal has been designed to facilitate the four nuts 114 mm PCD car. There are two major problems that prevent the current tire nut removal cannot access into the market. The problems are the tire nut removal is too heavy where it is hard for a female user to handle the tool. The materials for this tire nut removal also expensive and are not competitive in the market.

1.2 OBJECTIVES OF THE PROJECT

To overcome the above issues, some objectives were determined. The objectives are to produce a tire nut removal for 114 mm PCD with these qualities:

- Design and fabricate the tire nut removal with lighter weight compared with the current design.
- Utilize less expensive materials and production cost.
- Design a lower input torque and find the suitable gear system complete with suitable actuator that fulfills the required specification.

1.4 SCOPES OF PROJECT

This project is focusing on redesign and analysis of the tire nut removal which can produce high torque but at lighter weight component. The work scopes are done based on the following aspect:

i. Study the current mechanism of the tire nut removal.

ii. Redesign three optional tire nuts removal at lighter weight condition.

iii. Restructure the gear mechanism in increasing the torque and produce high speed using the Geartrax software

iv. Study on the material selection for gear mechanism

v. Choose the best actuator to run the mechanism of tire nut removal

1.5 JUSTIFICATION

As we all know, tire is the main component of a car. The current tire nut removal can settled one of the quandary problems of a tire. The improvement of tire nut removal is important because this product has a big potential in automotive accessory market. The improvement can help the entire car user especially women to simply change the type. The first model has accomplished the required force and consumed time. Now this project will enhance the tire nut removal 114 mm PCD cars on torque and force requirement and features of tire nuts removal especially in term of weight.

1.6 STRUCTURES OF THESIS

Chapter 1 introduces the overview of the tire nut removal. It is continues with the problems statement which related to the study and followed by the objectives, scope of the study, the justification and the structure of the thesis.

Chapter 2 presents the information of tire nut removal for the system choose in operating the tire nut removal, introduction of gear system, spur gear terminology, material selection of gear component in terms of light weight. In this chapter, the

suitable gear type and material use for the new design is determined from the comparison.

Chapter 3 includes the all proposed design where the physical parameter, consideration, and defect will be considered. This chapter also will discuss the manufacturing process use during fabrication of tire nuts removal, the design process of three suggested model of tire nuts removal include the technical specification of the entire suggested model. From discussion of chapter 3, it was enclosed with the designing process of the tire nuts removal design.

Chapter 4 begins with the analysis of three proposed design of tire nuts removal. From the analysis and technical specifications of entire suggested model, one of the tire nuts will be chosen to manufacturing process. In this chapter also will discuss about the actual process of fabrication of tire nut removal. The bill of materials also include in this chapter.

Chapter 5 presents the conclusion drawn from this Final Year Project and the recommendations will beneficially for future works progress.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

For this project, the 114 mm PCD cars has been chosen as product reference. This chapter covers the academic information about related project. In this chapter will explained about the types of the mechanical power system, the information of DC motors include the operation, the types of construction and commutation, basic gear theory, spur gear terminology, and types of materials used and the types of tools needed. Some of the information has been carried away from the previous thesis of the third version of tire nut removal. The data from the previous project will be used as guidance in the literature review of this project and there have some improvement on the data. This information has been collected from books, journals, company's website, market survey and last project thesis.

2.2 TYPES OF ACTUATOR SYSTEMS

Actuators are the key components of all mechanized equipment. An actuator is a device that converts energy to mechanical motion. (Jouaneh, M., 2011). There are many types of actuators available to drive machinery such as electric motors, internal-combustion engine, pneumatic and hydraulic.

Table 2.1 : Types of Actuators System

Type Of System	Explanation
Electric Motor System	Electric motors convert electrical energy into rotary mechanical energy which is then further converted to ultimately provide the needed use-energy. (Vienna, 2012). Electric motors produce useful work by causing the shaft to rotate. There are a wide variety of electric motors, based on the type of power supply which is alternating current (AC) motor or direct current (DC). It is widely used in equipment such as pumps, compressors, machine tools and robots.
Engine System	Engine system is a machine designed to convert energy into useful mechanical motion. It is divided by two which is internal combustion engine and external combustion engine such as steam engine. Engine system usually used for mobile applications such as vehicles, boats, and power generation equipment. (Jouaneh, M. 2011). The using of engine system can produce air pollution emissions due to incomplete combustion of carbonaceous fuel.
Hydraulic System	Hydraulic systems able to convert mechanical energy to fluid energy and then to mechanical work. Hydraulic systems use a fluid medium under pressure to create motion in machine components. The fluid can be steam, gases, water, oil or other media. (Pirro, D. M, et al., 2001). The principle of hydraulic system is very simple which Pascal's Law principle is. Pascal's Law stated that pressure applied anywhere to a body of fluid causes a force to be transmitted equally in all directions, with the force acting at right angles to any surface in contact with the fluid. This system usually in applications for lifts and presses among others.
Pneumatic System	Pneumatics is one of the technology systems that deals with the study and application of pressurized gas to affect mechanical motion. (Majundar, S. R. 2006). Pneumatic

