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JUDUL: <u>MODIFICATION OF PISTON SKIRT DESIGN</u>

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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 the degree of Bachelor of Mechanical Engineering.

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MODIFICATION OF PISTON SKIRT DESIGN

AHMAD SHAHRIL ASHRAF MOHAMED

A report is submitted in fulfillment
of the requirements for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
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APRIL 2008

STUDENT DECLARATION

I declare that this thesis entitled "*Modification of Piston Skirt Design*" is the result of my own research except as cited in the reference. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	: ....
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Date	: 6 May 2008

Dedicated to my beloved

Mother,

Sisters,

Brothers, and

My Father

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I feel grateful to Allah S.W.T because this project has successfully completed. In completion this final year project, I was in contact with many people that contributed toward my understanding and problem solving. In particular, I wish to express my sincere appreciation to my project supervisor, Mr. Azizuddin Abd Aziz for his guidance, advice and encouragement.

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Not forgetting my mother in giving me lots of supports in the aspects of moral, social and financial during my degree. This project definitely not exists without full encouragement from her.

ABSTRACT

Piston skirt wear is one of the main failure mechanisms affecting the life of automotive engines. Wear occur during operation because insufficient of lubricant oil in cylinder, over heat, connecting-rod non-alignment and other possible cause. At higher temperature the friction will increase because the piston skirt will expand. This friction can produce wear and scratch at piston skirt. The increase the friction will decrease effect the power output. The objectives of this project; is to design the new piston skirt can stand with high temperature and also can reduce the friction between piston skirt and cylinder wall. The scope of this project is to simulate the original piston skirt using SolidWork software, design three alternative piston skirt designs and to analyze and simulate the new design using Finite Element Analysis (FEA) software known as ALGOR software for failure analysis. From the calculation, the average temperature in combustion chamber is about 548 ^{o}C. Design – Three is proved to be the best alternative design with the modulus elastic of 2.62 x 10^9 N/m^2 . It is observed that at the original piston, high stress exist at the rib and curve of the piston and also high friction occur. In all alternative design piston skirt, the design has minimized the rib and curve at all piston skirt to reduce stress and this will also to reduce friction between piston skirt and cylinder wall.

ABSTRAK

Skirt piston haus salah satu kegagalan mekanisma yang memberi kesan kepada jangka hayat bagi sesebuah automotif enjin. Kehausan terjadi ketika beroperasi ialah disebabkan kegagalan daripada minyak pelincir di dalam gerek silinder, panas terlampau,tidak penjajaran rod pengubung, dan sebab-sebab lain. Pada suhu yang tinggi, geseran akan meningkat kerana pengembangan pada skirt piston. Geseran menghasilkan kehausan dan calar pada skirt piston. Meningkatnya geseran akan menyebabkan pengurangan kuasa keluaran. Objektif projek ini ialah untuk mereka baru skirt piston yang boleh bertahan dengan suhu tinggi dan juga boleh mengurangkan geseran di antara skirt piston dengan dinding silinder. Skop dari projek ini ialah untuk simulasi pada skirt piston yang asli dengan menggunakan perisian SolidWork, tiga rekaan alternatif skirt piston analisis dan simulasi pada rekaan baru skirt piston menggunakan perisian Finite Element Analysis (FEA) yang dikenali sebagai perisian ALGOR untuk menganalisis kegagalan. Daripada pengiraan, suhu purata di dalam ruang pembakaran ialah 548 ^{0} C. Rekaan ketiga membuktikan sebagai yang terbaik bagi alternatif rekaan dengan modulus elastik 2.62 x 10^9 N/m^2. Ianya dari permahatian pada piston asli, tekanan paling tinggi berlaku pada rusuk dan garisan lengkung dan pada geseran tinggi. Di dalam kesemua rekaan alternatif skirt piston, rekaan dibuat untuk meminimumkan rusuk dan garis lengkung pada kesemua skirt piston untuk mengurangkan tekanan dan ianya juga untuk mengurangkan geseran antara skirt piston dan dinding silinder.

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C_p	Specific heat of constant pressure
C_v	Specific heat of constant volume
N	Engine speed
P	Pressure
P	Power
Q_{HHV}	Higher heating value
Q_{LHV}	Lower heating value
R	Gas constant
T	Temperature
T_o	Standard temperature
V	Cylinder volume
V_{BDC}	Cylinder volume at bottom dead center
V_d	Displacement volume
V_{TDC}	Cylinder volume at top dead center
W	Work
k	Ratio of specific heats
m	Mass
m_a	Mass of air
m_f	Mass of fuel
m_m	Mass of gas mixture
n_r	Number of crank revolutions
q	Heat transfer per unit mass

r_c	Compression ratio
v	Specific volume
v_{BDC}	Specific volume at bottom dead center
v_{TDC}	Specific volume at top dead center
w	Specific work
η_t	Thermal efficiency
ρ	Density

LIST OF ABBREVIATION

BDC	Bottom dead center
mep	Mean effective pressure
pmep	Pump mean effective pressure
SI	Spark ignition
TDC	Top dead center
WOT	Wide open throttle

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CHAPTER 1

INTRODUCTION

1.1 General

Pistons are designed to resist high combustion temperature and their piston rings have to seal against high combustion pressure. There are a number of variations in piston design, which include shape, mass, provision for expansion, skirt design, and type of material.

Pistons are made of cast iron or aluminum alloy. Aluminum alloy pistons are used in petrol and smaller diesel engine because they are much lighter than cast iron piston. However, aluminum has a greater rate of expansion than the cast iron cylinder in which most pistons operate. Because of this, aluminum alloy pistons are specially designed to control expansion. Aluminum pistons are either forged or cast. Cast pistons are made by pouring molten aluminum into molds. Forged pistons are "hammered out" [3] from slugs of aluminum alloy.

1.2 Background Project

At a pistons, piston skirt useful to prevent piston slap and vibration in operating condition. When force distribution from combustion chamber to piston head, the skirt as method to give piston stability. Other function of piston skirt is to prevent the blowby through to the engine.

1.3 Problem Statements

During combustion stroke, the temperatures in combustion chamber will increase and produce friction between piston skirt and cylinder wall. At higher temperature the friction will increase because the piston skirt will expand. This friction can produce wear and scratch at piston skirt. The increase the friction will decrease effect the power output.

1.4 Objectives of Project

The objectives of this project;

i. To design the new piston skirt can stand with high temperature and also can reduce the friction between piston skirt and cylinder wall.
ii. To determine the stress for the new piston skirt design.

1.5 Project Scope

The scope of this project is as listed below:

i. Simulate the original piston skirt using SolidWork software.

ii. Design three alternative piston skirt designs.

iii. Analyze and simulate the new design using Finite Element Analysis (FEA) software known as ALGOR software for failure analysis.

1.6 Outline

Chapter 1 is explanation about introduction of the project. In this chapter also include the objectives and scope of the project.

Chapter 2 discusses on the literature review of piston skirt characteristic, and temperature distribution. This study based on the journals and text books.

Chapter 3 provides the project methodology for design piston skirt. Also for design the new piston skirt using Solid Work software and to analyze about influence of temperature distribution to piston skirt by using Finite Element Analysis (FEA) software known as ALGOR software for failure analysis.

Chapter 4 discuss about structure analysis of piston skirt finite element analysis software known as ALGOR. All the result of the structure simulation is show in this chapter.

Finally, Chapter 5 concludes the result of and simulation. The recommendation is provided for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of chapter two is to explain about the piston function to the engine and also to how temperature distribution at piston. This chapter also discusses about the effect to the piston skirt when the temperature distribute at all area of piston skirt be understand through mechanical automotive studies. This chapter will also show about the analysis on piston skirt. In addition, in order to analysis the piston skirt, a few types of element that must be determine such as material, and type of piston skirt design.

A piston is slightly smaller in diameter than the cylinder in which it operates. This gives it a working clearance of about 0.02 mm to 0.05 mm. If the piston has insufficient clearance, there will be no room for the piston to expand when it is hot and it will tend to seize on the cylinder wall. This would score both the piston and cylinder.

During the power stroke, up to 18,000 N of force is suddenly applied to the piston head. This happen 30 to 40 times a second to each piston at highway speed. Temperatures above the piston head reach 2204°C or high. Piston must be strong to take these stresses. They must also be light to reduce inertia loads on the bearing. [1]

2.2 Material of the piston

Figure 2.1 shows an aluminum piston used in automotive internal-combustion engine. These products must be manufactured at very high rates with very tight dimensional tolerance and strict material requirement in order to achieve proper operation. Economic concerns are obviously paramount, and it is essential that pistons be produced with a minimum of expensive finishing operations and with few rejected part.

Aluminum pistons are manufactured through casting because of its capability to produce near-net shaped part at the required production rates. However, with poorly designed molds, underfills or excess porosity can cause parts to be rejected, adding cost. These defects were traditionally controlled through the use of large machining allowances coupled with the intuitive design of molds based on experience.

The pistons are produced from high-silicon alloys, such as 413.0 aluminum alloy. This alloy has high fluidity and can create high-definition surface through permanent mold casting, it also has high resistance to corrosion, good weldability, and low specific gravity. The universal acceptance of aluminum piston for internal combustion engine application is due mainly to their light weight and high thermal conductivity. Their low inertia allows for higher engine speeds and reduced counterweighting in the crankshaft and the higher thermal conductivity allows for more efficient heat transfer from the engine. [10]

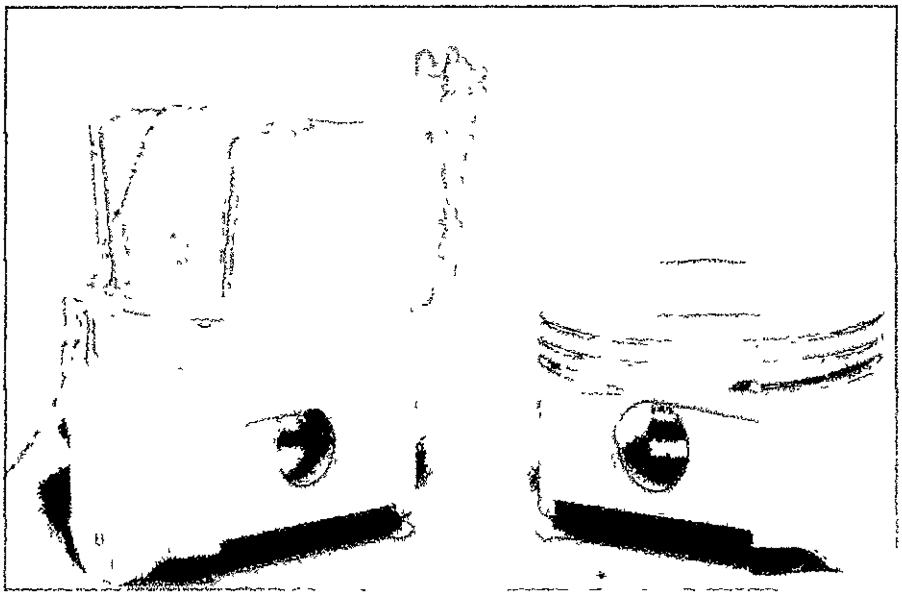


Figure 2.1: Aluminum 413.0

2.3 Case study

The first is to choose the type of the piston in four stroke engine as a case study. GN5 100cc four stroke engine types or EX5 dream will selected for doing in this analysis show in Figure 2.2. For this engine type it used air cooled system and, 4 cycle engine OHC. Other wise this engine type is has compress ratio about 9: 1 and the maximum torque is about 0.93 kg.m / 6000 rpm. [12]

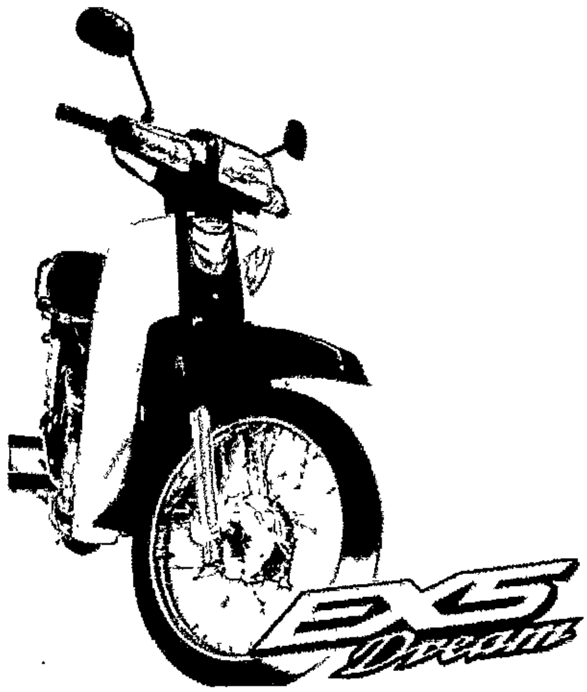


Figure 2.2: Model GN5 100cc EX5 Dream

There are a number of variations in piston design, which include shape, mass, provision for expansion, and type of material. Pistons are made of cast iron or aluminum alloy. Aluminum alloy pistons are used in petrol and smaller diesel engines because they are much lighter than cast iron pistons. However, aluminum has a greater rate of expansion than the cast iron cylinders in which most pistons operate. Because of this, aluminum alloy pistons are specially designed to control expansion.

This GN5 model 100cc also is made from aluminum alloy. By the way GN5 used the cast iron cylinder block. This cylinder block has diameter about 50mm cylinder, and stroke is about 49.5 mm. Figure 2.3 show that the GN5 cylinder block.

Figure 2.3: GN5 cylinder block

Figure 2.4 show the type of piston GN5, and this piston usually can be installed in engine 70cc because it suitable for all type of Boon Siew – Honda engine. This diameter of this piston is 50mm, and length is about 49.5mm

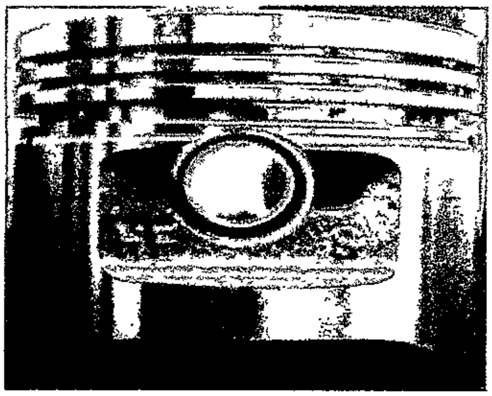


Figure 2.4: GN5 piston

2.4 Otto cycle

The cycle of a four-stroke, SI naturally aspirated engine at WOT is shown Figure 2.5. This is the cycle of most automotive engine and other four-stroke SI engines.

