UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN OPTIMIZATION OF CAR JACK USING FINITE ELEMENT ANALYSIS

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) with Honours

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) with Honours. The member of the supervisory is as follow:

………………………………

(Encik Abdul Halim Hakim bin Abdul Aziz)

ABSTRAK

Projek ini mengenai optimisasi reka bentuk jek kereta menggunakan analisis elemen terhad, di mana produk yang dikaji adalah jek gunting. Projek ini terdiri daripada enam reka bentuk jek gunting yang berada di pasaran yang dilukis semula menggunakan perisian SolidWorks. Reka bentuk tersebut kemudian dianalisis menggunakan analisis elemen terhad dalam Simulasi SolidWorks dan dibandingkan untuk mendapatkan nilai terendah tekanan Von Mises maksimum dan anjakan paduan maksimum yang akan dipilih sebagai penanda aras. Fasa optimisasi berlaku dengan mengoptimisasi reka bentuk jek gunting dengan penyokong sisi, kunci automatik dan boleh dilipat. Rekabentuk optimum tersebut kemudiannya dianalisis menggunakan analisis elemen terhad dalam Simulasi SolidWorks dan hasil analisis itu dibandingkan dengan data penanda aras. Jek gunting yang digunakan dalam projek ini diperbuat daripada keluli karbon (AISI 1045) dan boleh menahan beban sebanyak 500 kg. Jek gunting tersebut juga direka khas untuk digunakan dengan Perodua MyVi.

ABSTRACT

This project is about design optimization of car jack using finite element analysis, where the product studied is scissor jack. The project consists of the redesigned drawing of six existing scissor jacks in the market by using SolidWorks software. The existing designs are then analysed using finite element analysis in SolidWorks Simulation and compared in order to obtain the lowest maximum Von Mises stress and maximum resultant displacement to be selected as the benchmark. The optimization phase takes place by optimizing the scissor jack design with side supports, automated locks and can be folded. The optimized design is then analysed using Finite Element Analysis in SolidWorks Simulation and the result is compared with the benchmark data. The scissor jack used in this project is made from carbon steel (AISI 1045) and can withstand a capacity of 500 kg. It is also designated to be used with Perodua MyVi.

DEDICATION

To my beloved parents and sisters

ACKNOWLEDGEMENT

I would like to thank my supervisor, Mr. Abdul Halim Hakim bin Abdul Aziz, for his guidance throughout the completion of the project. Thousands of thanks to my parents and family who provides me with unending love and support all the time. Last but not least, my appreciation goes to the lecturers and friends who have helped me during difficult times. Thank you.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

FEA	-	Finite Element Analysis
CAD	-	Computer Aided Design
CAE	-	Computer Aided Engineering
2D	-	2 Dimensional
3D	-	3 Dimensional
ANSI	-	American National Standards Institute
ISO	-	International Organization for Standardization
DIN	-	Deutsches Institut für Normung (German Institute for Standardization)
GOST	-	Gosudarstvennyy Standart (State Standard)
JIS	-	Japanese Industrial Standards
BSI	-	British Standards Institution
SAC	-	Standardization Administration of China
NASTRAN	-	NASA Structure Analysis
FE	-	Finite Element
PSM	-	Projek Sarjana Muda
kg	-	Kilogram
mm	-	Millimetre
m	-	Metre
s	-	Second
N	-	Newton
MPa	-	Mega Pascal
GPa	-	Giga Pascal
AISI	-	American Iron and Steel Institute
F	-	Force
Min.	-	Minimum
Max.	-	Maximum

CHAPTER 1

INTRODUCTION

This chapter introduces the background of the project, the problem statement, the objective and also the scope of the project.

1.1 Background

In the repair and maintenance of automobiles, a raise of the vehicle is often necessary in order to get underneath the vehicle or simply to change a tyre. A tool that is used to perform the task is the vehicle jack. Basically, the jack is used in lifting a vehicle above the ground, just enough to enable vehicle maintenances or breakdown repairs. Although the vehicle jack does not play a part in the smooth running of a vehicle engine, yet its presence is important during tyre deflation. Without a jack, a vehicle owner will experience loss in time, money and energy (Dare & Oke, 2008).

