INVESTIGATION OF 1-DIMENSIONAL ANALYSIS FOR TWO-STROKE SPARK IGNITION (SI) ENGINE

ZABIDI BIN MOHAMAD

A report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Mechanical Engineering with Automotive

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

NOVEMBER 2008

SUPERVISOR'S DECLARATION

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

Signature : ....
Name of Supervisor: Mr. Nik Mohd Izual Hj. Nik Ibrahim
Position : Lecturer
Date : ....

Signature : ....
Name of Panel : Mr. Devarajan A/L Ramasamy
Position : Lecturer
Date : ....

STUDENT'S DECLARATION

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

Signature	: ……………………..
Name	: Zabidi bin Mohamad
ID Number	: MH 05054
Date	: …………………

ACKNOWLEDGEMENTS

I am grateful and would like to express my sincere gratitude to my supervisor Mr Nik Mohd Izual Hj. Nik Ibrahim for his germinal ideas, invaluable guidance, continuous encouragement and constant support in making this research possible. He has always impressed me with his outstanding professional conduct, his strong conviction for science, and his belief that this research is only a start of a life-long learning experience. I appreciate his consistent support from the first day I applied to graduate program to these concluding moments. I am truly grateful for his progressive vision about my training in science, his tolerance of my naïve mistakes, and his commitment to my future career. I also would like to express very special thanks to my co-supervisor Mr Aguk for his suggestions and co-operation throughout the study. I also sincerely thanks for the time spent proofreading and correcting my many mistakes. I would like to acknowledge their comments and suggestions, which was crucial for the successful completion of this study.

My sincere thanks go to all my friends and members of the staff of the Mechanical Engineering Department, UMP, who helped me in many ways and made my stay at UMP pleasant and unforgettable.

I acknowledge my sincere indebtedness and gratitude to my parents for their love, dream and sacrifice throughout my life. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to attain my goals.

ABSTRACT

The project is based on two-stroke engine. The two-stroke engine will be used as the testing engine that the performances can be determined. The objective of this project is to investigate and analysis the performance of two-stroke engine using a 1-Dimensional (engine gas dynamic) software. From this objective, the outcome of the project can be determined by using the 1-Dimensional software. The outcomes that need to be determined from this project are the performances of the engine. The 1-Dimensional software that was using in this project is GT-Power. GT-Power is using to model and simulate the two-stroke engine. First, the parameters of the two-stroke engine had been measured and then the modeling of the two-stroke engine had been built and simulated. After simulation process, the performances of the engines can be obtained right away. There are many information that can be taken from the GT-Power after simulating the engine but for analyzing, only several data had been chosen. Those data are pressure for scavenged port, in-cylinder and exhaust port, temperature for scavenged port, in-cylinder and exhaust port, brake power, brake torque, indicated mean effective pressure and brake specific fuel consumption. All of this information had been analyzed and the optimum engine speed had been determined at 1500 RPM to 2500 RPM because in this range, the brake torque and brake power is maximum while the brake specific fuel consumption also low.