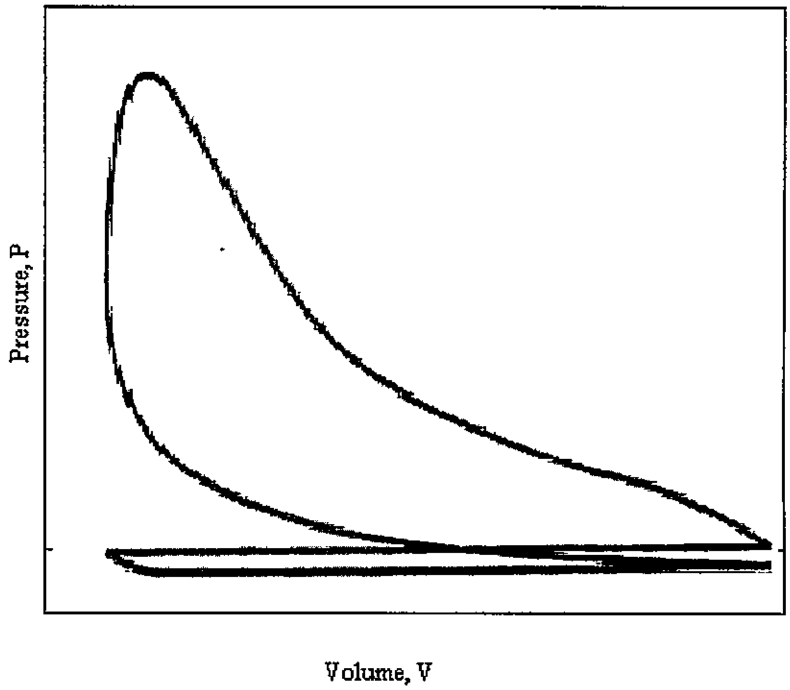


Figure 2.5: Indicator diagram for a typical four stroke cycle SI engine

The intake stroke of the Otto cycle starts with the piston at TDC and is a constant-pressure process at an inlet pressure of one atmosphere. This is good approximation to the inlet process of a real engine at WOT, which will actually be at a pressure slightly less than atmospheric due to pressure losses in the inlet air flow. The temperature of the air during the inlet stroke is increased as the air passes through the hot intake manifold. The temperature at point 1 will generally be on the order of 25° to

35°c hotter than the surrounding air temperature. The process will show in Figure 2.6. [3]

The second stroke of the cycle is the compression stroke, which in the Otto Cycle is an isentropic compression from BDC to TDC (process 1-2). In this process, the air/fuel mixture will compress. The end of compression is affected by the firing of the spark plug before TDC.

The compression stroke is followed by a constant-volume heat input process 2-3 at TDC. This replaces the combustion process of the real engine cycle, which occurs at close to constant- volume conditions. During combustion or heat input, a large amount of energy is added to the air within the cylinder. This energy raises the temperature of the air to very high values, giving peak cycle temperature at point 3. This increase in temperature during a closed constant- volume process result in a large pressure rise also.

The very high pressure and enthalpy values within the system at TDC generate the power stroke which follows combustion. High pressure on the piston face forces the piston back towards BDC and produces the work and power output of the engine.

The last stroke of the four- stroke cycle now occurs as the piston travels from BDC to TDC. Process 5-6 is the exhaust stroke that occurs at a constant pressure of one atmosphere due to the open exhaust stroke, which occurs at a pressure slightly higher than the surrounding pressure due to the small pressure drop across the exhaust valve and in the exhaust system.

2.4.1 Temperature analysis

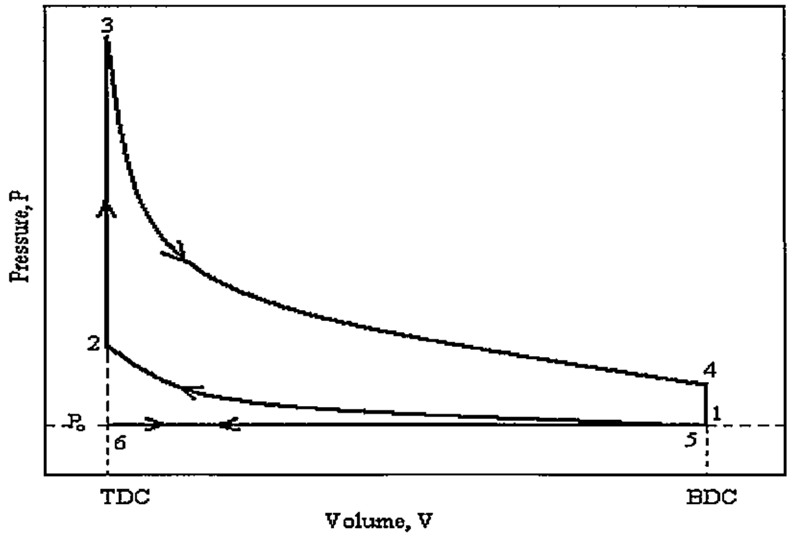


Figure 2.6: Ideal air-standard Otto cycle

In air-standard cycles, air is considered an ideal gas such that the following ideal gas relationships can be used:

$$Pv = \mathrm{RT}$$
$$PV = \mathrm{RT}$$
$$P = \rho \mathrm{RT}$$

Process 6-1 constant-pressure intake of air at P_0

Intake valve open and exhaust valve closed:

$$P_1 = P_6 = P_o$$
$$w_{6\text{-}1} = P_o\ (v_1 - v_2)$$

Process 1-2 compression stroke

All valve closed:

$$T_2 = T_1\ (v_1/v_2)^{k-1} = T_1\ (V_1/V_2)^{k-1} = T_1\ (r_c)^{k-1}$$

$$q_{1-2} = 0$$

k is specific heat ratio C_p/C_v

$$k = 1.4$$

r_c is compression ratio $V_1/V_2 = v_1 - v_2$

$$w_{1-2} = (P_2 v_2 - P_1 v_1) / (1 - k) = R\ (T_2 - T_1) / (1 - k)$$

Process 2-3 constant-volume heat input (combustion).

All valves closed:

$$v_3 = v_2 = v_{TDC}$$

$$w_{2-3} = 0$$

$$Q_{2-3} = Q_{in} = m_f Q_{hv} \eta_c = m_m C_v (T_3 - T_2)$$

$$= (m_a + m_f) C_v (T_3 - T_2)$$

$$Q_{hv} \eta_c = (AF + 1)\ C_v (T_3 - T_2)$$

$$q_{2-3} = q_{in} = C_v (T_3 - T_2)$$

$$T_3 = T_{max}$$

$$P_3 = P_{max}$$

Process 3-4 power or expansion stroke.

All valves closed:

$$q_{2-3} = 0$$

$$T_4 = T_3 (v_3/v_4)^{k-1} = T_3\ (V_3/V_4)^{k} = T_3\ (1/r_c)^{k-1}$$

$$P_4 = P_3 (v_3/v_4)^{k} = P_3 (V_3/V_4)^{k} = P_3\ (1/\ r_c)^{k-1}$$

$$w_{3-4} = (P_4 v_4 - P_3 v_3)/(1 - k) = R(T_4 - T_3)/(1 - k)$$
$$= C_v (T_3 - T_4)$$

Process 4-5 constant-volume heat rejection (exhaust blowdown).

Exhaust valve open and intake valve closed:

$$v_5 = v_4 = v_{BDC}$$
$$w_{4-5} = 0$$
$$Q_{4-5} = Q_{out} = m_m C_v(T_5 - T_4) = m_m C_v(T_1 - T_4)$$
$$q_{4-5} = q_{out} = m_m C_v(T_5 - T_4) = C_v(T_1 - T_4)$$

Process 5-6 constant-pressure exhaust stroke at P_o

Exhaust valve open and intake valve closed:

$$P_5 = P_6 = P_o$$
$$w_{5-6} = P_o(v_6 - v_5) = P_o(v_6 - v_1)$$

Thermal efficiency of Otto cycle:

$$(\eta_t)_{OTTO} = |w_{net}|/|q_{in}| = 1 - (|q_{out}|/|q_{in}|)$$
$$= 1 - [C_v(T_1 - T_4)/ C_v(T_3 - T_2)]$$
$$= 1 - [(T_4 - T_1)/ (T_3 - T_2)]$$

Only cycle temperature need to be known to determine thermal efficiency. This can be simplified further by applying ideal gas relationships for the compression and expansion strokes and recognizing that $v_1 = v_4$ and $v_2 = v_3$:

$$(T_2/T_1) = (v_1/v_2)^{k-1} = (v_4/v_3)^{k-1} = (T_3/T_4)$$

Rearranging the temperature terms gives

$$T_4/T_1 = T_3/T_2$$
$$(\eta_t)_{OTTO} = 1 - (T_2/T_1) \{[(T_4/T_1) - 1]/ [(T3/T_2) - 1]\}$$
$$(\eta_t)_{OTTO} = 1 - (T_2/T_1) = 1 - [1/(v_1/v_2)^{k-1}]$$

$$(\eta_t)_{OTTO} = 1 - (1/r_c)^{k-1}$$

$$(\eta_t)_{OTTO} = \frac{W_{net}}{q_{in}}$$

Only the compression ratio is needed to determine the thermal efficiency.

2.4.2 Mean Effective Pressure

Pressure in cylinder is continuously changing during the cycle. An average or mean effective pressure (mep) is defined by

$$w = (\text{mep})\Delta v$$

Or

$$\text{mep} = w/\Delta v = W/V_d$$

$$\Delta v = v_{BDC} - v_{TDC}$$

W = work of one cycle

w = specific work of one cycle

Or

$$\text{mep} = \frac{P \times n_r \times 10^3}{Vd \times N}$$

2.5. Piston type

Pistons are designed to resist high combustion temperature and their piston rings have to seal against high combustion pressures. Connecting rods have to withstand high stress as they transfer the reciprocating motion of the pistons to the cranks of the crankshaft.

The piston, piston rings, piston pin, connecting rod and the bearing form the piston and connecting- rod assembly. The various part are identified in Figure 2.7

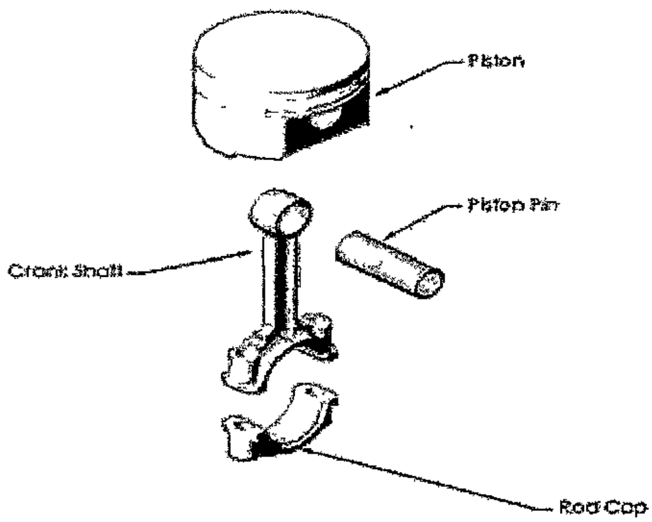


Figure 2.7: Piston and connecting-rod assembly

2.5 1 Piston skirt design

A piston in running engine is acted upon by the gas pressure and forces of inertia, which are variable in magnitude and direction, as well as by lateral force which press the piston against the cylinder wall. Uneven heating of the piston in radial direction and in height induces additional internal thermal stresses.

2.5.2 Type piston skirt

In most carburetor engine pistons, the ring belt is usually separated from the skirt by two symmetrical transverse slots show in Figure 2.8, which prevents heat rejection from the crown towards the skirt. Both part of the piston are connected only in the region of the bosses. The heat from the crown is transferred to the supplied to the skirt, the clearances between it and the liner can be slots reduce the rigidity of the piston. Slotted pistons are not used with high combustion pressures. [4]

In such design the skirt is made without longitudinal slots. This increases the contact area between the piston and the liner and makes it possible to reduce the assembly clearances between them, which change only negligibly upon heating. [4]

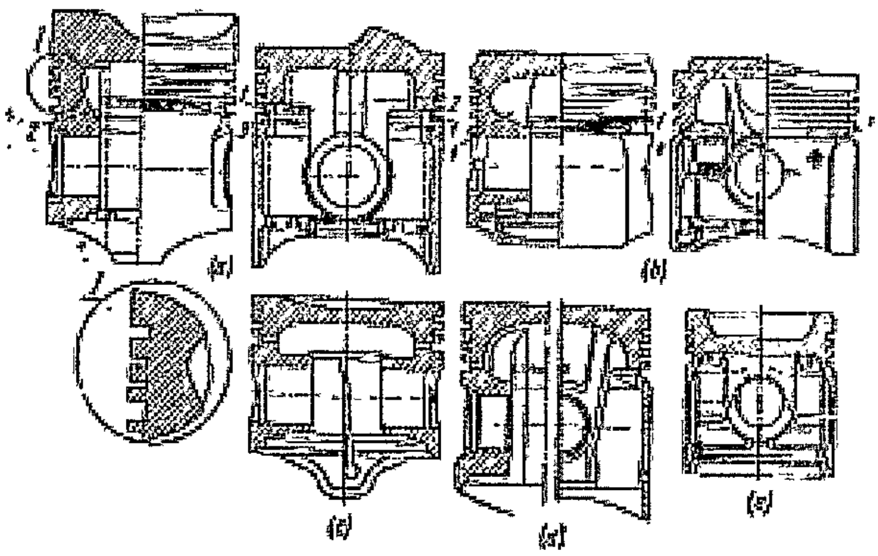


Figure 2.8: Basic skirt design

2.5.3 Type piston skirt design in market

The piston skirt was made lighter in order to lessen the inertial mass. Since lightening the piston causes the piston "neck" to rock back and forth, a molybdenum coating was applied to lessen friction [3]. The piston skirt was made lighter to reduce load on the engine show in Figure 2.9. Lightening the piston in such a way can cause the neck to rock back and forth when a small, uneven amount of friction is applied to the piston. To prevent this, a 5 micron Molybdenum coating was applied to the piston skirts to reduce friction. Shorter piston skirt reduces rubbing friction because of the smaller surface contact area. However, shorter skirts require closer tolerances between the piston and cylinder wall to keep the piston from cocking in the cylinder. [3]

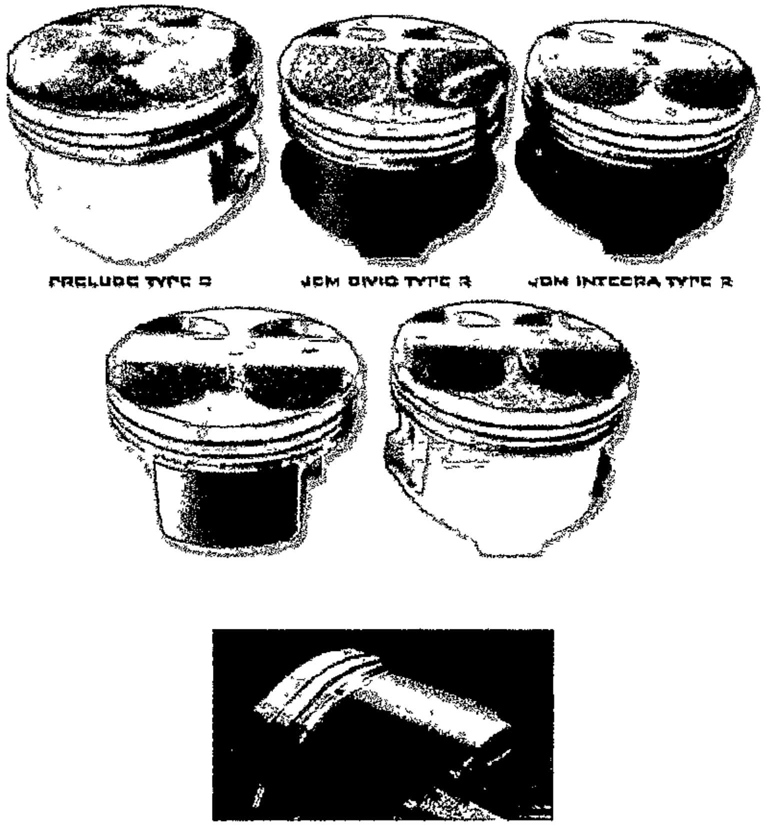


Figure 2.9: Type piston

2.6 Piston Temperature

In process burn the air/fuel mixture in combustion chamber, a heat will produce and the distribution temperature will happening at all entire piston.

