ONE-DIMENSIONAL SIMULATION OF A 4-STROKE SI ENGINE EMPLOYING NOVEL CYLINDER HEAD CONCEPT: INTAKE AND EXHAUST FLOW INVESTIGATION

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JUDUL: ONE DIMENSIONAL SIMULATION OF A 4-STROKE SI ENGINE EMPLOYING NOVEL CYLINDER HEAD CONCEPT: INTAKE AND EXHAUST FLOW INVESTIGATION

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KHAIRUL AIZAT BIN ABDUL RAHIM

Thesis submitted in fulfillment of the requirements for the award of the degree of Bachelor of Mechanical with Automotive Engineering

Faculty of Mechanical Engineering
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6 DECEMBER 2010

SUPERVISOR'S DECLARATION

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

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STUDENT'S DECLARATION

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

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Specially dedicated to
My beloved family, and those who have guided and inspired me throughout my journey of learning

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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

This project investigates the flow characteristic in novel cylinder head at various port size and runner length. Novel cylinder head engine is a design engine that operates in a 4-stroke operational cycle. This engine uses a second opposed piston in designed cylinder head that moves at half the cyclical rate of the main piston, thus giving six piston movements per cycle. Functionally, the second piston replaces the valve mechanism of a conventional engine. Intake and exhaust poppet valve is replaced with two-stroke reed valve and exhaust port similar with two-stroke engine mechanism. The flow in a pipe of an engine exhaust and/or inlet system is treated as one dimensional. This means that the pressures, temperatures and flow velocities obtained from the solution of the gas dynamic equations represent mean values over the cross-section of the pipes. 1-d simulation tool used in this investigation is GT-power. Simulation runs with limitation of port size not exceed 70% size of cylinder head and exhaust length is limit to length of the motorcycle. The parameters investigated are volumetric efficiency of engine at difference engine speed and mean pistons speed. The parameter to investigate is flow rate during motoring only. The engine speed is limited to 4000 rpm related to maximum torque of original engine. Volumetric efficiency is increase with bigger intake port and smaller exhaust port. Elongations of the exhaust pipes give an improvement potential of the engine efficiency. The optimal value to choose in the novel cylinder head from the simulation result is at intake port size of 24 mm and exhaust port 16 mm as it has the optimal efficiency. For runner length the optimal value at intake runner length 90 mm and exhaust runner length 1050 mm.

ABSTRAK

Projek ini mengkaji ciri-ciri aliran di kepala silinder baru dengan saiz pelbagai pelabuhan dan panjang paip. Novel kepala silinder enjin adalah rekaan mesin yang beroperasi dalam kitaran operasi empat lejang Mesin ini menggunakan omboh menentang kedua-dua di kepala silinder direka yang bergerak pada setengah tingkat kitaran piston utama, sehingga memberikan gerakan omboh enam pada kitaran. Fungsional, omboh kedua menggantikan mekanisme injap mesin konvensional. Intake dan exhaust injap popet diganti dengan injap buluh dua-stroke dan eksos port yang sama dengan mekanisme mesin dua-stroke. Aliran dalam paip mesin knalpot dan/atau sistem udara masuk dianggap sebagai satu dimensi. Ini bermakna bahawa tekanan, suhu dan kelajuan aliran yang diperolehi daripada penyelesaian persamaan gas dinamik merupakan nilai rata-rata di atas penampang paip. 1-d simulasi alat yang digunakan dalam penelitian ini adalah GT-power. Simulasi berjalan dengan keterbatasan saiz pelabuhan tidak melebihi 70% dari saiz kepala silinder dan knalpot panjang adalah batas untuk panjang motosikal. Parameter yang diteliti adalah kecekapan volumetrik enjin pada kelajuan perbezaan enjin dan bererti kelajuan omboh. Parameter untuk menyiasat adalah laju aliran semasa memandu saja. Kelajuan enjin terhad pada 4000 rpm yang berkaitan dengan torsi maksimum mesin asli. kecekapan volumetrik meningkat dengan port asupan yang lebih besar dan lebih kecil exhaust port.Elongations dari paip ekzos memberikan potensi peningkatan kecekapan enjin. Nilai optimum untuk memilih di kepala silinder baru dari hasil simulasi pada saiz asupan pelabuhan 24 mm dan lubang eksos 16 mm kerana memiliki kecekapan yang optimum.Untuk panjang runner nilai optimum pada panjang intake runner 90 mm dan exhaust runner panjang 1050 mm.