ABSTRAK

Projek ini adalah berdasarkan enjin dua lejang. Enjin dua lejang akan digunakan sebagai enjin ujian untuk mengetahui keupayaan enjin tersebut. Objektif projek ini adalah untuk menyiasat dan menganalisa keupayaan enjin dua lejang dengan menggunakan perisian 1-Dimensi. Melalui objektif ini, hasil projek ini boleh diperolehi dengan menggunakan perisian 1-Dimensi. Hasil yang diperlukan daripada projek ini adalah keupayaan enjin tersebut. Perisian 1-Dimensi yang digunakan dalam projek ini adalah GT-Power. GT-Power digunakan untuk membina model dan melakukan simulasi terhadap enjin dua lejang tersebut. Permulaannya, enjin dua lejang tersebut diukur dan kemudian model enjin dua lejang itu dibina dan akhirnya simulasi dilakukan. Selepas proses simulasi, keupayaan enjin tersebut dapat diketahui terus. Terdapat banyak maklumat yang dapat diperolehi daripada GT-Power hasil dari simulasi enjin tersebut tetapi untuk analisa, hanya beberapa data yang dipilih. Data-data tersebut adalah tekanan pada lubang kemasukan, dalam silinder dan lubang ekzos, suhu pada lubang kemasukan, dalam silinder dan lubang ekzos, kuasa, daya kilas, tekanan efektif purata dan penggunaan spesifik bahan bakar. Semua maklumat-maklumat ini akan dianalisa dan kelajuan optimum enjin tersebut dicatatkan pada 1500 RPM hingga 2500 RPM kerana pada kelajuan ini, brek tork dan brek kuasa adalah maksimum sementara penggunaan bahan bakar spesifik adalah rendah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Two-stroke engine is commonly known as simple engine. Compared to four-stroke engine, there are many advantages related to two-stroke engine. Mechanically simple, low cost and low weight are the advantages that make the two-stroke engine is the better engine but unfortunately in two-stroke engine lies a big disadvantage that make it limited in production for most of the automobile and machining industry. The disadvantage is the emission occurred in two-stroke engine that lead to the pollution in the environment. Put aside the pollution factor, two-stroke engine actually can provide more benefit whether to the manufacturers or the customers. The engine that provide low weight and mechanically simple reduce the production cost and time. Consequently, the manufacturers can produce more engines to be used in the industry. As for the customers, the benefit that they can get is the reasonable price with the high performance engine.

Before the manufacturers develop and produce the engine, they had to follow the proper steps to make sure the probability of loss during the process can be reduced to minimum. First step in the process is designing the engine by simulation. It is to ensure the engine that will be developed can produce the desired output and performance with the required size [4]. There are many types of designing the engine whether using the 1-Dimensional, 3-Dimensional or even 2-Dimensional modeling [12].

The basic modeling for the engine simulation is 1-Dimensional. In 1-D modeling, it is all about mathematical, formula and calculation [49]. There is no imaging about the shape of the engine like 3-D modeling, but it is critical in simulating engine. It is because the 1-D modeling can be the benchmark for either 3-D modeling or developing the real engine. Other than that, the 1-D modeling also simple and can be developed in short of time. So, the probability of loss money and time when simulate using 3-D or develop the real engine can be reduced because the engine had been successfully simulated by using 1-D. So, the process of developing the engine can be continued without facing the big problems.

Actually, simulate, design and develop the real model is connecting to each other. In case of two-stroke engine, the simulation of the engine is critical because the designer must know all the parameter and geometry for the engine before designing the engine. Otherwise, the output and performance of the engine cannot match the required one.

In this project, the objective is to investigate and analysis the performance of two-stroke engine using a 1-Dimensional (engine gas dynamic) software. As mentioned before, the simulation of the engine is very important when designing and developing the two-stroke engine. The purpose of this project is to ensure whether the results obtained from the 1-D simulation approaching the results obtained from 3-D simulation and experimentation of the real engine. Also, from this project, it can be proved that whether the 1-D simulation can be used for the rapid prototyping. Lastly, this project can prove whether there is any difference between the two-stroke engine with firing and two-stroke engine with motoring.

CHAPTER 2

LITERATURE REVIEW

2.1 INTERNAL COMBUSTION ENGINE

2.1.1 Introduction

The internal combustion engine with spark-ignition had been developed in 1876 by Nicolaus A. Otto. The compressed ignition or diesel engine had been developed by Rudolf Diesel in 1892 [31]. The normal internal combustion engine is generally one of two types, spark ignition petrol or gas engines and diesel engine [13]. The conventional internal combustion engine basically can be classified by four stroke and two stroke engine. In four stroke engine, the processes occurred in the cycle are intake stroke, compression stroke, power stroke and exhaust stroke. In two stroke engine, the processes involve only compression stroke and power/expansion stroke [9][53].

2.1.2 Basic Parameters

2.1.2.1 Bore and Stroke

For conventional internal combustion engine, the piston reciprocates in the cylinder between two fixed position called the top dead centre (TDC) and the bottom dead centre (BDC) [9][19]. TDC is the position of the piston when it forms the smallest volume in cylinder and BDC is the position of the piston when it forms the largest volume in the cylinder. The distance between TDC and BDC is called the stroke of the engine while the diameter of the piston is called the bore [9].