2.6.1 Temperature distribution at piston

The piston is subjected to the full effects of combustion and so it has to be resistant to heat. Type operating temperatures are shown in Figure 2.10. In operating conditions, these temperatures can become even higher.

There is a big difference between the temperature of the head of the piston and skirt of the piston. The heat cause expansion and this is greatest at the top of piston. For this reason, the lands at the top of the piston are given extra clearance. They could be as much as smaller in diameter than the skirt. [2]

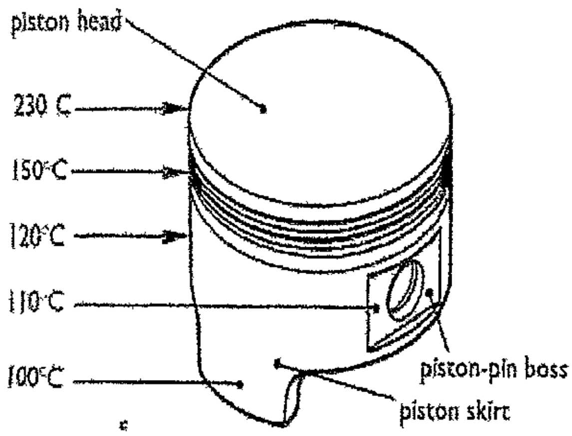


Figure 2.10: A sample of operating temperatures of various part of a piston

2.6.2 Control of Piston Temperature

There are several method used to prevent pistons from expanding excessively. These include cam grinding, using steel struts, controlling the heat path, and oil cooling. All pistons have some means of controlling their temperature and some pistons have more than one.

A piston that is cam-ground is slightly oval in shape. The piston is obtained by relieving some metal in the area of the piston-pin bosses' show in Figure 2.11. This makes the diameter of the piston slightly smaller at piston-pin bosses than at the thrust face. This allows the piston to be fitted to the cylinder with minimum clearance at the thrust sides. The extra clearance provides at the bosses by cam grinding allows for piston expansion. In cam-ground can given about piston warms up, skirt expansion increases the area of contact like show in Figure 2.12.

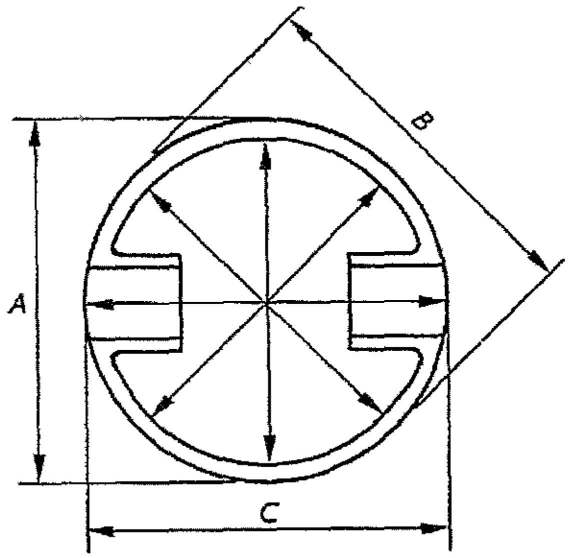


Figure 2.11: Cam-ground piston. A-large diameter, B-extra relief a likely scuffing area. C- smaller diameter.

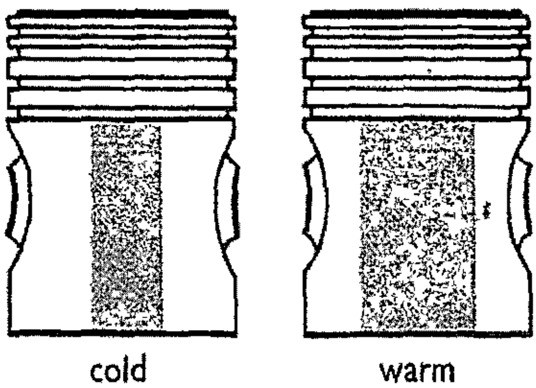


Figure 2.12: Skirt expansion increase the area of contact (shading area)

2.7 Piston thrusts

The piston also has a side thrust during the compression stroke, but this is on the opposite side of the cylinder. Also, this is a lesser thrust because the downward force from compression is much less than the downward force of combustion.

The thrust are sometimes referred to as the major and minor thrusts. Because the thrust during the power stroke (major thrust) is most important, this side of the engine is often referred to as the thrust side of the engine show in Figure 2.13. It is necessary to know about the thrust side of an engine because the piston in most engines has to be engine because the piston in most engines has to be installed in a particular way.

The greater wear occurs in the plane of the connecting rod on the major thrust side of the cylinder. This wear will also vary along the length of the cylinder on both sides. Additional wear to various degrees will occur in the other rotation planes and at various distances along the length of the cylinder. As an engine ages, this wear can become signification in some spots. Even if the cross section of an engine cylinder is perfectly round when the engine is new, wear will erode this roundness with times.

To reduce friction, model engine use piston that have less mass and shorter skirts. Shorter piston skirt reduces rubbing friction because of the smaller surface contact area. [3]

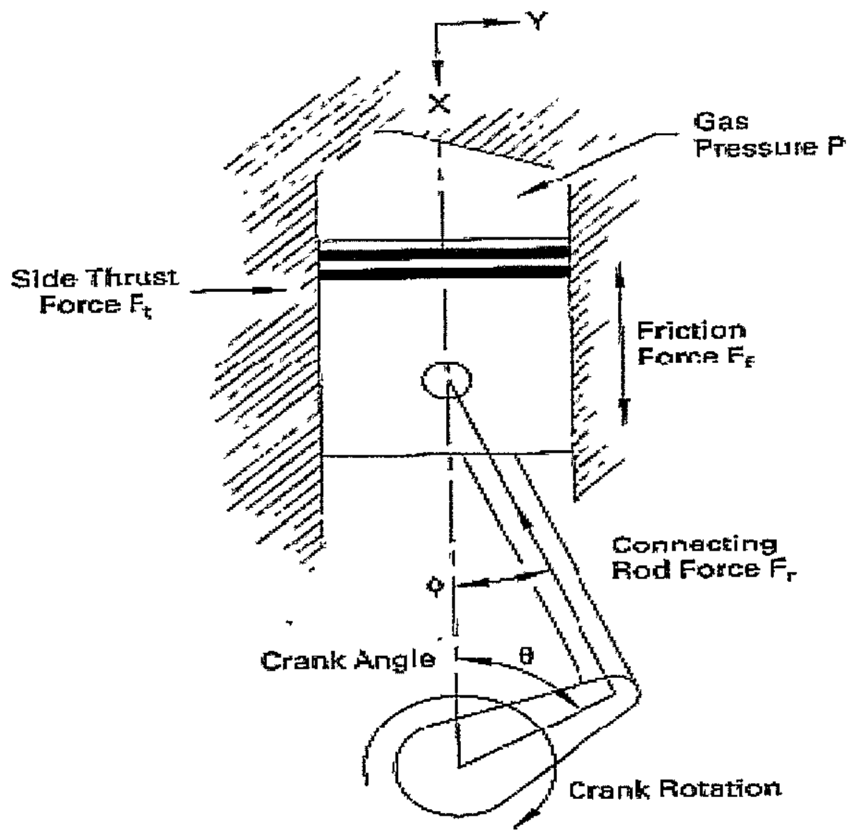


Figure 2.13: Thrust side of the piston

2.8 Piston skirt friction

In operation condition, the piston skirt will produce high friction between skirt and cylinder wall. This friction exist when the piston will resizes and it expanded

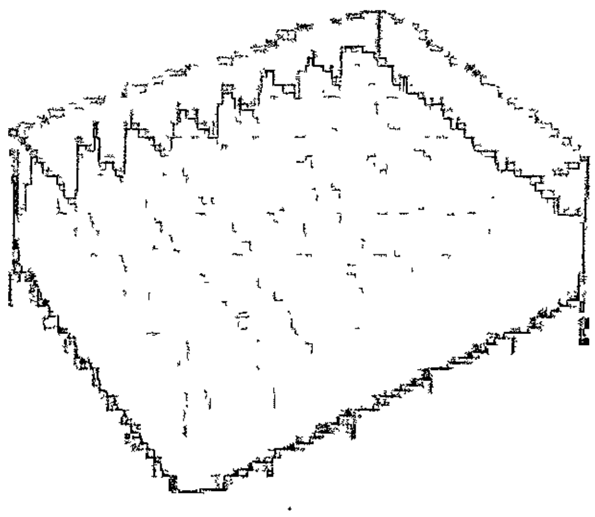
2.8 1 Friction between skirt and cylinder line

When the piston skirt and cylinder bore first contact with each other under the load, the peaks of machining marks start to become flattened due to wear, and the actual contact area becomes larger. This polishing process had also been observed. [6]. At this stage, the oil film pressure is large enough to partially support the normal load, and the skirt/bore contact is in the mixed lubrication regime. The coefficient of friction increases with the increase of load during the break-in stage, which normally takes 6–12 min. After break-in, due to the increase of normal load and contacting temperature, the lubrication condition gradually turns into the boundary lubrication regime.

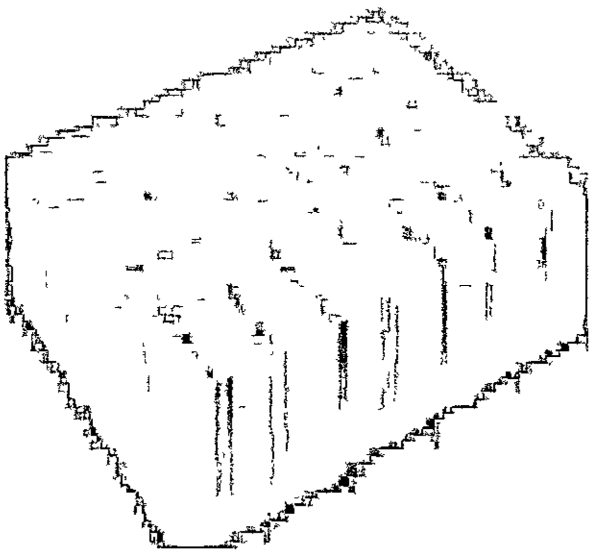
The coefficient of friction remains at a steady level even though load increases periodically. When scuffing occurs, the two metal surfaces directly contact with each other under the oil starvation condition. Surfaces are roughened quickly and the coefficient of friction increases rapidly. This wear to failure process can be seen on the surface of an iron plated piston skirt as shown in Figure 2.14. From the Figure 2.14 show that wear at piston skirt. In there surface contact at skirt it rough refer to red color and after polish the piston skirt, the friction between piston skirt and cylinder wall be reduces.

Further reductions of the clearance below 50 microns did not improve friction; in fact friction increased at very small clearances. Therefore, the potential of varying the piston-to-liner clearance in friction reduction is limited. [7]

The oil film thickness (oil availability and supply) between the piston-skirt and liner has a significant effect on piston-skirt friction power loss. Accordingly, oil film thickness is a strong parameter affecting skirt-friction. [7]



(a)Before test



(b) After polish wear

Figure 2.14: Surface profiles piston skirt: (a) before test; (b) after polish wear

2.8.2 Structure of piston to reduce a friction

Along with the smaller piston pin offset, the skirt area has been expanded toward the periphery with the aim of reducing friction by lowering the skirt surface pressure at top of the center show in Figure 2.15.At Figure 2.15 proved that where doing modification at piston pin can reduce the friction between skirt and cylinder wall when in operation condition. [8]

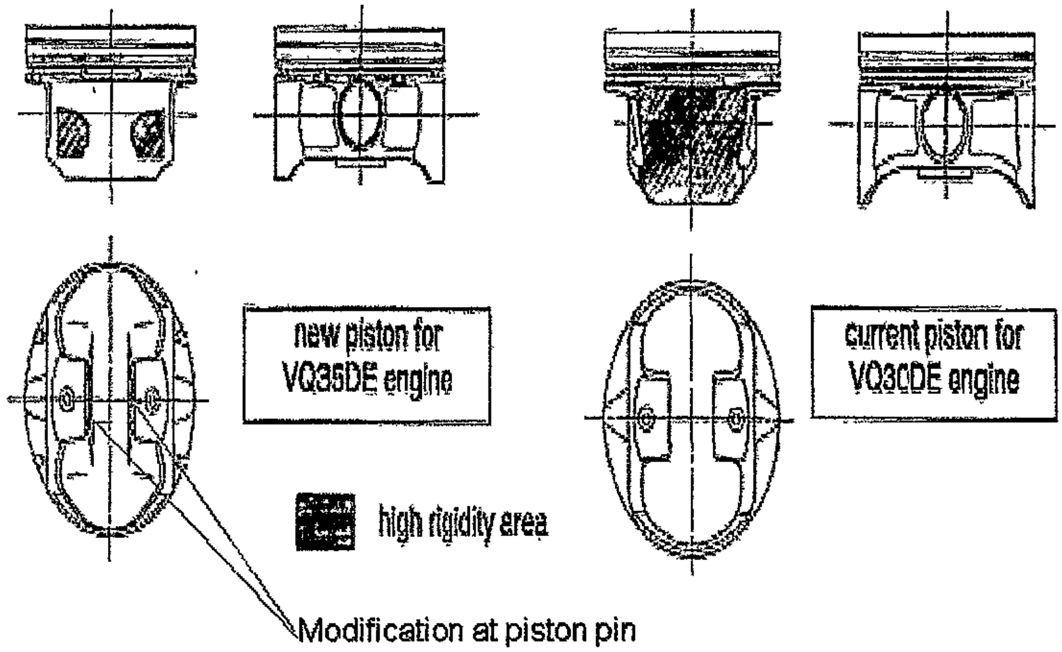


Figure 2.15: Modification at piston pin

2.9 Piston damaged

Piston seizure, with severe damage concentrated in the lower area of piston skirt because damaged concentrated on one face lack of lubrication. The damage on both faces progression of damage caused by lack o lubrication. Insufficient piston to cylinder clearance, cylinder bore distortion and general engine overheating. Figure 2.16 show that effect of seizure at skirt piston.