Most people are familiar with the basic car jack, which is manually operated and often included as standard equipment for most new cars. The most important fact of a jack is that, it gives the user a mechanical advantage by changing the rotational force on the screw into linear motion, allowing the user to lift the vehicle to the required height. According to VanGelder (2014), there are three types of car jacks, which are mechanical jack, hydraulic jack and pneumatic jack. Most car jacks that are included with cars are mechanical jacks. Of the mechanical jacks, there are scissor jacks, which are common in newer cars, and screw jacks, which are common in older cars.

A mechanical jack is usually found in the trunk of the car with the spare tyre, as shown in Figure 1.1. Both the scissor jack and the screw jack use an arm for the car owner to raise the car. Oghenekome et al (2014) describes that in order to lift up the car by using scissor jack, the jack is first notched into a hard point on the car's undercarriage. Figure 1.2 shows the notch underneath the car. The lug nuts are then loosened and the arm is turned in a clockwise motion to raise the car. As the arm is turned, a large screw pushes the car up by shortening the distance between the end points of the jack. The mechanism moves along the screw thread which consequently lifts the car up with relatively little effort.

Figure 1.1: Spare tyre in the trunk of a Volvo XC60

(Source: <http://www.team-bhp.com/forum/official-new-car-reviews/95361-volvo-xc60-test-drive-review.html> 12/09/15)

Figure 1.2: Notch underneath the car to fit the car jack

(Source: <http://www.howitworksdaily.com/how-do-scissor-jacks-lift-cars> 12/09/15)

The car comes down by reversing the process. The screw is turned counter clockwise and the lug nuts are tightened after the car's tyre has minimal weight on the surface. The jack is then lowered the rest of the way. The scissor jack is called as it is because of the structure of the jack that consists of diagonal metal components that expand and contract in the same way as a pair of scissors. When using a vehicle jack, it must be placed on a flat surface so that the jack does not toppling over, and making the car fell down unexpectedly. Furthermore, the user must ensure that no one is sitting in the car as the car is being lifted up. This is because there is a lot of weight that is supported by the jack with the car itself.

Nowadays, a vehicle jack is an important tool to have in the vehicle due to unknown upcoming incident such as flat tyre in the journey. A flat tyre usually comes at the least unexpected moments, like when going on a long journey, in the highway or in the middle of the woods for instance. As the car is unable to keep moving, the driver has to replace the inflated tyre with the spare tyre. This is a waste of time and energy and even will endanger the driver if he are jacking and changing the tyre in hurry. Working near a vehicle that is supported by a car jack can be fatal, as one does not know when the jack will lose its function and fails.

Therefore, a study on the load that can be lifted by the car jack is crucial to ensure that the specified capacity of the car jack is accurate and dependable so that the user will not experience the unfortunate event of a failed car jack. In order to verify the figure, an analysis called as Finite Element Analysis (FEA) is conducted on the car jack. FEA is a computerized method of simulating and predicting the behaviour of a product that is affected by variety of conditions, such as stresses, vibration, motion, heat, fluid flow, and other physical effects, hence showing whether the product will break or work the way it is supposed to function.

In this project study, the existing designs of scissor jacks in the market are analysed using Finite Element Analysis (FEA) in SolidWorks Simulation software. The analysis is done to determine the maximum stresses that can be applied on the devices before they fail. An optimization of the scissor jack is then conducted by redesigning the scissor jack and analysing the optimised design using FEA. The result of the analysis is then compared with the analysis from the existing designs of scissor jacks. The optimization is done based on the existing car jacks' designs in order to improve the quality and hence, the safety features of the car jack.

1.2 Problem Statement

These days, most of the cars were equipped with a scissor jack, as it is smaller and easier to store compared to other jacks. Although the car jack is an important device for the changing of tyre, the use of it may lead to accident and sometimes fatal. According to Iskandar (2008), a serious number of accidents that involve car jacks have been reported all over the world with an average of 160 injuries each year. Injuries varied from amputation to fractures and crush injuries. The major factor that caused the injuries is the insufficient safety features of the car jacks.

