FAILURE OF PISTON ENGINE USING FINITE ELEMENT ANALYSIS

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for the award of Bachelor of Mechanical Engineering with Automotive Engineering

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering.

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Date: 6 DECEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this report is my own except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This project deals with analysis the failure of piston engine using FEA. The objective of this thesis is to develop the geometry of piston engine using Solidwork software and to investigate the maximum stress using stress analysis and maximum temperature using thermal analysis. The project describes the finite element analysis techniques to predict the failure of piston and identify the critical locations of the components. Aluminum alloys material was studied in this project which commonly used in industry. The three-dimensional solid modeling of piston engine was developed using the solidwork software. The strategy of validation of finite element model was developed. The finite element analysis was then performed using ALGOR software. The finite element model of the components was analyzed using the static stress with linear material model and steady-state heat transfer. Finally, the maximum stress and maximum temperature were obtained previously are employed as input for the failure of piston. Pistons from petrol engines, from automobiles, will be analyzed. Damages initiated at the top head, ring grooves, pin holes and skirt are assessed. Stresses at the piston crown and pin holes, as well as stresses at the grooves and skirt as a function of land clearances are also presented. The results can also significantly reduce the cost to produce the piston, and improve product reliability and improve the fatigue strength and durability.

ABSTRAK

Projek ini berkaitan dengan kajian kegagalan omboh enjin menggunakan FEA. Tujuan dari tesis ini adalah untuk mempebaharui geometri mesin omboh menggunakan perisian solidwork dan untuk menyiasat tekanan tertinggi dengan mengunakan kajian tekanan dan menyiasat suhu tertinggi dengan mengunakan kajian haba. Projek ini menjelaskan teknik untuk memprediksi kegagalan piston dan mengenalpasti lokasi kritikal di bahagian. gabungan Aluminium alloy dipelajari dalam projek ini kerana umumnya digunakan dalam industri pembuatan. Pemodelan padat struktur tiga-dimensi mesin piston dibangunkan menggunakan perisian solidwork. Perancangan berkaitan finite element model dibangunkan. Kemudiannya finite element analysis dilakukan dengan menggunakan perisian ALGOR. Finite element model dikaji dengan mengunakan voltan statik dengan bahan model yang berkadar terus dan pemindahan panas keadaan tetap. Akhirnya, voltan maksimum dan suhu maksimum diperolehi sebelumnya bekerja sebagai masukan bagi kegagalan piston. Omboh dari mesin minyak, dari kereta, akan dikaji. Kerosakan bermula pada kepala atas, alur cincin, lubang pin dan rok undian. Menekankan pada atas omboh dan lubang pin, serta menekankan pada alur dan rok sebagai fungsi dari jarak antara lain juga disediakan. Keputusan ini juga dapat secara dikelaskan dengan mengurangkan kos untuk menghasilkan omboh, dan meningkatkan kebolehpercayaan produk dan meningkatkan kekuatan keletihan dan daya tahan.

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LIST OF SYMBOLS

$°C$	Degree Celsius
g	Gram
σ	True stress, local stress
F	Force
P	Pressure
A	Area
L	Liter
Pa	Pascal
F	Force
K	Kelvin
m	Meter

LIST OF ABBREVIATIONS

AA	Aluminum alloy
Al	Aluminum
Fe	Iron
Mg	Magnesium
Ni	Nickel
Si	Silicon
Mn	Manganese
Sn	Tin
Zn	Zinc
SAE	Society of Automotive Engineers
ASTM	American Society for Testing and Materials
FE	Finite element
FEM	Finite element model
FEA	Finite element analysis
RPM	Revolution per minutes

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter briefly describe about the failure of piston engine using finite element analysis. The other aspects that will be discussed include problem statement, objectives and scope of the system.