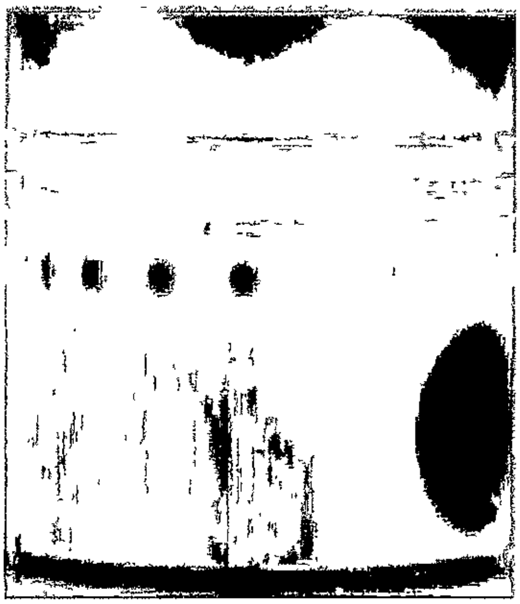


Figure 2.16: Piston skirt damage

2.10 Scuffing at piston skirt

Scuffing is a moved faster in moving object and it can produce the wear at moving object. Piston skirt/cylinder bore scuffing is one of the main failure mechanisms that affect the life of automotive engines.

2.10.1 Scuffing occurred by shortage of engine oil - Thrust side

The scuffing caused by lack of oil starts from around pin and moves to skirt part. The color of piston skirt is partly changing. Mostly, top ring part is not damaged at all. The scuffing caused by lack of oil is different to the scuffing caused by lack of coolant that whole piston skirt is scratched and its damaged part is slight and it shows scratches in certain part. Figure 2.17 show that piston skirt damage because lack of oil.

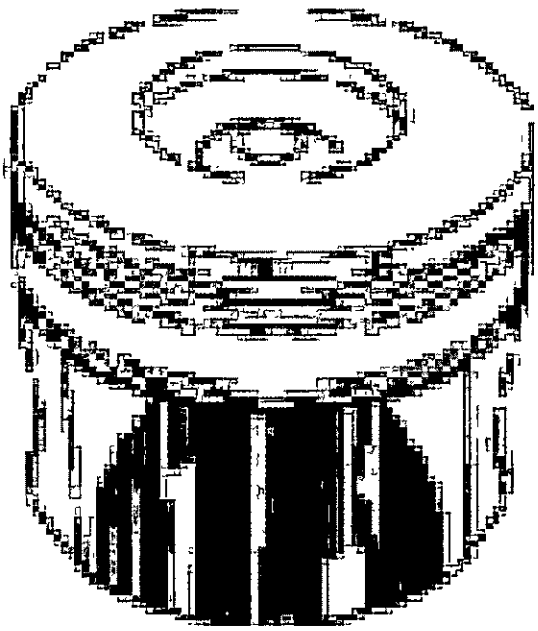


Figure 2.17: Piston skirt damage because thrust side

2.10.2 Scuffing occurred by shortage of engine oil - Antihrust side

It shows trace of accumulated oil in piston and it is no rough and shows delicate texture. The part of piston skirt could be faded. If the defect is founded in early stage, anti-thrust shows light damages in comparison to thrust direction (A part that affected by lateral pressure when engine rotates, side of fuel pump). At this point, it is possible to be seen that wasn't damaged or was damaged very slightly. Figure 2.18 damage the skirt at antihrust side.

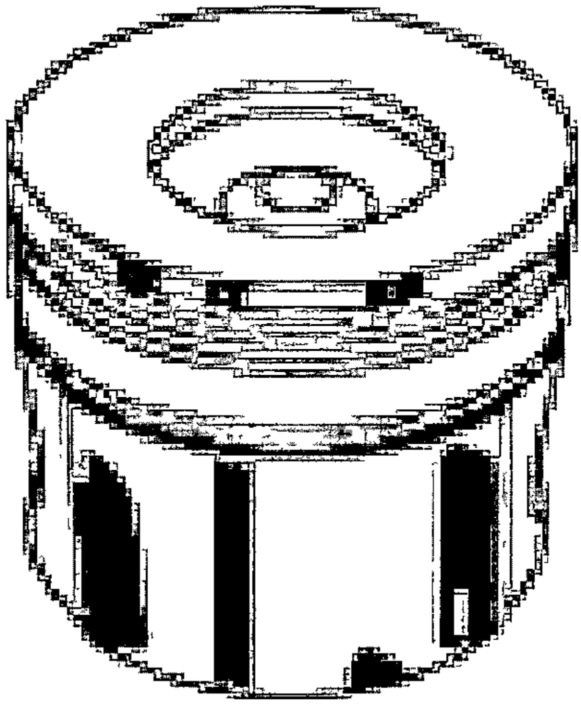


Figure 2.18: Piston skirt damage because antihrust side

2.10.3 Scuffing occurred by shortage of coolant - Thrust side

Scuffing appears whole parts of piston skirt. If operates it for long time in this condition and connected damages are occurred, entire piston will be scratched into direction of cylinder. Scratches with vertical direction are more thick and rough than the lack of oil. Substances taken off from piston moves to upward and it damages surroundings of ring. Wear on ring appears entire part and lower part would be more seriously damaged. Figure 2.19 show that influence scuffing because long time in condition.

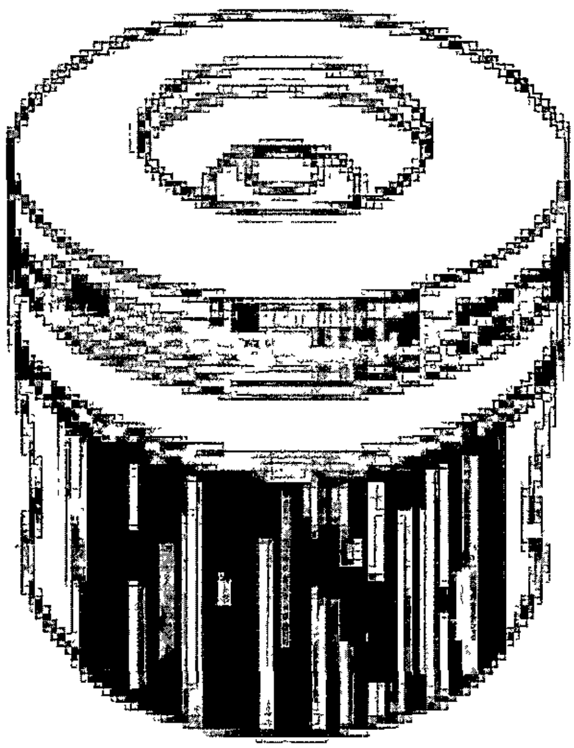


Figure 2.19: Piston skirt damage because thrust side

2.10.4 Scuffing occurred by shortage of coolant: Antihrust side

The degrees of progress are differently shown after defected but it shows very similar result with direction of thrust. According to circumstances, it shows two lines of vertical scratches around both pins. Vertical lines are shown in whole piston from upper to lower parts. Figure 2.20 show influence coolant because the temperature is very high.

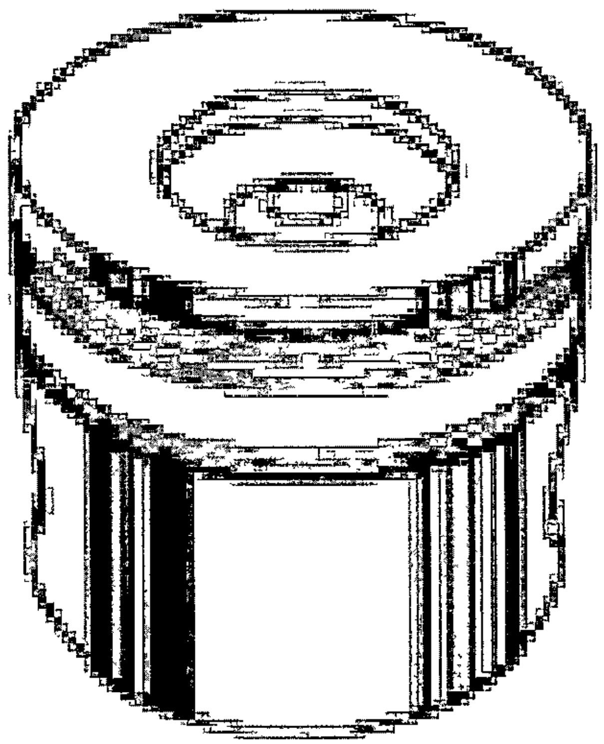


Figure 2.20: Piston skirt damage because antihrust side

2.10.5 Skirt anti-scuffing performance

A load will exits in cylinder, where this load is effect to piston operation. It also has two loads at piston operation like under small loads and under large loads. This load can give an effect to the piston deformation especially at piston skirt. In under a condition of high combustion force generated by a large-bore engine, it is possible to maintain good skirt anti-scuffing performance show Figure 2.21. [8]. The greatest wear occurs in the plane of the connecting rod on the major thrust side of the cylinder. Significant, but less, wear will occur on the minor thrust side. This wear will also vary along the length of the cylinder on both sides. Additional wear to various degrees will occur in the other rotation planes and at various distances along the length of the cylinder. As an engine ages, this wear can become significant in some sports.[3]. In this two figures show that the contact between skirt and cylinder wall influence. From here can see at current skirt has large wear compare at new skirt.

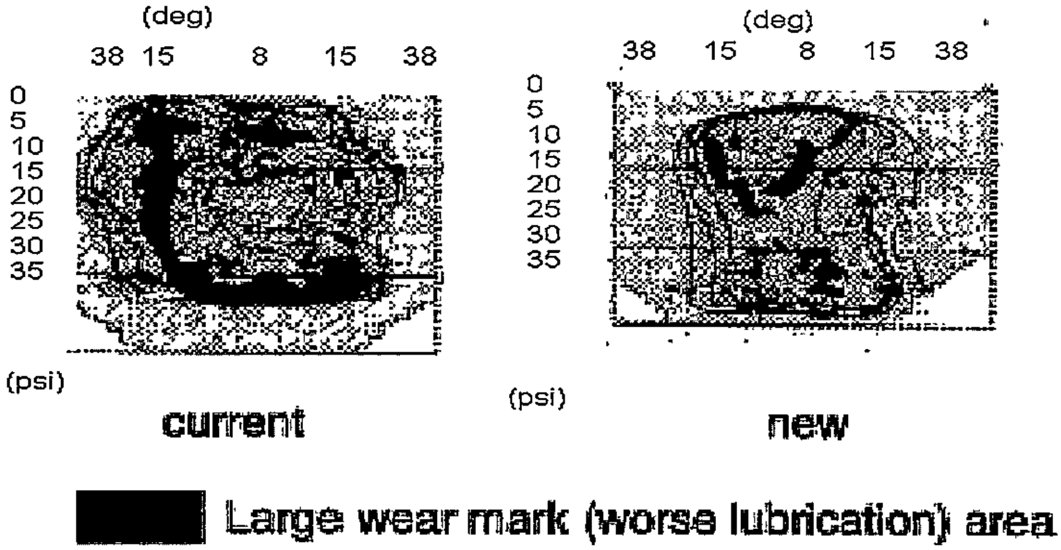


Figure 2.21: Comparison of skirt wear mark distribution

2.11 Pressure and Stress at Piston

This pressure exist in combustion camber and then it transfer to piston head and areas pin piston hole. The bigger influence of this pressure, it can damage the piston pin holes and piston head. It proved by using FEA analysis. Piston running in engine has mechanical fatigue. The mechanical fatigue is in a piston has crack. This fatigue happen because exist critical stressed areas. Stresses as the loads acting externally on the piston. [11]Although stresses on pistons change with piston geometries and engine pressures, Figures show a typical stress distribution on an engine piston and stressed areas. It is not intended to determine the real stresses acting on the piston. The dynamic and thermal stresses are not also included in Figs.2.22. It is clear that there are mainly two critical areas: the top side of piston pin hole and two areas at the piston head. If holes or grooves are introduced on the pin hole it is possible to introduce critical stressed areas on those discontinuities.

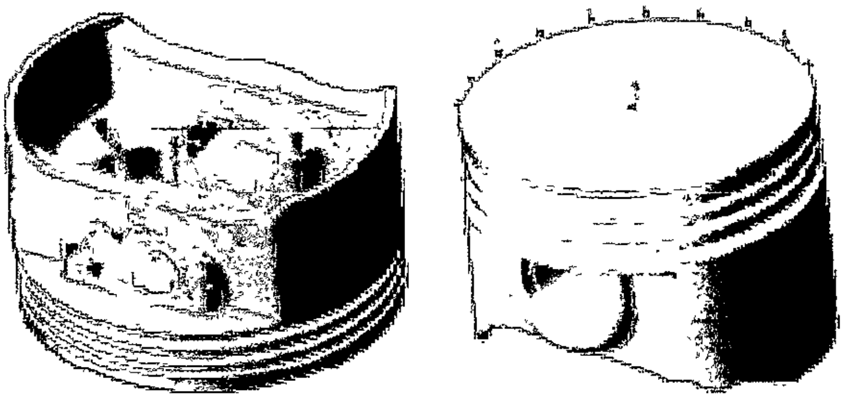


Figure 2.22: Pressure at head area and restrains at piston pin hole

2.12 FEA: Finite Element Methods software

It also refers to finite element method (FEM). It is one of the CAE tools. It is a numerical method for solving engineering problem and physics. FEA useful for problems with complicated geometries, loadings and material properties, where analytical solutions cannot be obtained.