2.1.2.2 Compression Ratio

There are also some other terms that must be understood first before proceeding to the researching of the engine. The air-fuel mixture will enter the cylinder through intake valve while the function of the exhaust valve is to expel the combustion products from the cylinder. The minimum volume formed in the cylinder when the piston is at TDC is called the clearance volume while the displacement volume is the volume displaced by the piston as it moves between TDC and BDC [9]. The compression ratio is the ratio of maximum volume formed in the cylinder to the minimum volume [9][14] as shown in equation 2.1.

$$r = \frac{V_{\max}}{V_{\min}} \tag{2.1}$$

2.1.2.3 Mean Piston Speed

A parameter that important for calculation the engine behaviour as a function of speed is the mean piston speed [53]. The formula is as shown in equation 2.2

$$\bar{U}_p = 2LN \tag{2.2}$$

where L stand for stroke and N stand for rotational speed of crankshaft.

2.1.2.4 Air/Fuel Ratios

In engine testing, the air mass flow rate and fuel mass flow rate are measured. The ratio of these flow rates can be defined as shown in equation 2.3

$$AF = \frac{m_a}{m_f} = \frac{\dot{m}_a}{\dot{m}_f} \tag{2.3}$$

where m_a stand for mass of air and m_f stand for mass of fuel.

2.1.3 Performance

2.1.3.1 Brake Torque and Power

Torque can be defined by a measure of engine's ability to do work. The brake torque can be measured by using a dynamometer [53]. The brake torque can be measured using the equation 2.4

$$T = Fb \tag{2.4}$$

where F stand for force and b stand for the distance between centre of rotor and force.

Power can be defined as the rate at which work is done [53]. The brake power can be calculated using the equation 2.5

$$P = 2\text{p}NT \tag{2.5}$$

where p stand for angular speed, N stand for crankshaft rotational speed and T stand for torque.

2.1.3.2 Mean Effective Pressure

The other important terms that frequently used in conjunction with reciprocating engine is the mean effective pressure (MEP). It is a fictitious pressure that, if it acted on the piston during the entire power stroke, would produce the same amount of net work as that produced during the actual cycle [9]. MEP can be calculated using equation 2.6.

$$MEP = \frac{W_{net}}{V_{\max} - V_{\min}} \tag{2.6}$$

2.2 TWO-STROKE ENGINE

2.2.1 Introduction

Two stroke spark-ignition engine can be identified by the definition of both zero-dimensional time-varying control volumes such as cylinder or crankcase and one-dimensional devices like intake or exhaust manifold. The fundamental processes like combustion, fluid dynamics and scavenging can be modelled using up-to-date approaches [5].

2.2.2 Basic Operation

The operation of the two stroke engine is quite simple compared to four stroke engine [8][9]. When the piston at TDC, the trapped air and fuel charge is being ignited by the spark plug, producing a rapid rise in pressure and temperature which will drive the piston down on the power stroke [8][14][16]. Below the piston, the opened inlet port is inducing air from the atmosphere into the crankcase due to the increasing volume of the crankcase lowering the pressure below the atmospheric value [8][14].

Then, above the piston, the exhaust port has been opened. It will allow the hot and high pressure exhaust gas to transfer from the cylinder to the exhaust ducts. As the area of the port is increasing with crankshaft angle and the cylinder pressure is falling with time, the exhaust duct pressure profile is increasing to a maximum value. Below the piston, the compression of the fresh charge is taking place [8][14].

Next process, above the piston the initial exhaust process, referred to as blowdown, is nearing completion and with the piston having uncovered the transfer ports, this connects the cylinder directly to the crankcase through the transfer ducts. If the crankcase pressure exceeds the cylinder pressure then the fresh charge enters the cylinder. This process is known as scavenge process [8].

Condition for the next process, in the cylinder, the piston is approaching the trapping point or exhaust closure. The scavenge process has been completed and the cylinder is now filled with a mix of air, fuel and exhaust gas. As the piston rises, the cylinder pressure should also rise, but the exhaust port is still open and barring the intervention of some unsteady gas-dynamic effect generated in the exhaust pipe, the piston will spill fresh charge into the exhaust duct to the detriment of the resulting power output and fuel consumption [8].