Rankine (2007) stated in a news release that a jack is expected to withstand up to 1000 kilograms, but the Consumer Affairs of Government of South Australia has done several tests which showed that the jack fails to work after lifting 250 kilograms. In addition, the tests revealed that when the jack has a lifting weight close to its 1000 kilograms capacity, it may physically break. The tests also proved that the jack has the tendency to deform under the weight it is supposed to hold, thus it does not comply with the requirements of the Australian Standard for vehicle jacks.

In order to encourage improvements in automotive lift technology especially in the area of safety, an organization called as Automotive Lift Institute (ALI) was established. Before, up until late 1990s, car jack manufacturers were permitted to claim that their products were safe although they did not meet any set standard. However after ALI has been established, they cooperate with the American National Standards Institute (ANSI) to ensure that all jacks and lifts satisfy a set number of performance standards in order to be ALI/ANSI certified.

Although there have been organizations like ALI to monitor the safety standard of car jacks, the existing car jacks still have insufficient safety features. For instance, current car jacks do not have a lock to secure the position of the jack, or extra beam to withstand the heavy load of the car. Therefore, it can be seen that the improvement in automotive car jack is really needed to make the tool more efficient, reliable, high quality and most importantly high safety features. Hence, this report is prepared to analyse the design of the existing car jacks and then optimize the design so that it is safer to be operated.

1.3 Objectives

The aim of this project is to perform structural analysis on car jack design to determine the best design optimization for the car jack.

This can be accomplish by following these objectives:

- To redesign the existing car jacks using SolidWorks software.
- To analyse the car jack designs using Finite Element Analysis.
- To optimize the car jack design.

1.4 Scope of Project

This project comprises the design, analysis and optimization of car jack. The type of car jack that will be used in this project is scissor jack as it is more common to vehicle users. The capacity of the scissor jack is 500 kg and the jack is targeted to be used with compact cars such as Perodua Myvi which weighs about 970 kg. Perodua MyVi is selected to be the target object as it is used by many people and has been the best-selling car in Malaysia from 2005 to 2010.

This project will be started by redesigning six existing designs of scissor jack in 3D modeling by using CAD software, which is SolidWorks software. The designs will then analysed by using Finite Element Analysis (FEA) in SolidWorks Simulation software. The results of the analyses will be compared and the smallest values of maximum Von Mises stress and maximum resultant displacement will be chosen as a benchmark.

The optimization of scissor jack will begin by designing a new concept of scissor jack. The optimized design will then undergo FEA simulation and the result of the analysis will be compared with the selected benchmark. The analysis' result of the optimized design must be lower than the benchmark as to ensure that the design is safe. The material to be used for the scissor jack and its properties will also being considered in optimizing the scissor car jack.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A literature review is a discussion on published materials like books, journals, thesis, articles, reports and conference proceedings. The main purpose of this literature review is to obtain information about the project from the previous researches. This chapter will describe the topics that are related to car jack, car group, Computer Aided Design (CAD) and Finite Element Analysis (FEA).

2.2 Car Jack

A car jack is a device that functions to easily lift all or part of a car above the ground in order to gain access to area underneath the car or to change the tyre. Car jacks normally take advantage of mechanical force to enable an individual to raise a vehicle by manual force (Noor et al., 2008). At present, a variety of car jacks have been produced to lift a vehicle from a ground surface. Iskandar (2008) stated that there are three major types of car jack that have been commercialized for vehicle users, which are the mechanical type, hydraulic type and pneumatic type.

Oghenekome et al. (2014) pointed out that the type of car jack used will influence the amount of physical force for operating the jack to raise the car to the required height. A suitable jack, which is determined by the surrounding environment and the strength of the user, will reduce most of the time that results in a lot of exertion from the individual which could gradually weaken the person’s energy.