systems commonly use compressed atmospheric air, as it is abundant and inexpensive. Since air is compressible, unlike the liquid or electricity used in electrical and hydraulic systems, it can be difficult to control the speed and precision of a pneumatic system. When very specific speeds and positioning are needed, additional systems may need to be constructed and put into place to offer additional control, which can be a costly solution. It is mostly used in machinery applications such as pick-and-place robots and in air-powered tools. (Jouaneh, M. 2011)

2.3 INTRODUCTION TO DC MOTORS

A DC motor is a mechanically commutated electric motor powered from direct current (DC). Nowadays, DC motors widely uses in many industrial applications, robot manipulators and home appliances because of their high reliabilities, flexibilities and low costs. (Manafeddin, N, et al., 2010). Industrial applications use dc motors because the speed-torque relationship can be varied to almost any useful form. Traditionally, a DC motor was considered to be a variable speed motor and AC motor was considered as a constant speed motor. Although the future trend is towards the AC drives, DC drives are currently used in many industries because of the torque speed characteristics of DC motor that can be varied over a wide range while retaining high efficiency compared to AC motors.

2.3.1 Types of Construction

There are many types of DC motors construction. Some DC motors have a rotating armature winding but non-rotating armature magnetic field and some have static field winding or permanent magnet. Different connections of the field and armature winding provide different inherent speed/torque regulation characteristics. The speed of a DC motor can be controlled by changing the voltage applied to the armature or by changing the field current.

(i) Series Wound

In a series-wound motor, the stator and rotor coils are connected in series. (Jouaneh, M. 2011). A series wound DC motor has the armature and field windings connected in a series circuit. These motors are available as a modification for those applications requiring very high starting torque and high speed regulation.

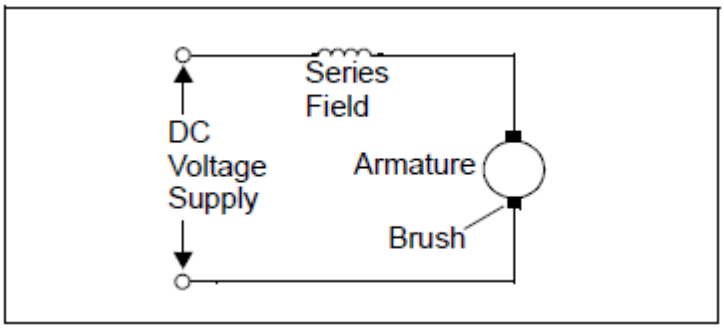

Figure 2.1 : Series Wound DC Motor Circuit and Curve

Source : Condit, R. (2004)

(ii) Shunt Wound

A shunt wound DC motor has the armature and field windings connected in parallel. As a shunt DC motor cannot carry high currents, it is unsuitable for applications requiring a high starting torque. So, it requires its shaft load to be small to start functioning. The resistance of the shunt windings in a shunt DC motor is very high. As a result, when electric voltage is supplied to the shunt DC motor, very low amount of current flows through the shunt coil. Shunt wound DC motor have a nearly constant speed under varying loads. (Jouaneh, M. 2011). This make them attractive to drive machine tools and rotating equipment such as blowers or fans where it is desirable to have steady speeds.

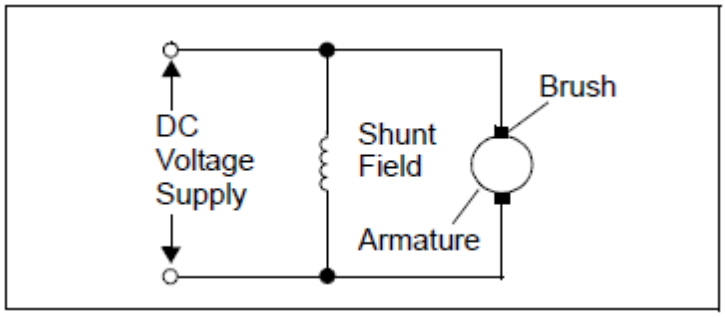

Figure 2.2 : Shunt Wound DC Motor Circuit and Curve

Source : Condit, R. (2004)

(iii) Compound Wound

A compound wound DC motor is basically a combination of shunt wound and series wound configurations. (Jouaneh, M. 2011). A winding is connected in series with the armature as in a series DC motor. Another winding is connected in shunt with the armature as in a shunt DC motor. This combination presents us the double advantage of having the torque characteristics of a series motor and the constant speed characteristic of a shunt motor in one compound wound motor. This type of motor is used whenever speed regulation cannot be obtained from either a series or shunt wound motor. The torque and speed characteristics are the result of placing a portion of the field winding circuit in series with the armature circuit.