2.2.3 Combustion Process

For any engine, combustion process is the most important process. The right time for the combustion process will lead to more power output and better fuel consumption. An analysis about the combustion process and quick throttle opening for two stroke engine had been studied. The outcome of the analysis is the exhaust-pressure wave is heavily fluctuated and it was caused by fluctuation of combustion velocity and duration for crank-angle [28].

The combustion chamber geometry is vital in spark ignition engine. The combustion model using the equivalent integral length scale shows the amplified turbulence effect of the bowl in a bowl-in-piston chamber. Also, the spark plug location affects combustion significantly in the total burning duration and the burning duration of a disc chamber is more dependent on a spark plug location than a hemisphere chamber [39].

2.2.4 Scavenging Process

The important thing when talk about two stroke engine is scavenging system. Scavenging is the operation of clearing the cylinder of burned gases and filling it with fresh mixture combination between intake and exhaust process [31]. The performance of the scavenging system is highly dependent on the dimensioning of the inlet, transfer and exhaust port [14][23]. Scavenging and filling the cylinder with a compressed fresh charge admitted through a scavenging port when the piston approaches a bottom dead centre [16]. Actually, the power of two stroke engine is influenced by the scavenging efficiency [21][22][23]. There are ways of scavenging the two stroke engine such as cross-scavenging, loop scavenging and uniflow scavenging [21][40]. The best in scavenging efficiency is uniflow scavenging [21].

2.2.5 Improvement

To improve the performance and durability of two stroke engines, pressure, volume and temperature of crankcase are the important parameters which need optimisation. Investigation of the previous histories have been done with reference to pressure fluctuations, backflow, Kadenacy effect, list approximation, ring sticking, engine seizure, crankcase volume, crankcase temperature, cylinder barrel temperature, engine speed and physical parameters of the engine [33].

2.2.6 Advantages and Disadvantages

Although two stroke engine is known as simple and low cost engine [42][47], its widest practical utilization only for low-output mopeds and motorcycles [5][7][29][43]. Also, two stroke engine offered some advantages such as cost reduction, specific output increase, NOx emission control, size and weight reduction [5]. The two stroke engine also can generate the same power as four stroke engine as the same size but at higher air/fuel ratios [15][44] and has better power to weight ratio compared to four stroke engine [47]. The disadvantages of two stroke engine are high emission and fuel consumption [34][44]. In the ported two stroke engine, 20-40% of the fresh charge passes unburned from the cylinder. This results in power loss and a very high concentration of unburned hydrocarbons in the exhaust [34].

2.2.7 Research and Development

2.2.7.1 Introduction

To reduce the emission in two stroke engine, many ways had been developed. Firstly, a pump operable to periodically pump air unmixed with fuel into the combustion chamber. Second, a fuel injector communicating directly with the combustion chamber and inject fuel unmixed with air directly in the combustion chamber. In the exhaust system, an exhaust manifold will communicate with the combustion chamber and operable to produce a thermal reaction to reduce engine exhaust emission [20].

2.2.7.2 Stratified Scavenging

The stratified scavenging had been applied to two stroke engine to improve fuel consumption and reduce exhaust emission [35][37][41][43]. The stratified scavenging system consists of long passages from crankcase to scavenging port and the supplemental air system intake system directly to the scavenging port [30]. This system is achieved by delivering the fuel into the rear transfer passage from a remote mechanical fuel metering device, operated by intake manifold pressure as shown in Figure 2.1. The outcome of the method is a 65% reduction in HC emission [29].

