I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of the scope and quality for the award of the degree of Bachelor Degree of Mechanical Engineering (Thermal-Fluid).

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Date : 25 MEI 2006

ANALYSIS AND SIMULATION OF 4-STROKE DIESEL ENGINE PERFORMANCE

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This report is submitted to Mechanical Engineering Faculty in partial fulfillment of the requirements for the award of the degree of Bachelor Degree of Mechanical Engineering (Thermal-Fluid)

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June 2006

I declare that this thesis entitled "Analysis and Simulation of Four Stroke Diesel Engine" is the result of my own research except as cited in the references.

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Date : 25 MEI 2006

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ABSTRACT

The purpose of this study is to investigate the performance characteristics of the four-stroke diesel test engine that is available in the lab. The parameters measured from the test engine are speed, torque, power output, fuel consumption and exhaust gas temperature. The purpose of this study is also to develop a simulation model involving air flow in engine performance. The exhaust temperature measured from the test engine will be used for simulation purpose. The simulation is carried out on the exhaust port of the cylinder head. The temperature deduced from simulation is compared with experimentally obtained results to from a correlation between experiment and simulation. Based on the measured parameters the optimum operating speed of the test engine is determined. The results obtained from this study indicates that there two speeds that gives the highest output power which are at 1800 rpm and 2600 rpm respectively. At this speeds the torque recorded is the highest and thus gives the highest power. The specific fuel consumption decreases with increasing power. Maintenance guidelines recommendation are proposed based on the experimental results.

ABSTRAK

Tujuan kajian ini adalah untuk menganalisis ciri-ciri kecekapan enjin diesel 4 lejang yang terdapat di makmal. Parameter yang akan dikaji daripada enjin diesel 4 lejang ini adalah seperti laju, daya kilas, kuasa yang dijanakan, kadar penggunaan bahan api dan suhu gas keluaran. Selain itu suatu model simulasi turut dibangunkan untuk menunjukkan pengaliran udara dalam enjin. Dalam projek ini kepala enjin iaitu bahagian keluaran gas secara spesifiknya telah dipilih sebagai model simulasi. Suhu gas keluaran dari model simulasi ini dibandingkan dengan suhu yang diperolehi secara eksperimen untuk menghubungkaitkan eksperimen dan simulasi. Selain itu parameter-parameter yang diukur dari enjin diesel 4 lejang itu juga akan digunakan untuk mendapatkan laju enjin paling optimum. Hasil keputusan yang di dapati dari kajian ini terdapat 2 nilai laju optimum yang telah direkodkan yang akan memberikan nilai kuasa yang maksimum. Nilai laju ini ialah 1800 rpm dan 2600 rpm. Pada kedua-dua nilai laju ini, daya kilas yang terhasil adalah maksimum sekaligus memberikan nilai kuasa yang maksimum juga. Keputusan penggunaan bahan api spesifik didapati menurun dengan meningkatnya nilai kuasa. Kesemua hasil keputusan ini amatlah berguna dalam penghasilan panduan penjagaan enjin.

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LIST OF SYMBOLS

SYMBOL	DEFINITION
N	Speed
P	Power
T	Temperature
t	Time
M	Mass
m	Mass flow rate
V	Volumetric flow rate
v	Velocity
ρ	Density
a	Local velocity of sound
D	Diameter
N	Revolution per minute
b_e	Specific Fuel Consumption
M_d	Torque

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Various studies have been carried out by foreign universities like Wayne State University, Automotive Research Center by University of Michigan, New Orleans University and so on involving diesel engine simulations. Anyhow the simulations carried out covers simulation on engine performance characteristics optimization. Automotive Research Center by University of Michigan even designed a simulation code called SELENDIA code for performance characteristics optimization.

Numerous studies have been previously and is still being conducted regarding simulation of four stroke diesel engines especially in foreign countries. Anyhow these studies were more towards simulation on the performance characteristics of the engine like simulation on torque, power, speed, fuel consumption and air flow in engine. These researches were done on a four stroke diesel engine various types of cylinder comprising from single cylinder, heavy-duty turbo charged multi-cylinder. Simulation is done using software's like MATLAB-SIMULINK and certain researches have also developed their own simulation software like ADVISOR and SELENDIA.