2.2.1 Mechanical Jack

Most car jacks that are included as a tyre repair kit in cars are the mechanical type. This is because they are smaller and hence, easier to store compared to other types. Scissor jack and screw jack are two common kinds of mechanical jack (Dare & Oke, 2008).

2.2.1.1 Scissor Jack

Babu (2015) claimed that scissor jacks have been in use since 1930s. A scissor jack is a tool that was designed with a cross-hatch mechanism, just like a scissor, to raise a vehicle off the ground for repairs and maintenance, as shown in Figure 2.1. The jack typically works in a vertical manner as to lift up the vehicle. It opens and folds, exerting pressure to the support beams that make the crossed patterns, thus making the jack to move. Scissor jacks are simple mechanisms that are used to operate on large loads over short distances.

Figure 2.1: Scissor Jack

(Source: <http://www.wayco.co.nz/w1013.htm> 16/09/15)

Dare & Oke (2008) added that when the scissor jack is being used, a clockwise rotation of the handle arm will cause the support beams to open, thus producing a lift to the vehicle. However, when the jack is not in use or in unload condition, the handle arm is given a reverse rotation, that is a counter clockwise rotation, which collapses the support beams and makes it compact enough for packaging.

According to Bariskan (2014), most scissor jacks are designed in a similar concept that consists of four lifting arms, a base plate, a carrier member, eight connection pins, a power screw and a crank shaft. Figure 2.2 shows the assembly drawing of a scissor jack with the name of the parts. When the crank is rotated, the screw turns, and consequently raises the jack. The screw functions like a gear mechanism. The screw thread, which acts like teeth of a gear, turns and moves the four arms, producing a linear motion. The four arms are all linked at the end with a bolt that allows the corners to fold.

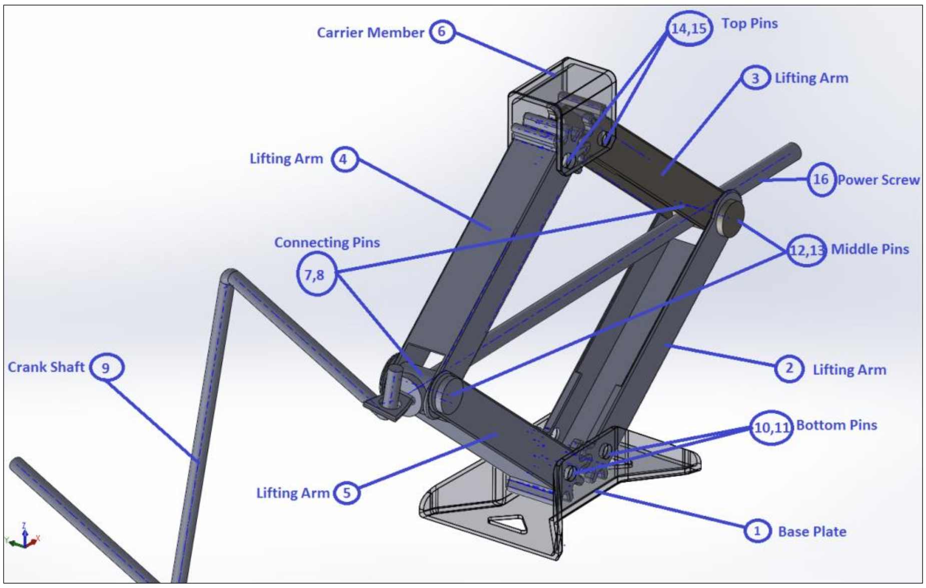

Figure 2.2: Assembly drawing of scissor jack (Bariskan, 2014)

2.2.1.2 Screw Jack

For a screw jack in operation, Dare & Oke (2008) describes the mechanism as two gearwheels that are engaged together, forming a bevel gear in which their shafts are at an angle of 90^o, as shown in Figure 2.3. One gearwheel positions the handle while the other meshes its internal thread, which is in its bone, with the load screw. By rotation of the handle, the driving gearwheel is rotated and the force is transmitted to the driven gearwheel, which results in a raise of the load pad and consequently a raise of the vehicle.