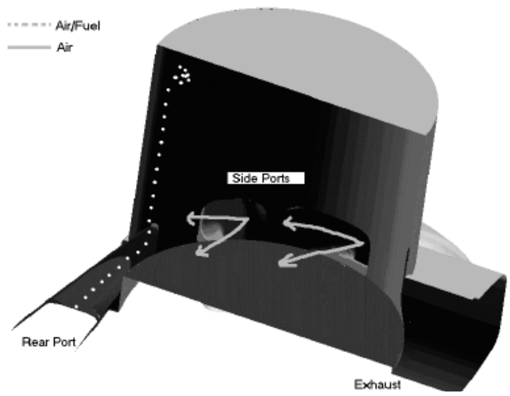

Figure 2.1: Stratified scavenging cylinder [35]

The stratified scavenging system for two stroke engine can be developed to highest level to obtain greater results. Effective trapping was obtained by injecting fuel into the crankcase and inducing air through an inlet at the top of the transfer ducts. The results showed significant improvement over the standard homogeneous scavenge engine. The brake specific fuel consumption was reduced by up to 22% and the brake specific hydrocarbons by up to 55% [36].

2.2.7.3 Leaner Combustion Technology and Stratified Scavenging

To improve the efficiency and decrease the emission cause by two stroke engine, a research had been made. The objective of the research is to reduce the hydrocarbon emission and improve the thermal efficiency of two stroke engine. Two kind of engine had been used in this research. One is prototype two stroke cycle engine with leaner combustion technology and air-head stratified scavenging [29][30][41], the other one is current two stroke cycle engine with Schnurle scavenging [41]. The specification of the engine had been listed in Table 2.1 [7].

Table 2.1: Engine specification [7]

Model	Prototype Two-Stroke	Current Two-Stroke
Displacement (cm^3)	33.6	33.6
Bore (mm)	36	36
Stroke (mm)	33	33
Effective Compression Ratio	7.5	7.5
Intake Method	Crankcase reed valve	Piston valve
Scavenging Method	Air-head stratified scavenging	Schnurle scavenging
Ignition System	CDI with CPU	Transistor
Cooling Method	Air	Air
Rated Power (kW)	1.10 (target)	1.10
Rated Speed (rpm)	7000	7000

To obtain the result from this experiment, the apparatus like Bex-5100 G2 raw gas sampling and a dynamometer model PH-A03 had been used. The result of the experiment had been shown in Figure 2.2 and Table 2.2 [7].

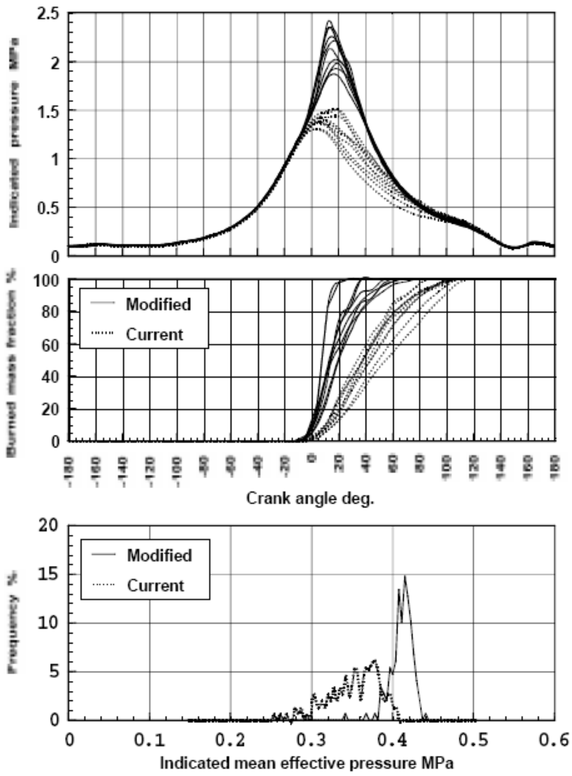

Figure 2.2: Effect of the modified combustion chamber [7]

Table 2.2: Summary of test result [7]

Item		**R & D Target**	**Prototype Two-Stroke**	**Current Two-Stroke**
Mass Emission at Rated Speed (g/h)	THC	-	42.9	230.3
	CO	-	68.3	97.1
	NOx	-	2.80	2.71
Mass Emission at Idle Speed (g/h)	THC	-	34.9	46.5
	CO	-	27.4	38.2
	NOx	-	0.12	0.11
Weighted Emission (g/kWh)	THC	67	44.6	208.4
	CO	174	67.9	89.7
	NOx	5.36	2.68	2.41
Thermal Efficiency	%	18	20.6	13.6
Rated Power	kW	1.10	1.05	1.13