Commercial FE software has many types to doing analysis like ABAQUS, ALGOR, ANSYS, COSMOS, MSC/NASTRAN, LS-DYNA, and many more have related with FE software.

Figure 2.23 shows the symmetry analysis will doing in finite element (ALGOR). In solid body under stress is a solid of revolution. The result from analysis we can take half of the result.[10]. In any symmetry drawing, the result we can consider at symmetry of the result.

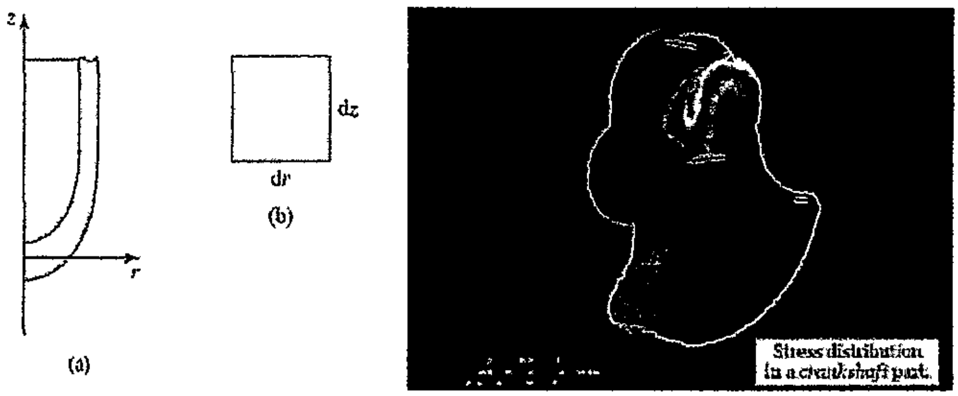


Figure 2.23: Half result from analysis

CHAPTER 3

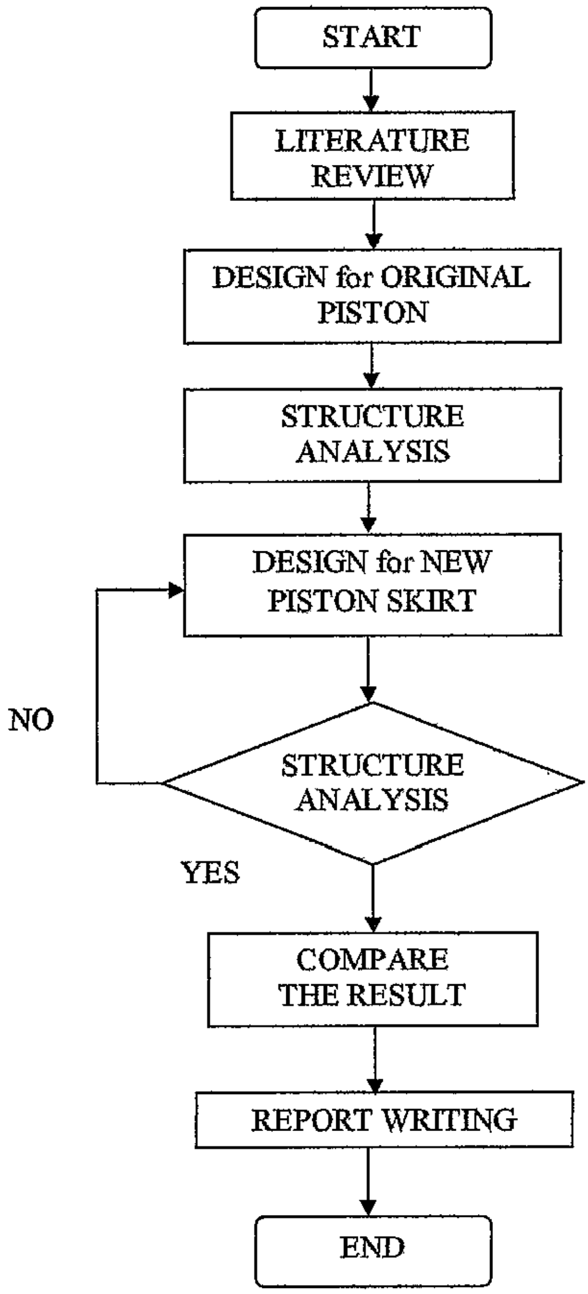
METHODOLOGY

3.1 Project Methodology

Project methodology play important role in order to design the new piston skirt. It is because this project methodology becomes a guideline for the overall project progress from the beginning until finish. Before start design the piston skirt, the function and characteristic of the piston skirt should be known. So, at the beginning of the project, some research and literature review about piston skirt is important to enhance the knowledge.

Generally, this project involves of designing and analysis influence the temperature distribution for strain-stress to the piston skirt. Virtually the drawing process is designed by Solid Work.

It was analyzed using Finites Element Analysis software (ALGOR). This Finites Element Analysis software (ALGOR) important to ensure that the strain-stress to piston because influence the temperature. The simulation and analysis of the new design using Finite Element Analysis (ALGOR) software also enclosed together in report writing. Figure 3.1 shows the flow chart of project methodology.



Study and gather information related to piston skirt and select the model piston. Search for material and influence the temperature distribution for stress to piston skirt

Get the dimension of the piston and draw by using Solid Work software, also install the piston in cylinder block to doing running-in to determine the wear at piston skirt

Analyze and simulate design structure using finite element analysis (ALGOR) software for failure analysis

Draw the new piston skirt by using Solid Work software after determine the wear at piston skirt

Analyze and simulate design structure using finite element analysis (ALGOR) software for failure analysis

Doing a comparison between the original piston skirt with the new piston

Write a report include of literature review, project methodology, result, discussion and conclusion

Figure 3.1: Flow chart of project methodology

3.2 Literature review

Literature review was studied about type of the model and specification to used in this analysis and also discuss about Otto cycle. From Otto cycle it helps to determine average temperature in engine 100c. Other wise, in this literature also take about temperature assumption and operation of the piston.

In previous studies, piston has many type skirt design and it include about many type piston temperature distribution depend on type of engine. In a engine, the piston has major and minor thrust at piston side and in there exist the friction between skirt and cylinder wall and also at there produce the wear.

Other, piston will damage influence of scuffing at skirt and influence of wear can damage the piston. At piston existed pressure and stress. Both pressure and stress acting at head of piston head and piston pin. Beside that, for this analysis aluminum as are material to used to analyze and material will used in this analyze is aluminum 413.0 has good modulus elastic. In doing analyze, many software can determine about stress, but in this project, FEA-ALGOR as method as using to analyze this piston.

3.3 Simulate of Original Piston

First step is get the dimension of the piston to doing the design, and usually a basis to mention for this GN5 piston is about height is about 45mm and diameter is about 50mm also for the weight 84 gram. Figure 3.2 show how to determine the dimension of piston.

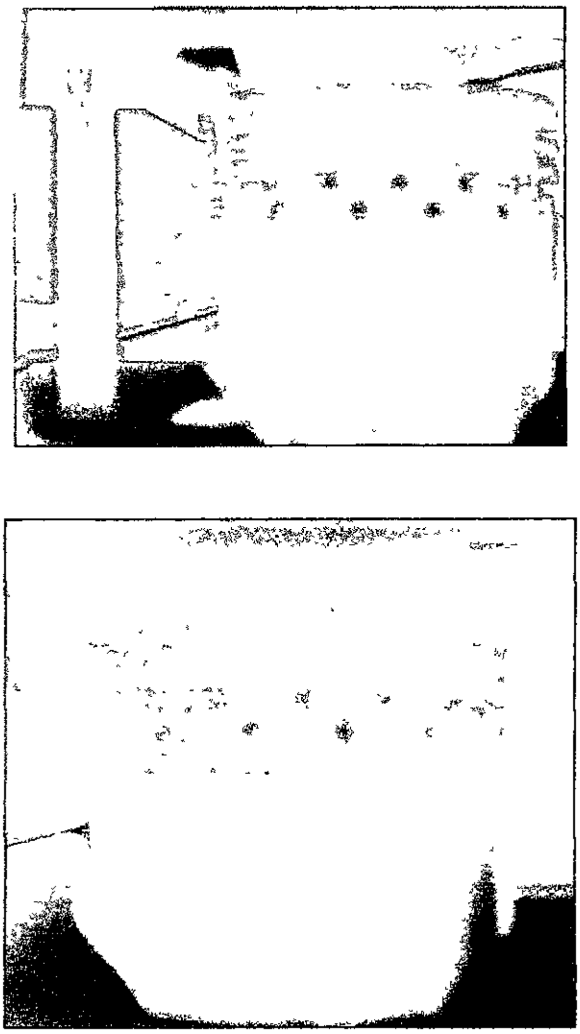


Figure 3.2: GN5 piston

Drawing can be doing after consider all parameter of the piston like height, diameter of the piston at outside and inside diameter of piston. It shows in Figure 3.3, 3D drawing of GN5 piston.

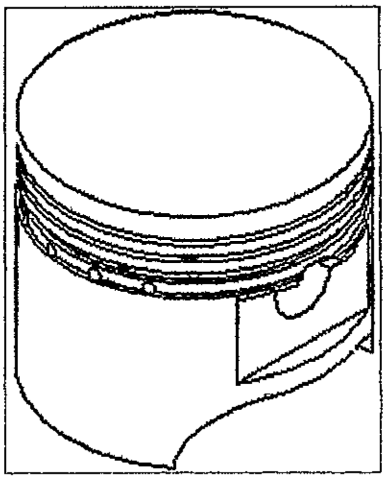


Figure 3.3: 3-D drawing GN5 piston

Before design the new piston skirt, firstly must doing the running-in the piston GN5. It is because to given the piston will suitable with temperature distribution exits in combustion chamber to piston skirt. It to prevent the piston stuck the piston between cylinder block. Beside that, a running-in is about average 1000km above. Figure 3.4 show that a process to install the piston into cylinder block.

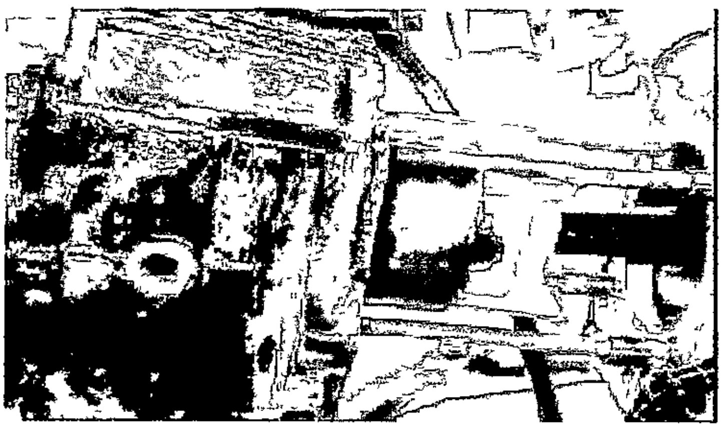


Figure 3.4: Installed piston into cylinder block

After settle the running-in the piston will remove the piston from cylinder block for determine wear area in piston skirt. The piston skirt will expend because of temperature distribution at same time, the friction happen between piston skirt and cylinder line. Because this friction, the wear happen at piston skirt. Usually when increase the friction at same time decrease the power.

Figure 3.5 show the wear at piston skirt and cylinder line. For there we can determine where that the area of wear happens. This happen because temperature distribution to piston skirt. This figure will take after the piston remove to cylinder block, and it take after doing a running-in about 1000 km.

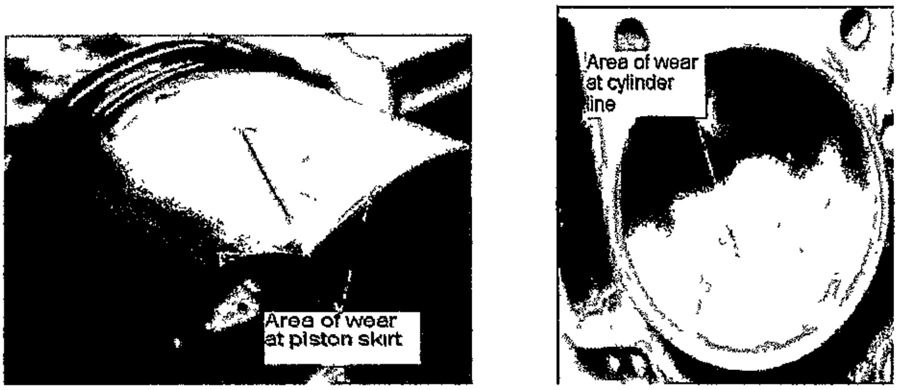


Figure 3.5: Area of wear at piston skirt and cylinder line

3.4 Structure analysis for piston

For this project, by using finite element analysis (ALGOR) software for determine about strain-stress influence of temperature distribution at piston skirt. In the first step, the piston will choose design scenario for determine about analysis. After that the piston will be selected to single analysis for analyze the piston. The piston analysis will doing at static analysis, and it be analyze in static stress with linear material model. Figure 3.6 show that the step to analyze this piston.

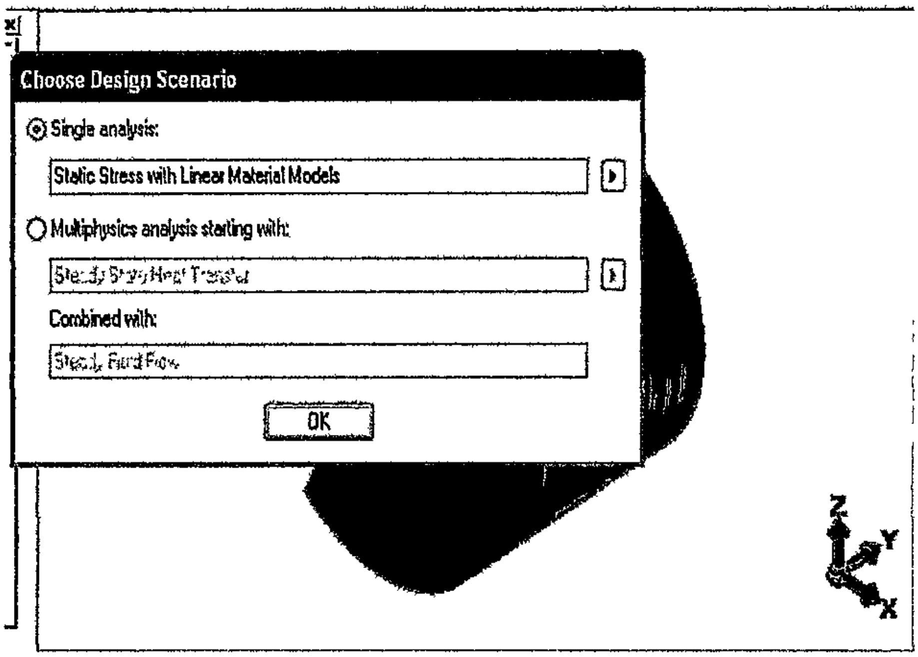


Figure 3.6: Static stress analysis

After choose a part to analysis, the piston must setting to mesh the model. In this part, the piston in category solid type meshes. Beside that, mesh size is about 50% for easy to analysis and to get more accurate mesh at model. Figure 3.7 show how to mesh the model.