However researches did not perform practical measurement using a test engine to calculate the torque, power, speed and fuel consumption. Practical measurement using a calibrated test engine should be done hand in hand by these researches as it serves a significant measurement of the accuracy of the self developed simulation software developed by these researches. Anyhow practical measurement has been conducted only by those developers of the test engine like Gunt-Hamburg and TQ Education and Training Limited at small scale using single cylinder certain range of parameters according to the limitation of the test engine designed.

1.2 Importance of The Study

The main purpose of this study is to conduct practical measurement on the performance characteristics of the 4 stroke single cylinder diesel test engine that is available in the lab. Apart from that a simulation will also be carried out regarding the air flow in the engine cylinder. The results obtained will be used to propose a standard guideline for engine maintenance and vital parameters that directly affects the engine performance. Knowledge on performance characteristics of a 4 stroke diesel engine is essential. The study conducted will be helpful to propose a standard guideline of procedure for engine maintenance and vital parameters that directly affects the engine performance. Improper or insufficient maintenance will have a negative effect on the combustion process and lead to accelerated wear of engine components resulting in an increase in emissions.

1.3 Objective of The Study

a) To investigate the performance characteristics of the four stroke diesel engine that is available in the lab.

b) To develop a simulation model involving airflow in engine performance.

1.4 Scope of The Study

a) To conduct practical measurement involving air consumption, fuel consumption, speed and torque.

b) To develop a simulation model for certain parts of the engine using available CFD software.

c) To propose standard guidelines of procedure for engine maintenance based on the study.

1.5 Expected Outcomes

a) Measurement results for specific fuel consumption, torque and power.

b) Simulation of air flow for the exhaust port from the cylinder head.

CHAPTER 2

THEORY

Diesel engine is also known as compression ignition engine and can operate in either 2 stroke or 4 stroke cycle. Anyhow in this study our interest will only be on 4 stroke cycle. Basic design performance parameters in diesel engine include compression ratio, swept volume, clearance volume, power output, mechanical efficiency, indicated mean effective pressure, brake mean effective pressure, specific fuel consumption and more.

Diesel engine is a type of an IC engine in which the burning of the fuel is generated due to fuel-air mixture compression. They are used in heavy vehicles like trucks, buses and also for emergency power generation and in diesel-electric submarine. The basic principle behind the operation of diesel engine is only air is drawn into the cylinder with a high pressure fuel injector when the piston reaches the top of its motion. The fuel is thicker for diesel engine and burns slower than petrol. Anyhow the piston is already moving down by the time the combustion completes so that the diesel engine looses some of the potential energy.

Proper control of compression ignition engine depends on i) air motion ii) fuel injection. There are also 2 main combustion chambers that are i) Direct injection ii) Indirect injection. These will be discussed more in detail during combustion process of a compression engine.

Basically a compression ignition engine goes through 4 events that are i) intake ii) compression iii) power and iv) exhaust. Since our study will only revolve around 4 stroke cycle it means that the engine requires 4 strokes of piston to complete a full cycle. It requires 2 rotation of crankshaft.

IC engines generally have low initial capital cost, proven reliability, strong maintenance, high partial load efficiency, heat recovery capabilities, does not require external inlet fuel compression and the output not affected by higher ambient temperature.

2.1 Operation of Compression Ignition Engine

2.1.1 Intake Stroke

Air and fuel are inducted into a cylinder when the piston is at its downward stroke. The intake valve is opened and air is drawn in. Filters are attached to remove particles and extend the life of the engine.

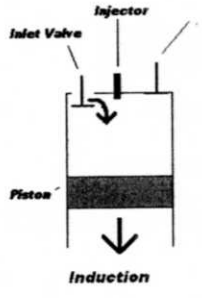

Figure 2.1: Intake Stroke

2.1.2 Compression Stroke

Happens when the piston is at its bottom dead centre (bottom of cylinder). At this stage the intake valve closes and seals the upper end of the cylinder. The crankshaft rotates and pushes the connecting rod and piston up thus compresses the air-fuel mixture in the cylinder. This increases the pressure and makes it more combustible.