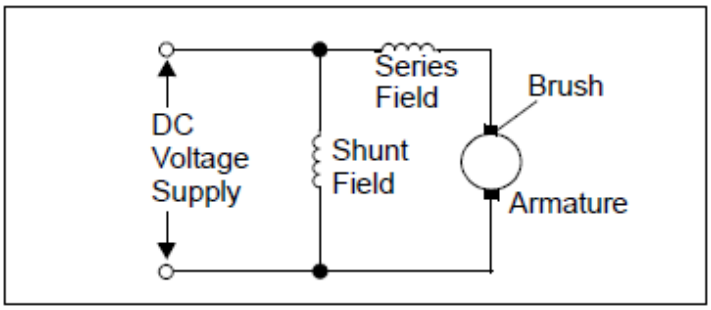

Figure 2.3 : Compound Wound DC Motor Circuit and Curve

Source : Condit, R. (2004)

(iv) Permanent Magnet

A permanent magnet motor is built with a standard armature and brushes, but has permanent magnets in place of the shunt field winding. Permanent magnet DC motors have similar characteristics to DC shunt wound motors in terms of torque, speed, reversing and regenerative braking characteristics. These motors have starting torque several times that of shunt motors and their speed load characteristics are more linear and predictable. Torque varies a lot with speed, ranging from maximum (stall torque at zero speed) to zero torque at maximum (no load speed). (Gieras, J. F. 2002). Through this type of motor has very good starting torque capability, the speed regulation is slightly less than that of a compound wound motor. Hence, this type of DC motor is suitable for the application where torque and speed need to be adjusted. When adding the cost of a DC motor and control system, this type of motor is less expensive to operate, since there is no need for a shunt field winding exciter supply. Along with less expensive operation, this type of motor is simpler to install, with only the two armature connections needed. This motor type is also simpler to reverse the connections to the armature.

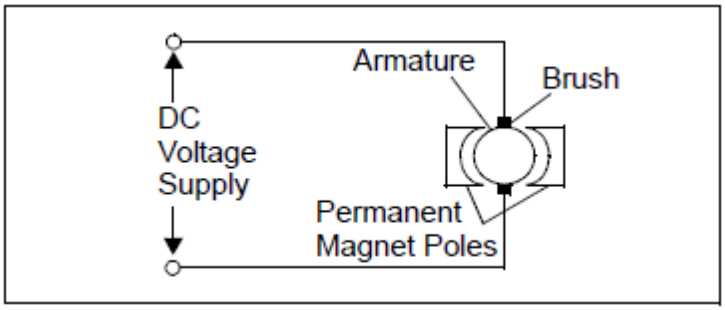

Figure 2.4 : Permanent Magnet DC Motors and Curve

Source : Condit, R. (2004)

2.3.2 Types of Commutation

Commutation is aprocess of transferring current from one connection to another within an electric circuit. When direct current is supplied to a winding on a rotor that is subjected to a stationary magnetic field, it experiences a rotational force

and resulting output torque. As the stator north and south poles are reversed relative to the rotating winding, the rotor current is reversed by a commutator in order to maintain the unidirectional torque required for continuous motor action. There are two type of of commutation in DC motor as stated in below; brushed and brushless.

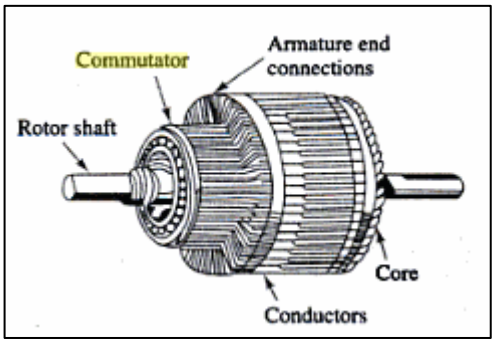

Figure 2.5 : Basic Commutator for DC Motors

Source : Singh, R. R. (2010)

(i) Brush

Brush DC motors are made of the same basic components a stator, rotor, brushes and a commutator. Unlike other electric motor types such as brushless DC or AC induction, BDC motors do not require a controller to switch current in the motor windings. Instead, the commutation of the windings of a BDC motor is done mechanically. Advantages of a brushed DC motor include low initial cost, high reliability, and simple control of motor speed. Disadvantages are high maintenance and low life-span for high intensity uses. Maintenance involves regularly replacing the brushes and springs which carry the electric current, as well as cleaning or replacing the commutator. These components are necessary for transferring electrical power from outside the motor to the spinning wire windings of the rotor inside the motor.