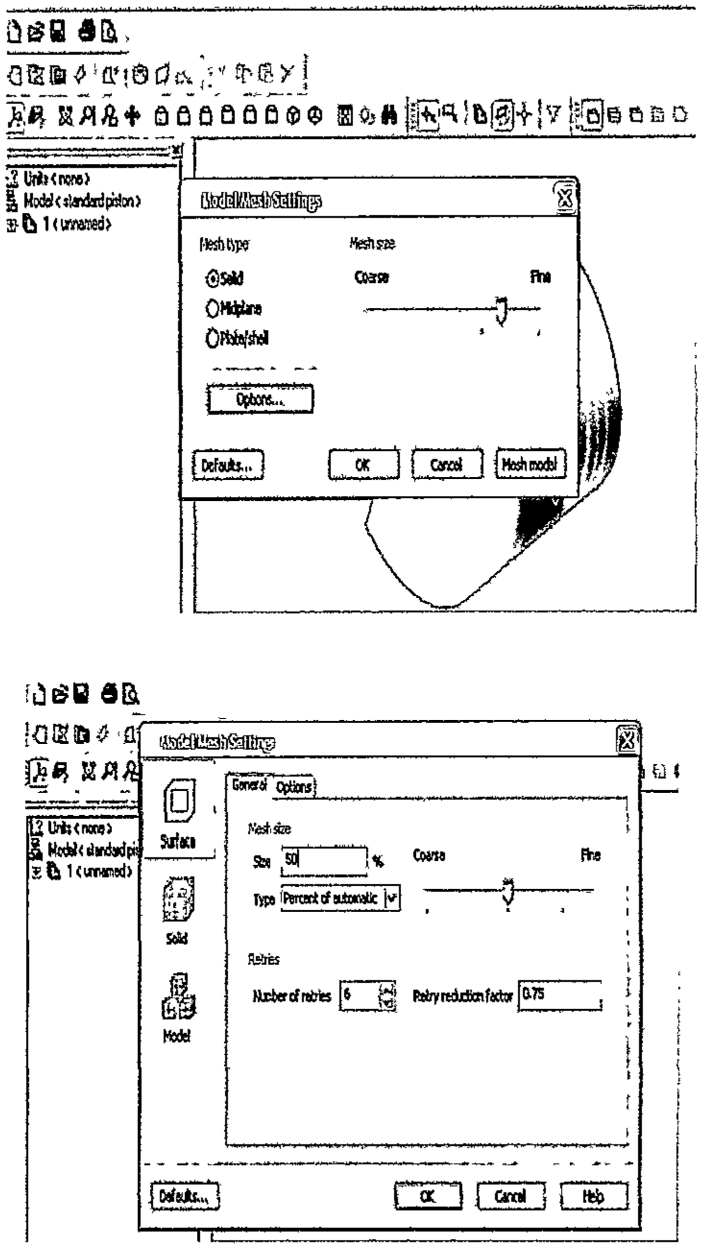


Figure 3.7: Model mesh

After doing done at the model, the model will mesh at show in Figure 3.8 a. at there will see, that solid mesh surface at all part the model. Beside that for definite the unit, all in this analysis used metric (SI) at show 3.8 b

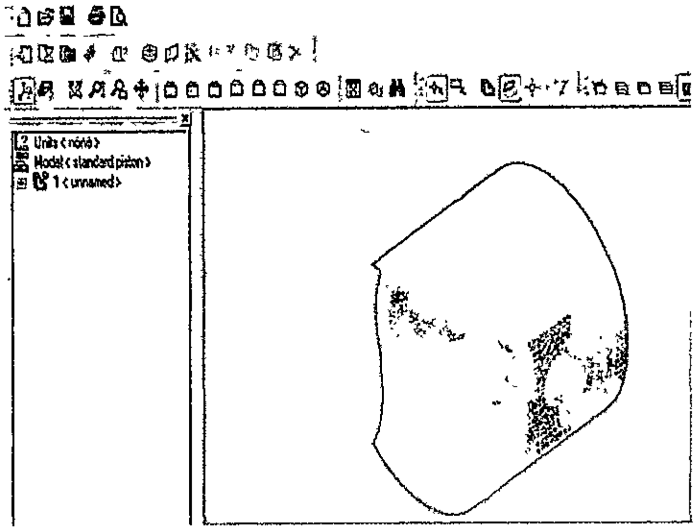


Figure 3.8 a: Solid mesh surface

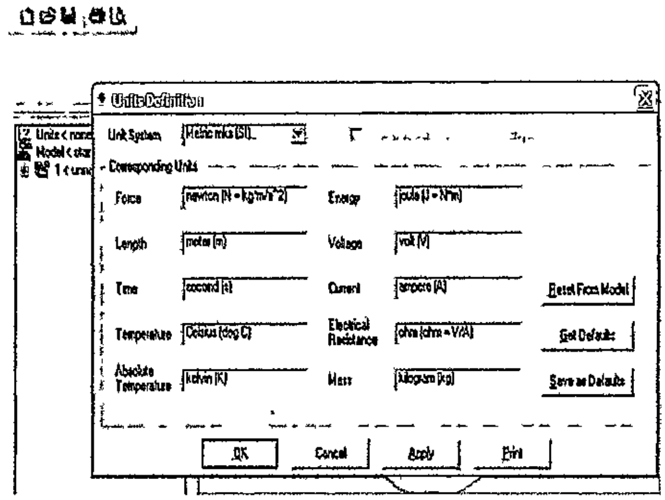
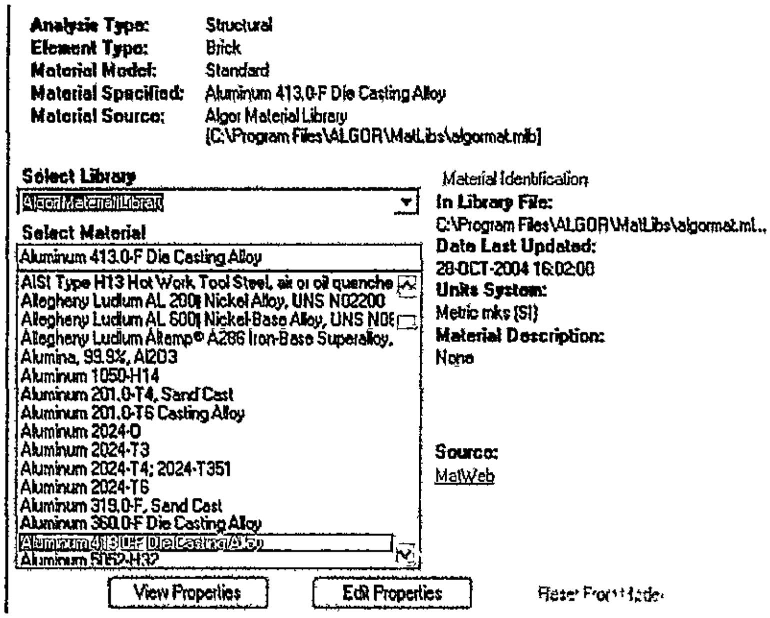


Figure 3.8 b: Metric unit

For this analysis, material of this model is Aluminum 413.0-F die casting alloy. This material has modulus of elastic is about 71 x 10^9 N/m^2 show in Figure 3.9.

Otherwise to produce piston, it has many type material but depend on company to select the material to produce the piston.



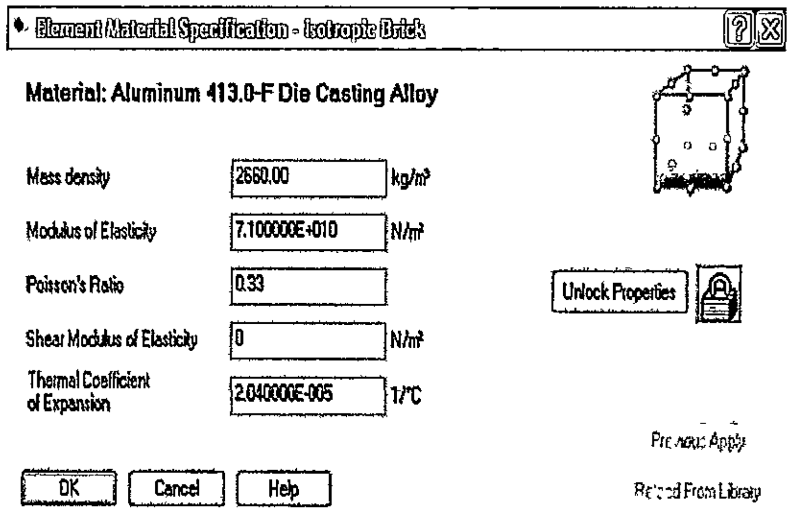


Figure 3.9: Material and elastic of aluminum

This piston has three axis like X, Y and Z. because this analysis must analyze at static analyze, so at all axis will fixed. Fixed will doing at all pin hole it because at this part, the pin bosses connected with connecting-rod. At real movement condition Y and Z axis, exits movement because thrust side and force at top of piston head. Figure 3.10 show how to fixed piston hole pin.

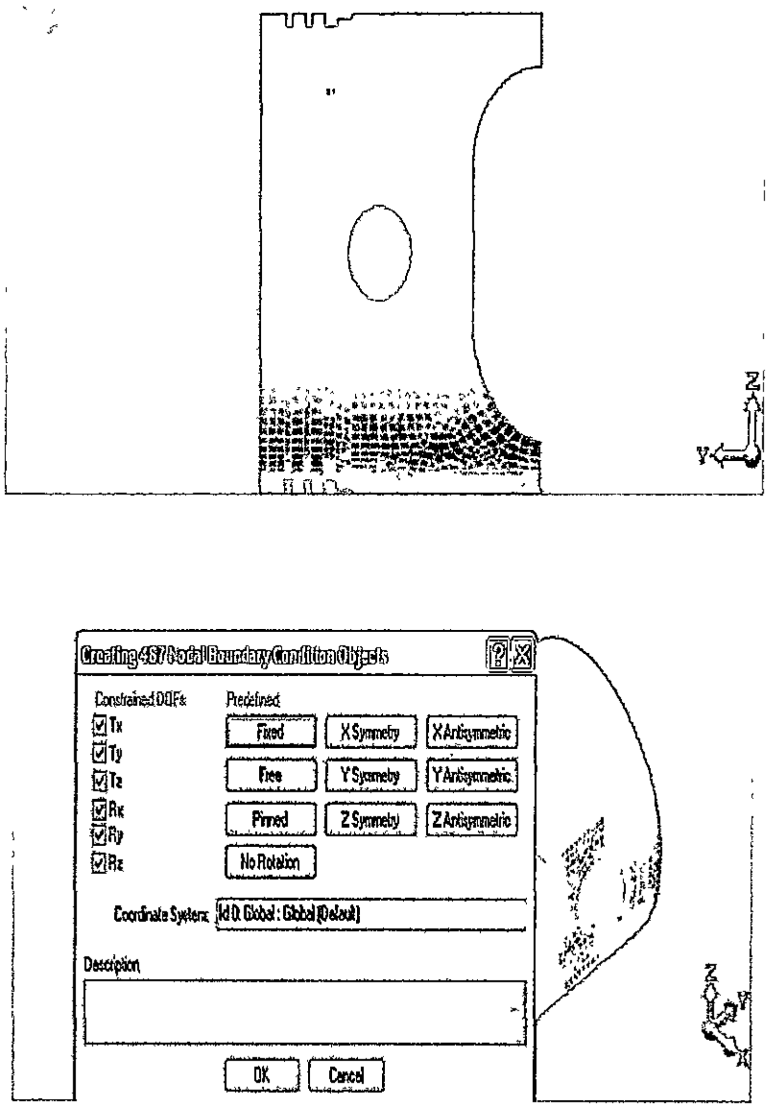


Figure 3.10: Piston pin hole fixed

Figure 3.11 shown at surface at piston will select. It for analyze about temperature at surface piston. It embrace at all surface include at inside and outside the piston. At other term to analysis, the average temperature will apply at piston surround. This average temperature gets from in combustion chamber.

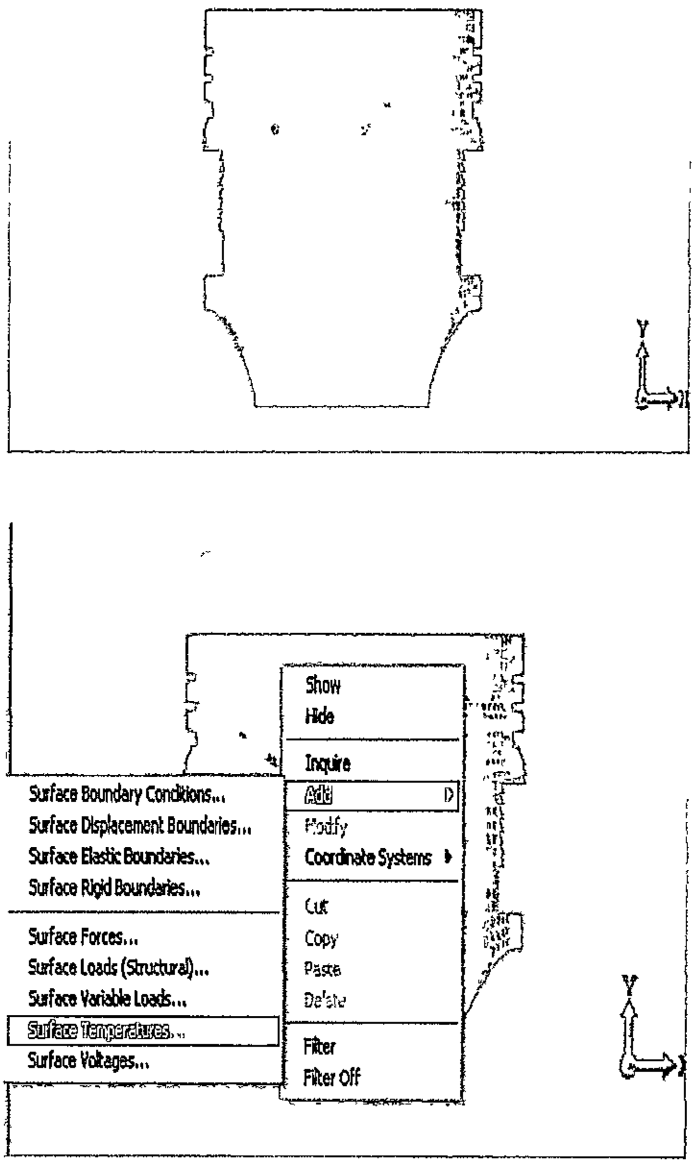


Figure 3.11: selected of piston surface

This Figure 3.12 shows a surface temperature acting at all surface piston. From the figure, can see that entire piston will distribute will temperature. This piston must give temperature it is because, to concern the maximum stress can happen which area and also it is because this static analyze.