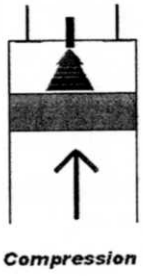

Figure 2.2: Compression Stroke

2.1.3 Power Stroke

Occurs when the compression ratio is sufficiently high (16:1) to cause the air-fuel mixture to ignite. As combustion occurs the high pressure will push the piston is pushed downward and the gas expands.

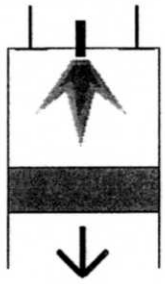

Figure 2.3: Power Stroke

2.1.4 Exhaust Stroke

As the crankshaft continues to rotate, reciprocating motion is created and pushes the connecting rod upward. The piston also travels upward, the exhaust valve is opened and the gas is pushed outside.

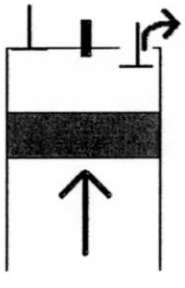

Figure 2.4: Exhaust Stroke

This completes 1 cycle.

2.2 Compression Ignition Combustion System

The operation of Compression Ignition depends on proper control of air motion, adequate mixing of air with fuel and fuel injection. The characteristics of ideal combustion are should have a high output, high efficiency, rapid combustion and clean exhaust and silent. There are two types of fuel injection namely direct injection in which fuel is injected into the main chamber and indirect injection that has divided combustion chamber.

a) Direct Injection

This has less air motion to compensate for high injection pressures up to 1500 bar. Multiple hole nozzles requires higher injection pressure. Compression ratio is between 12:1 to 16:1 and the combustion chamber is compact in the piston, this reduces heat loss from the air. The main advantages of direct injection engine are its' simplistic design and cheaper to produce. Besides it also has high fuel economy. The main disadvantage is it produces higher emission compared to indirect injection engine.

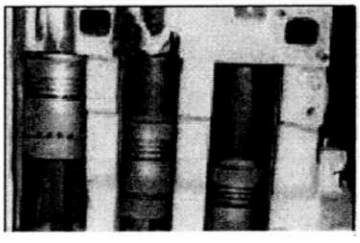

Figure 2.5: Direct Injection

b) Indirect Injection

This has a divided combustion chamber. It has a pre-chamber in which fuel is injected and a main chamber with the piston and valves. The purpose of having a separate combustion chamber is to speed up the combustion process and to increase engine output by increasing engine speed.

Indirect Injection uses heat-resistant inserts with a low thermal conductivity. This insert is quickly heated up by the combustion process and reduces ignition delay sequence. Fuel is injected and impinges on the combustion chamber insert. The air jet breaks up and fuel evaporates. During initial combustion the burning air + fuel mixture is ejected into the main chamber and thus generates lots of turbulence. This ensures rapid combustion in the main chamber without having to provide an ordered air motion during induction stroke.

Main advantages are reduces ignition delay, have greater air utilization and faster combustion. Whereas the disadvantages are complicated design compared to direct injection engine.

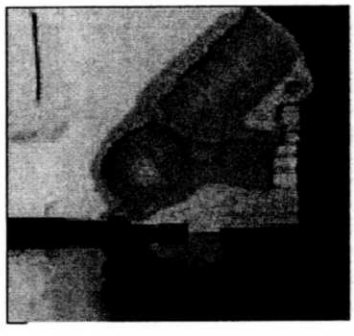

Figure 2.6: Indirect Injection

2.3 Types of Combustion Chamber

There are 4 main types of combustion chamber namely hemispherical bowl, shallow bowl, shallow toroidal bowl and deep toroidal bowl. Classes of combustion chambers :

- pre-combustion chamber – rely on turbulence to increase engine output by increasing engine speed
- swirl chamber – rely on ordered air motion to raise combustion speed

2.4 Differences Between Direct and Indirect injection

Table 2.1: Difference between Direct Injection & Indirect Injection

Direct Injection	**Indirect Injection**
Injector nozzle protrudes direct into cylinder space through the head and therefore sprays diesel direct into the combustion chamber.	Injector nozzle does not protrude through the head and injects into separate chamber within the head.
Require very minimum glow plug at start up.	A very inefficient process. Some diesel engine also have pre-combustion nozzles in pre-combustion chamber.