1.2 PROJECT BACKGROUND

A piston is a component of reciprocating engines, pumps and gas compressors. Piston was located in a cylinder and is made gas-tight by piston rings. In an engine, its purpose is to transfer force from expanding gas in the cylinder to the crankshaft via a piston rod. In pump, the function is reversed and force is transferred from the crankshaft to the piston for the purpose of compressing or ejecting the fluid in the cylinder. In some engines, the piston also acts as a valve by covering and uncovering ports in the cylinder wall (Silva 2004).

Starting by many years ago, piston materials and design have been update or evolved over the years and will continue to get better or improvement every evolved until fuel cells, exotic batteries or something another makes the internal combustion engine obsolete. Because of piston may be considered the ‘heart’ of an engine that can become of the reason continuous effort of evolution (Silva 2004).

1.3 PROBLEM STATEMENT

In engineering field, the result of failure must be exactly true. Finite element analysis will be able to analysis the created design as well when all the specification is known, then, that can show the better result. From the review, there are several problems should be highlighted in this project. These include:

i- Failure of piston engine may cause damage to automobile as well as an accident.
ii- It is a need to study the failure of piston to prevent any harm injury to human.

1.4 PROJECT OBJECTIVE

There are three main objectives that must be achieved:

i- To develop the geometry of the piston using SOLIDWORK software
ii- To investigate the maximum stress using stress analysis
iii- To investigate the maximum temperature using thermal analysis

1.5 SCOPES OF THE PROJECT

A several scope needs to be identified in order to analysis the piston. This project will be focusing on an analysis of the failure of the piston. This scope area will be done first by finding the literature review about the piston, SOLIDWORK software and ALGOR software. Next, the type of piston that is used for petrol engine from automobile and four-stroke cycle will be analyzed. Then, all information about piston will be collected. Besides that, the material that will be used is aluminum alloy. The others scope is to design the piston using SOLIDWORK software and analysis by ALGOR software. Finally, the maximum stress and maximum temperature will be determined.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will be explaining about the literature review. This chapter will introduce the fundamental of the piston and the basic type of piston. Other various method and comparisons on different software approach related to the project is also stated in this chapter.

2.2 FUNDAMENTAL OF PISTON

A piston is a cylindrical piece of metal that moves up and down inside the cylinder which exerts a force on a fluid inside the cylinder. Pistons have rings which serve to keep the oil out of the combustion chamber and the fuel and air out of the oil. Most pistons fitted in a cylinder have piston rings. Usually there are two spring-compression rings that act as a seal between the piston and the cylinder wall, and one or more oil control ring s below the compression rings. The head of the piston can be flat, bulged or otherwise shaped. Pistons can be forged or cast. The shape of the piston is normally rounded but can be different. Figure 2.1 shows the part of piston engine. A special type of cast piston is the hypereutectic piston. The piston is an important component of a piston engine and of hydraulic pneumatic systems (Smart 2006).

Piston heads form one wall of an expansion chamber inside the cylinder. The opposite wall, called the cylinder head, contains inlet and exhaust valves for gases.

