MODIFICATION OF PISTON SKIRT DESIGN

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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 $^{\circ}$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 ^{o} 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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LIST OF SYMBOL

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 overview

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]

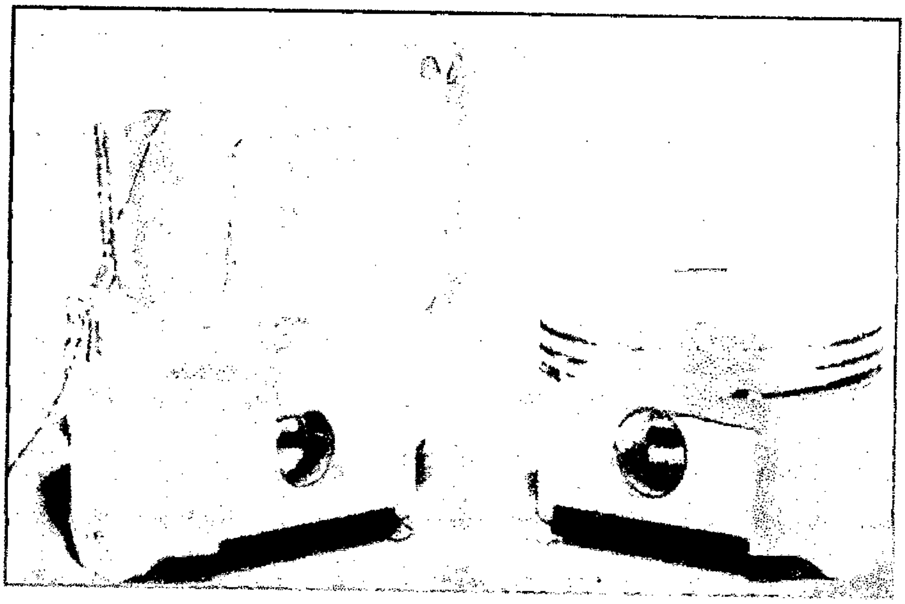

Figure 2.1: Aluminum 413.0

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.

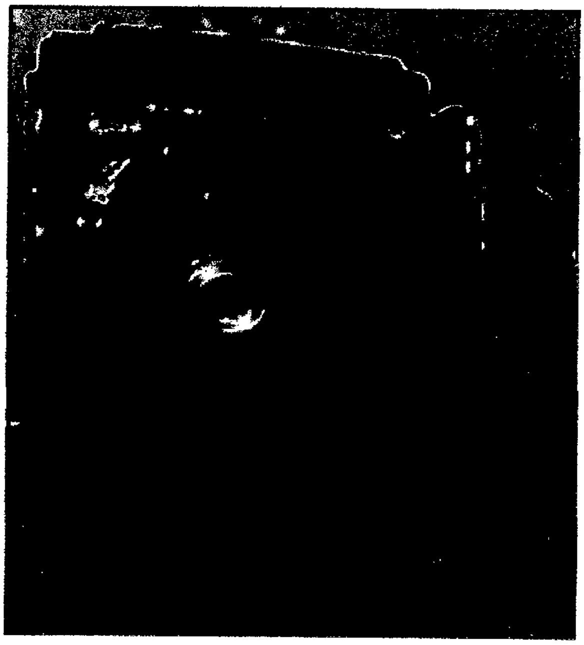

Figure 2.3: GN5 cylinder block

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

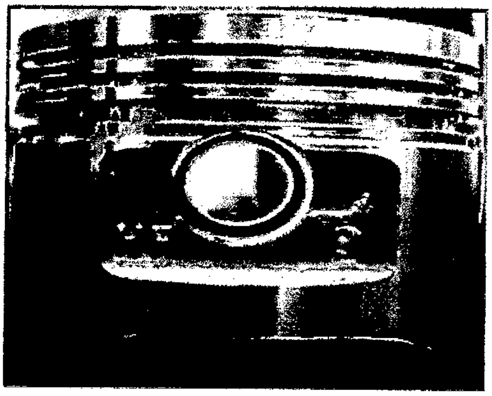

Figure 2.4: GN5 piston

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.

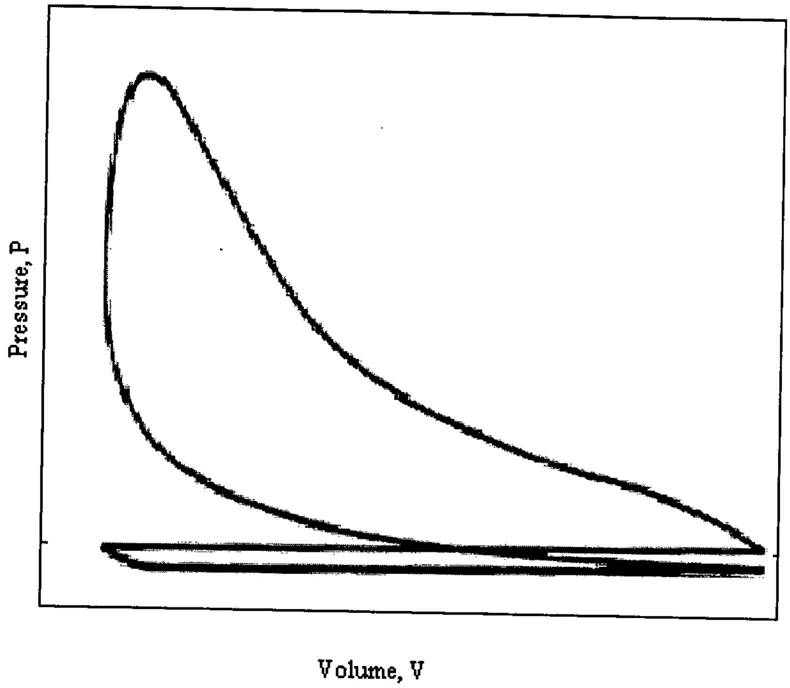

Figure 2.5: Indicator diagram for a typical four stroke cycle SI engine

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.