(ii) Brushless

Brushless DC motors (BLDC) are a kind of synchronous motor. This indicates the magnetic field produced by the stator and the magnetic field produced by the rotor twirls at the same frequency. BLDC motor is built with a permanent magnet rotor and wire wound stator poles. As the name implies, the BLDC motors do not use brushes for commutation; instead they are electronically commuted. Advantages of brushless motors include long life span, little or no maintenance, and high efficiency. Disadvantages include high initial cost, and more complicated motor speed controllers. Some such brushless motors are sometimes referred to as "synchronous motors" although they have no external power supply to be synchronized with, as would be the case with normal AC synchronous motors.

2.4 INTRODUCTION OF GEARS

A gear can be defined as the mechanical element used for transmitting power and rotary motion from one shaft to another by means of progressive engagement of projections called teeth. (Gopichand, M. A, et al., 2012). Two or more gears working in tandem are called a transmission and can produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, torque, and direction of a power source. When two gears of unequal number of teeth are combined a mechanical advantage is produced, with both the rotational speeds and the torques of the two gears differing in a simple relationship.

2.4.1 Types of Gears

Gear designs vary depending on the requirements for rotation speed, degree of gear reduction and torque loading. There are various type of gears as stated below :

(i) Spur Gears

Spur gears are designed to transmit motion and power between parallel shafts. (Madsen, D. A. and Madsen, D. P., 2011). There are two types of spur gears which is external and internal spur gear. External spur gears are designed with the teeth of the gear on the outside of a cylinder and it is the most common type of gear used in manufacturing. Internal spur gears have teeth inside of the cylindrical gear. The advantages of spur gears over other types are the low manufacturing cost, simple design and ease of maintenance. The advantages include low load capacity and higher noise levels than other types.

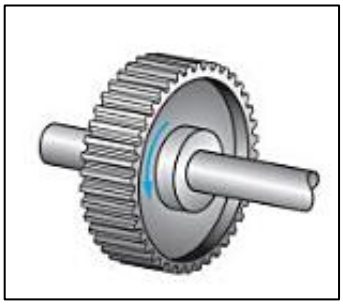

Figure 2.6 : Internal Spur Gear

Source : Madsen, D. A. and Madsen, D. P. (2011)

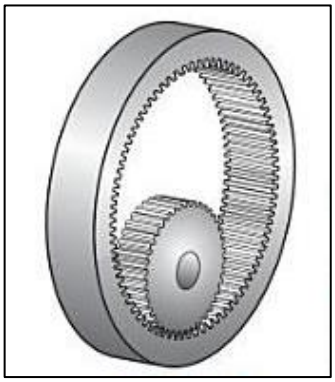

Figure 2.7 : External Spur Gears

Source : Madsen, D. A. and Madsen, D. P. (2011)

(ii) Helical Gears

Helical gears have their teeth cut at an angle, allowing more than one tooth to be in contact. (Madsen, D. A. and Madsen, D. P., 2011). Helical gears carry more load than spur gears and operate quietly and smoothly. The disadvantage of helical gears is that they develop end thrust. End thrust is a lateral force exerted on the end of the gear shaft. Thrust bearing are required to reduce the effect of this end thrust. Double helical gears are designed to eliminate the end thrust and provide long life under heavy loads but there are difficult and costly manufacturing.

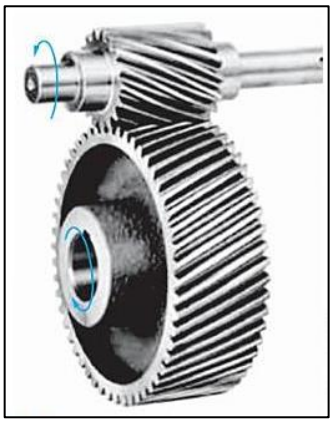

Figure 2.8 : Helical Gears

Source : Madsen, D. A. and Madsen, D. P. (2011)

(iii) Bevel Gears

Bevel gears are conical in shape, allowing the shafts of the gear and pinion to intersect at 90° or any desired angle(Madsen, D. A. and Madsen, D. P., 2011). The teeth on the bevel gears have the same shape as the teeth of spur gears except they taper toward the apex of the cone. Bevel gears provide for a speed change between the gear and pinion Mitter gears are the same as bevel gears except both the gear and the pinion are the same size and are used when shafts must intersect at 90° without speed reduction. Spiral bevel gears have the teeth cut at an angle which provide the same advantages as the helical gears over spur gears.