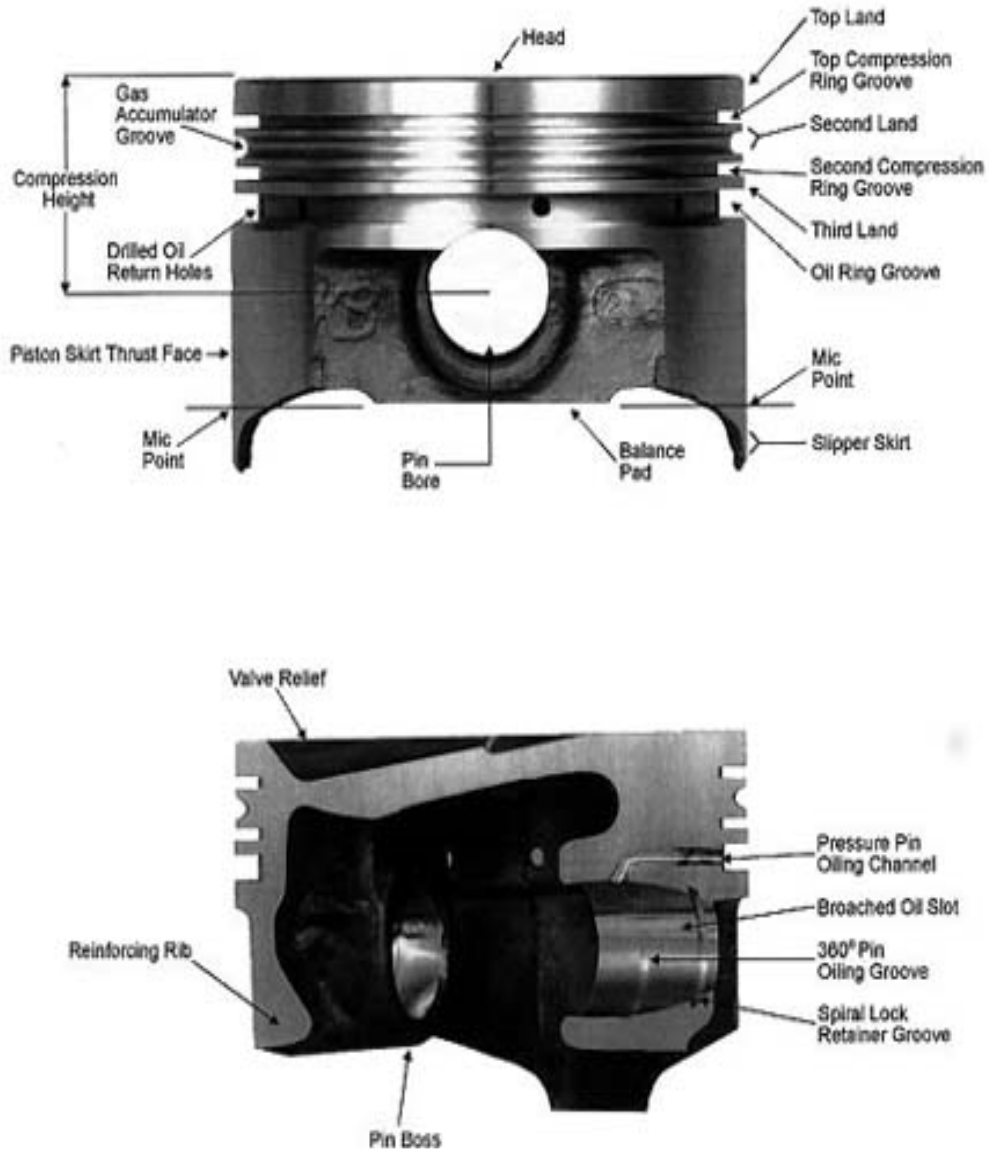

Figure 2.1: The part of the piston. That are consists of many parts that be assemble.

Source: NASIOC (2008)

As the piston moves inside the cylinder, it transforms the energy from the expansion of a burning gas usually a mixture of petrol or diesel and air into mechanical power in the form of a reciprocating linear motion. From there the power is conveyed through a connecting rod to a crankshaft, which transforms it into a rotary motion, which usually drives a gearbox through a clutch (AutoZentro 1990).

2.3 TYPES OF PISTON

On this new modern century, many type of piston that have been design or already in the market. Every type of piston has their capability and also has limitation. Some of these types will now be considered (Stratman 2010).

2.3.1 Two-Stroke Piston

Figure 2.2 shows two stroke piston that be made by casting process. These pistons are mainly used in gasoline and diesel engines for passenger cars under heavy load conditions. They have cast-in steel strips but are not slotted. As a result, they form a uniform body with extreme strength.