Figure 3.12: Surface temperature acting at piston

3.5 Designs the new piston skirt

In this part, three news piston skirts will design to compare with standard piston and after consider about wear at standard piston.

3.5.1 Design -One

Refer to original piston and determine at wear on piston skirt, so in this project three types of the new piston skirt will design to compare about influence of temperature distribution. For type one, the piston is not have advance modification will do compare between the original piston. It only reduces an area at pin bosses and a modification at same as the type of piston in market. Figure 3.13 show the new piston skirt. For full dimensional drawing please refer to appendix C

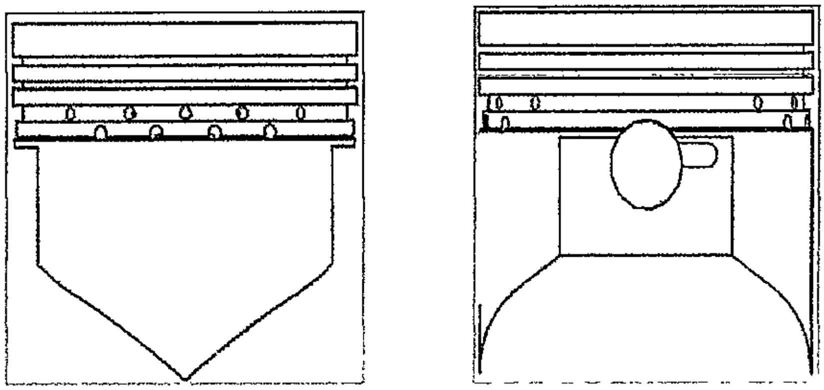


Figure 3.13: Design - One

3.5.2 Design- Two

Designs a type two of the piston skirt, is we consider at wear exist at piston skirt surface. In this type the piston skirt design with hole at surface piston skirt. It is because this hole is for to reduce the wear when the piston in operation. In this piston, have two holes at piston skirt, where this hole exist at upper and lower in piston skirt. This two holes will connected each other to get one part. Figure 3.14 show the type two of the piston skirt. For full dimensional drawing please refer to appendix D.

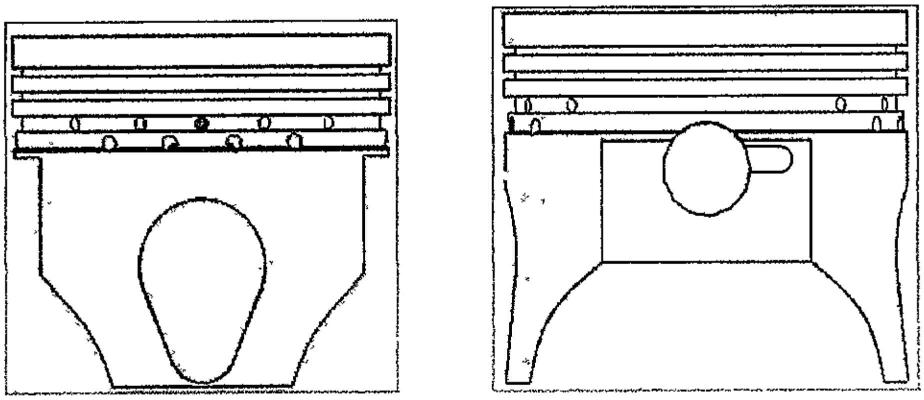


Figure 3.14: Design – Two

3.5.3 Design- Three

This type is the extreme piston skirt design. The design will reduce more part at piston like area of pin bosses, at side piston skirt and also the skirt will design like crown skirt. This type is design to reduce at all wear exist at area of pin bosses, side skirt and also the skirt will cute straight to reduce the wear. Figure 3.15 show the type three of new piston skirt. For full dimensional drawing please refer to appendix E.

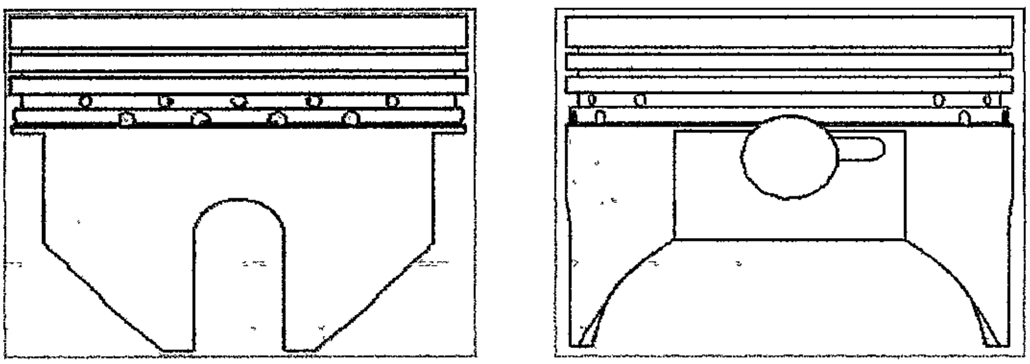


Figure 3.15: Design - Three

CHAPTER 4

RESULT AND DISCUSSION

4.0 Introduction

In this chapter will discuss about the result after doing the analysis. The result will obtain after the piston will given temperature at all surface of the piston. This referenced temperature will take from temperature exist in combustion chamber. For this analysis, average temperature will take as a temperature reference. The temperature reference will take from temperature one (intake temperature) until last temperature (blow down).

Also because of temperature distribution, the stress will shows in this chapter included the value of maximum and minimum of stress. Comparison will doing base on color at pistons after temperature distribution. From there, we can determine that which one is better between standard piston and news design.

4.1 Result for standard piston skirt

Figure 4.1 shows the influence of temperature at standard piston skirt. From there, exist tress at the piston skirt. The concern get from this analysis is about the maximum stress happen at this piston like a maximum value is about 1.59×10^9 N/m^2. From this result, the maximum stress exists at curve of piston rib. Where this happen because this rib will expand more when the temperature distribution at this area. Also from a concern may be crack if the stress at go above 71×10^9 N/m^2.

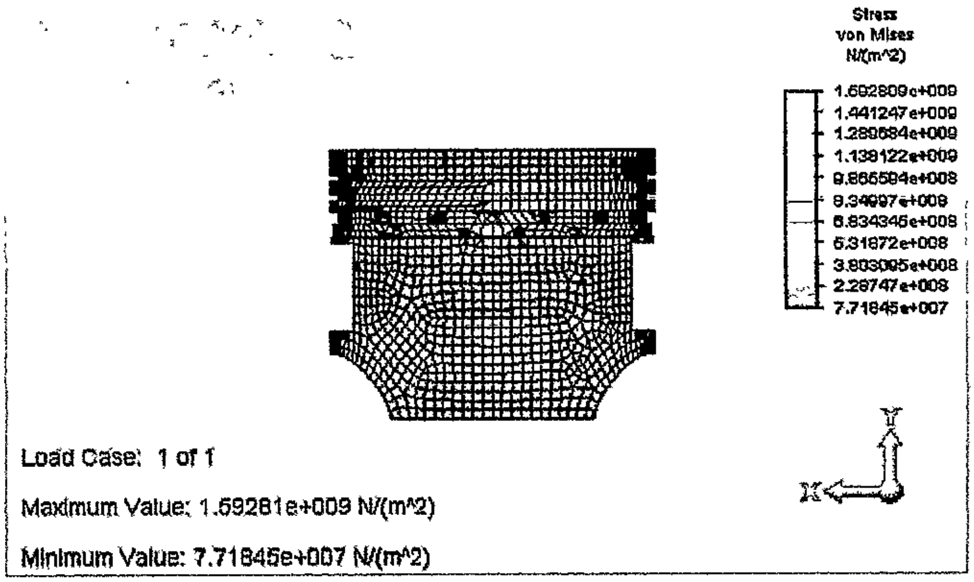


Figure 4.1: Stress at standard piston skirt

4.2 Result for Design - One

Figure 4.2 show the result influence temperature distribution to type one piston skirt. The value of this piston is a maximum stress at this design is about 6.41 x 10^9 N/m^2. From a concern will get from this type is the stress at this piston like high that to compare between the standard piston. But the area and color of the piston type is better than if compare to piston standard. Our prediction for this type why the stress in this type is more better compare to the standard piston because may be after reduce the area of the piston, the distribution is more better.

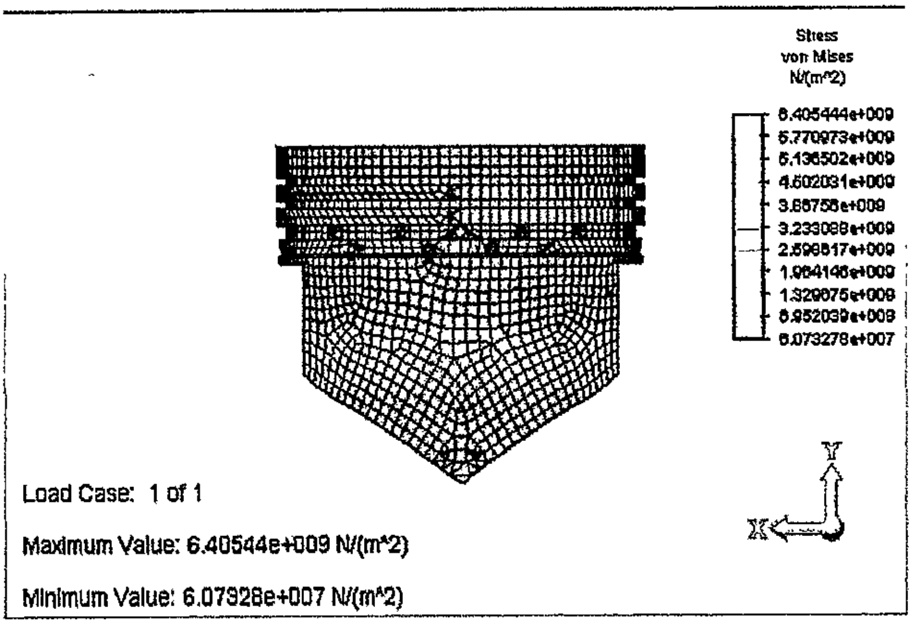


Figure 4.2: Stress at Design - One

4.3 Result for Design – Two

Figure 4.3 show that the result influence temperature distribution at type two piston skirt. From the result get, the maximum stress for this design is about 6.90 x 10^9 N/m^2. Compared between type one and standard piston skirt, the value of stress for this type will increase, because modification at area of piston skirt reduced. Because of the reduced, the maximum stress will exist at curve of piston skirt. But to compare with a color exist influence temperature distribution, this piston look better and safe to install in engine.

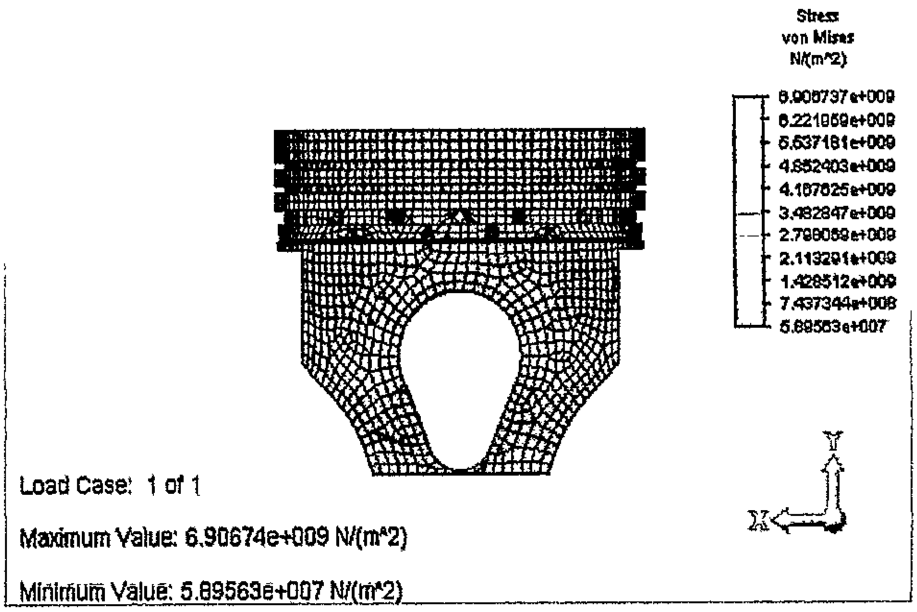


Figure 4.3: Stress at Design - Two

4.4 Result for Design - Three

After doing extreme modification at piston skirt, the result obtains at Figure 4.4 and the maximum stress in this design is about 2.62 x 10^9 N/m^2. Refer to figure show the stress in this type is at both side of skirt after doing hole. Prediction will be considered at this stress happen because the piston expanded, and the stresses exist at nearly at notch of piston skirt. Influence of this stress may give crack at this piston skirt.

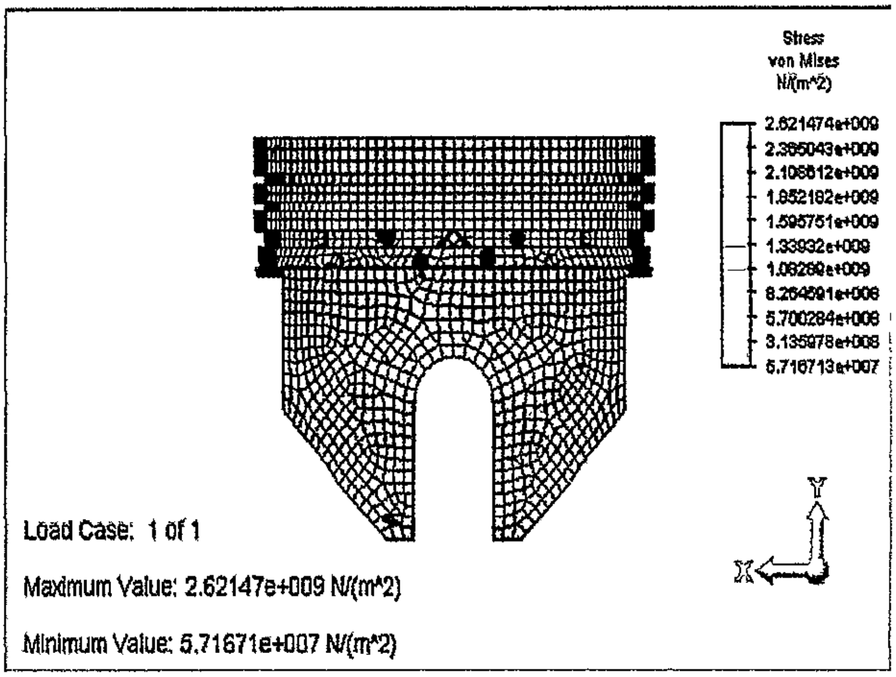


Figure 4.4: Stress at Design - Three

CHAPTER 5

CONCLUSION

5.1 Conclusion

As a conclusion refers to the result, the objectives are achieve where three design piston skirts can stand with temperature apply at surface temperature. The temperature will apply in this analysis is about 548 ^{o} C and this temperature as a reference temperature and it take form the average temperature in combustion chamber. Refer from the result the three designs perform good design because all design has modulus of elastic less than 71 x 10^9 N/m^2 for material aluminum 413.0.