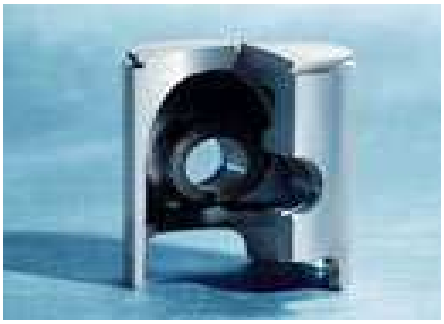

Figure 2.2: Two stroke piston.

2.3.2 Cast Solid Skirt Piston

Cast solid skirt pistons have a long service life. Furthermore this piston more useable that can be used in gasoline and diesel engines. Besides that, their range of applications extends from model engines to large power units as shown in Figure 2.3. Piston top, ring belt and skirt form a robust unit.

Figure 2.3: Piston cast solid skirt piston.

2.3.3 Forged Solid Skirt Piston

For this piston as shown in Figure 2.4, there are made by forged process that gives the piston more strength. This type of piston can mainly be found in high performance series production and racing engines. Besides that, due to the manufacturing process, they are stronger and therefore allow reduced wall cross-sections and lower piston weight. Also, due to relative manufacturing procedures, forged pistons tend to be more expensive than other process.

Figure 2.4: Forged solid skirt piston.

2.3.4 Hydrothermik Piston

For this type of piston as shown in Figure 2.5, that gives very quiet running pistons are used primarily in passenger cars. On the other hand, the pistons have cast-in steel strips and are slotted at the transition from ring belt to skirt section.

Figure 2.5: Hydrothermik piston.

2.3.5 Hydrothermatik Piston

Mainly, these pistons are used in gasoline and diesel engines for passenger cars under heavy load conditions as shown in Figure 2.6. They have cast-in steel strips but are not slotted. Besides that, they form a uniform body with extreme strength.

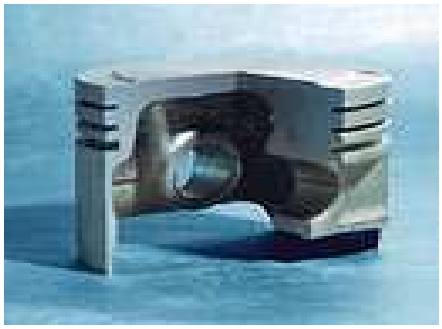

Figure 2.6: Hydrothermatik piston

2.3.6 Ring carrier pistons with pin boss bushes

This type of pistons is for diesel engines as shown in Figure 2.7. There have a ring carrier made from special cast iron that is connected metallically and rigidly with the piston material in order to make it more wear resistant, in particular in the first groove. Furthermore, the pin boss bushes made from a special material, the load-bearing capacity of the pin boss is increased.

Figure 2.7: Piston ring carrier pistons with pin boss bushes.

2.3.7 Ring carrier pistons with cooling channel

These types of piston that ring carrier pistons with cooling channel are used in conditions with particularly high operating temperatures as shown in Figure 2.8. Because of the high temperatures at the piston top and the ring belt, intensive cooling is provided with oil circulating through the cooling channel.

Figure 2.8: Piston ring carrier pistons with cooling channel.

2.3.8 Ring carrier pistons with cooling channel and crown reinforcement

This is a piston ring carrier piston with cooling channel and crown reinforcement as shown in the Figure 2.9. These pistons are used in diesel engines under heavy load conditions. For additional protection and to avoid cavity edge or crown fissures, these pistons have a special hard anodized layer (HA layer) on the crown.

Figure 2.9: Ring carrier pistons with cooling channel and crown reinforcement

2.3.9 Pistons with cooled ring carriers

For these pistons, ring carriers and cooling channels are combined into one system in a special production process as can say that is combination of ring carrier pistons with cooling channel and ring carrier pistons with cooling channel and crown reinforcement as shown in Figure 2.10. Besides that, this provides the pistons with significantly improved heat removal properties, especially in the first ring groove**.**

Figure 2.10: Pistons with cooled ring carriers.