By do a compared between both new designs with standard piston referred to the result, the Design – Three can prove that it more better compare other original piston and Design –One also Design – Two · It is because, the value modulus elastic of Design – Three (2.62 x 10^9 N/m^2) greater than original piston (1.59 x 10^9 N/m^2) and it less than Design – One (6.41 x 10^9 N/m^2) also Design – Two (6.90 x 10^9 N/m^2). It is observed that at the original piston, high stress exist at the rib and curve of the piston and also high friction occur. In all alternative design piston skirt, the design has minimized the rib and curve at all piston skirt to reduce stress and this will also to reduce friction between piston skirt and cylinder wall.

5.2 Recommendation

With all the analysis result, we achieve that modification at piston skirt will continues for determine about the performance of the engine because by reduce the friction between piston skirt and cylinder wall by check using dynamometer.

Through reduce the friction between piston skirt and cylinder wall, it can help to increase the performance of the engine. From doing modification at piston skirt, it can help about fuel consumption in engine without charge the properties of fuel also.

REFERENCES

1. Crouse- Anglin (1993) *Automotive Mechanics.*

2. Heywood, J. B. Mc Graw –Hill (1988) *Internal Combustion Engine Fundamentals*

3. Pulkrabek, W.W (1997) *Engineering Fundamentals of the Internal Combustion Engine*

4. *Motor Vehicle Engine VII* (1990)

5. http://www.Team-Integra. Net accessed on January 2007

6. Y. Wong, C. Yoa, G.C Barber, B.Zhou, Q.Zou (2005). *Scuffing resistance of coated piston skirts run against cylinder bores.*

7. S. h Mansouri V. W. Wong (1894). *Effect of Piston Parameter On Piston Secondary Motion and Skirt- Liner Friction.*

8. Shibuya, N. et. all (2002). *Development of a Low Friction Piston with a New Flexible Skirt Structure of a 3.5-L V6 Gasoline Engine.*

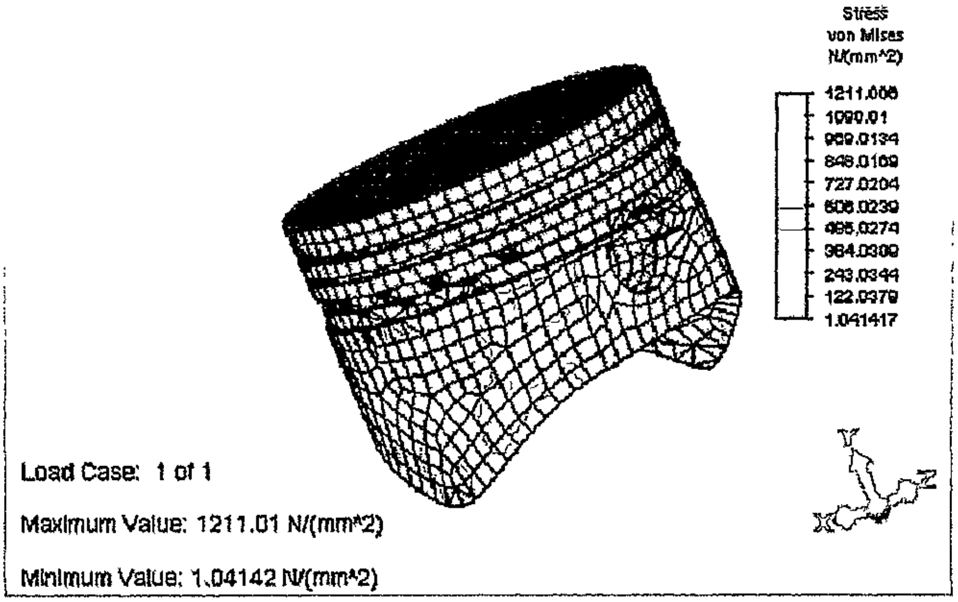
9. Kalpakjian, S. Prentice Hall (2006) *Manufacturing Engineering and Techonology.*

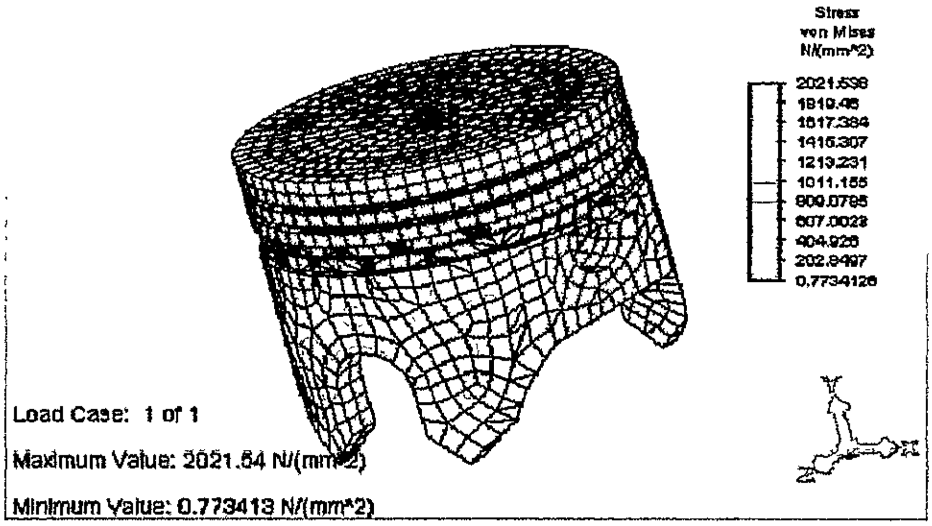
10. Lecture Note BMM3663 Cae and Failure Analysis

11. F.S. Silva(2005) *Fatigue on Engine Piston- A compendium of Case Studies.*

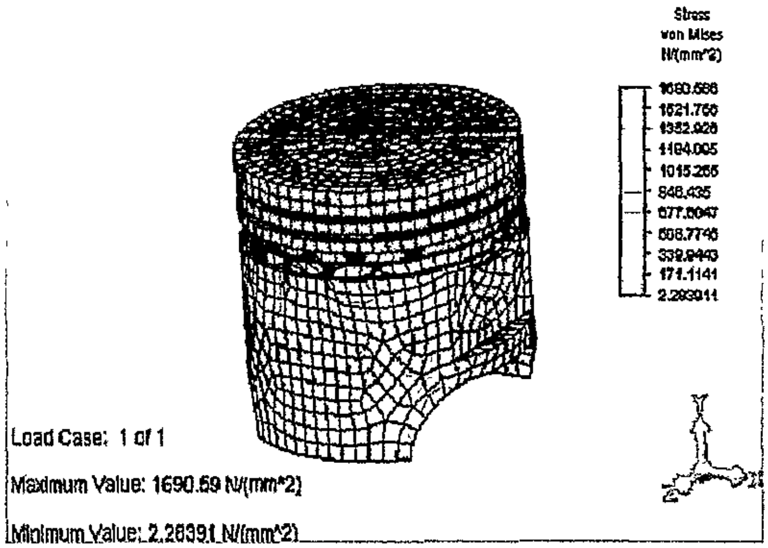
12 www.Boon Siew Honda.com accessed on January 2007

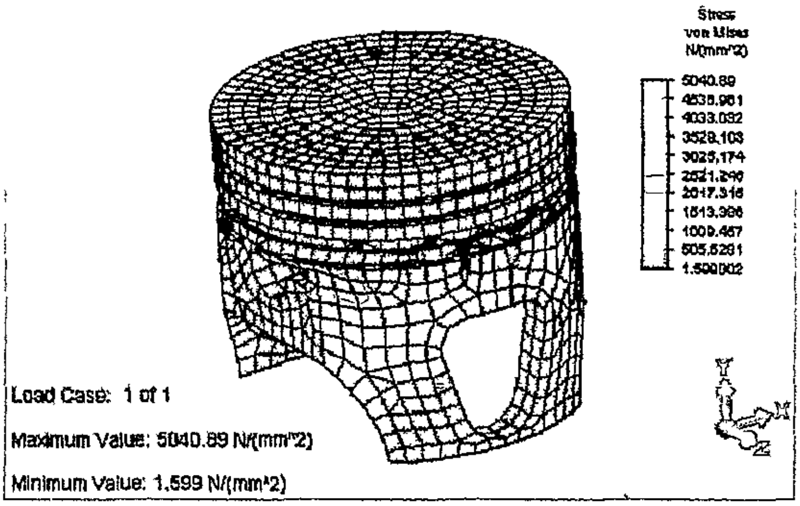
APPENDIX A


Stress
von Mises
N/(mm^2)
1211.006
1090.01
969.0134
848.0169
727.0204
606.0239
485.0274
364.0309
243.0344
122.0379
1.041417
Load Case: 1 of 1
Maximum Value: 1211.01 N/(mm^2)
Minimum Value: 1.04142 N/(mm^2)

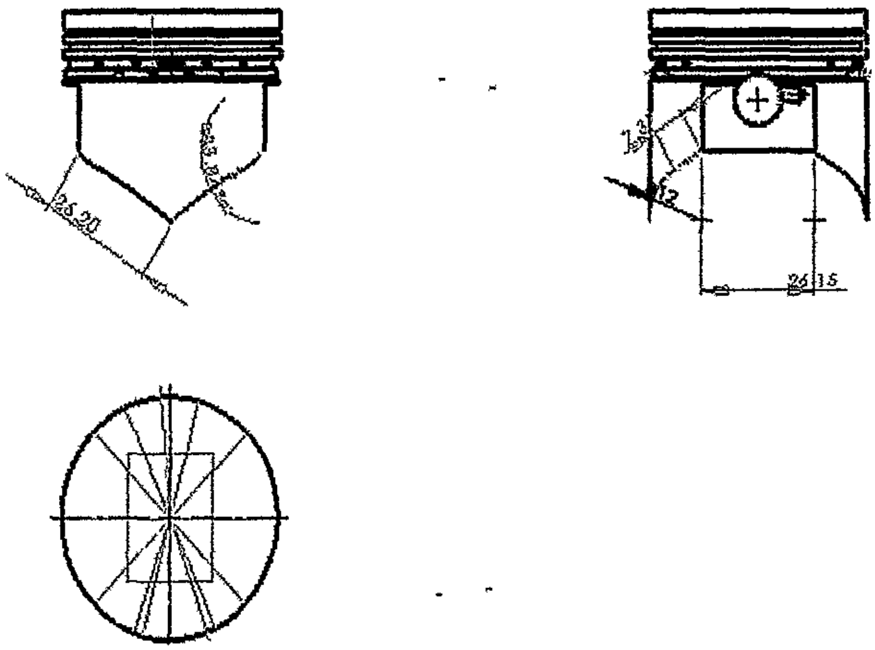

Stress
von Mises
N/(mm^2)
2021.538
1819.46
1617.384
1415.307
1213.231
1011.155
809.0795
607.0023
404.926
202.8497
0.7734126
Load Case: 1 of 1
Maximum Value: 2021.54 N/(mm^2)
Minimum Value: 0.773413 N/(mm^2)

APPENDIX B

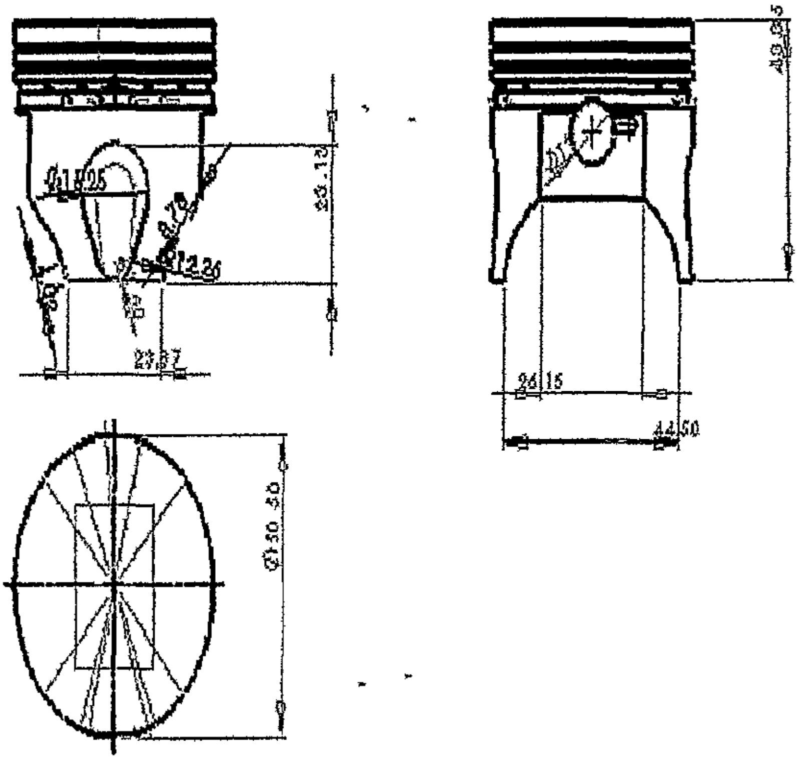

Stress
von Mises
N/(mm^2)
1690.586
1521.760
1352.926
1184.005
1015.265
846.435
677.6047
508.7746
339.9443
171.1141
2.283911
Load Case: 1 of 1
Maximum Value: 1690.59 N/(mm^2)
Minimum Value: 2.28391 N/(mm^2)
Y
Z
X


Stress
von Mises
N/(mm^2)
5040.89
4536.961
4033.032
3528.103
3025.174
2521.246
2017.316
1513.386
1009.457
505.5281
1.599002
Load Case: 1 of 1
Maximum Value: 5040.89 N/(mm^2)
Minimum Value: 1.599 N/(mm^2)
Y
X
Z

APPENDIX C



APPENDIX D



APPENDIX E