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LIST OF SYMBOLS

ηv	Volumetric efficiency
ρ	Density
Vd	Displacement volume
N	Engine speed
$\dot{m}a$	Mass flow rate
V_c	Clearance volume
r_c	Compression ratio
%	Percentage
Vs	Versus
C_d	Discharge coefficient
D_v	Diameter
L_v	Valve lift
A_c	Curtain area

LIST OF ABBREVIATIONS

TDC	Top Dead Center
BDC	Bottom Dead Center
ABDC	After Bottom Dead Center
ATDC	After Top Dead Center
RPM	Revolution per minute
P-V	Pressure versus volume
SI	Spark ignition

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Spark ignition (SI) engine is the most common engine that been use all over the world. In the past few years SI engine have been improved in term of efficiency and pollutant emissions. The quest for an engine which having the same or more power with higher fuel efficiency than the existing ones has started before many years. Of these the reasons developed three six stroke engines is undergoing tremendous research works. During every cycle in a typical four stroke engine, piston moves up and down twice in the chamber, resulting in four total strokes and one of which is the power stroke that provides the torque to move the vehicle. But in a six stroke engine there are six strokes and out of these there are two power strokes. The automotive industry may soon be revolutionized by a new six-stroke design which adds a second power stroke, resulting in much more efficiency with less amount of pollution. The six-stroke engine uses a second opposed piston in each cylinder that moves at half the cyclical rate of the main piston, thus giving six piston movements per cycle. Functionally, the second piston replaces the valve mechanism of a conventional engine but also increases the compression ratio. The currently notable designs in this class include two designs developed independently: the Beare Head engine, invented by Australian Malcolm Beare, and the German Charge pump, invented by Helmut KottmannGriffin six-stroke engine.

1.2 PROBLEM STATEMENT

Novel cylinder head give a positive effect on the performance. In order to improve and to get a batter other factor and parameter need to investigate. In this study it focuses in the intake and exhaust flow. The design will be using reed valve for the intake system and exhaust port for the exhaust system. The volumetric efficiency of the design is use to measure the effectiveness of the engine.

1.3 OBJECTIVE

The objective of this project is to:

i. To model the intake and exhaust ports of novel cylinder head in GT-Power
ii. To investigate the flow characteristic of various port sizes and timing in GT-Power.

1.4 SCOPES

This study is limited to the intake and exhaust of a small engine which employing novel cylinder head. The parameter to investigate is flow rate during motoring only. The engine speed is limited to 4000 rpm related to maximum torque of original engine. The various port size is varies not exceed 70% size of cylinder head.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The novel cylinder head design had shown a positive effect on the performance and also to the environment compare to the original engine. In order to get a batter performance, few other factors need to be considered. Some of the factors are optimizing intake flow, valve timing, stress analysis, fuel injection and ignition timing, heat transfer analysis, fabrication and testing. These studies focus in modeling and simulate intake and exhaust system for novel cylinder head using GT-power as 1-D simulation tool. The investigation is on the flow characteristic when using various port sizes, length and timing.

2.2 ENGINE CYCLES

Operating cycle of internal combustion engine can be divided into a sequence of separate processes which is intake, compression, expansion, and exhaust. With models for each process, a simulation of a complete engine cycle can be build which can be analyzed to provide information on engine performance.

2.2.1 Four-Stroke Operating Engine Cycle

The first person to actually build a car with this engine was German engineer Nikolaus Otto. That is why the four-stroke principle today is commonly known as the Otto cycle and four-stroke engines using spark plugs often are called Otto engines. The Otto cycle consists of adiabatic compression, heat addition at constant volume, adiabatic expansion and rejection of heat at constant volume. In the case of a four-stroke Otto cycle, there are also an isobaric compression and an isobaric expansion, usually ignored since in an idealized process those do not play any role in the heat intake or work output.

Four –stroke operating engine cycle is called an Otto Cycle. The operating cycle is approximated by the air-standard cycle as shown in Figure 2.1.

The intake stroke starts with piston at TDC and is at an inlet pressure of one atmosphere. It is a constant pressure process 1-6 Figure 2.1.

The second stroke of the cycle is compression stroke, which is an isentropic compression from BDC to TDC process 1-2 Figure 2.1. In a real engine, the beginning of the stroke is affected by the intake valve not being fully closed until slightly after BDC and at the end if compression it is affected by the firing of the spark plug before TDC. The combustion process 2-3 in Figure 2.1 is at constant-volume conditions. In the real engine, combustion stated slightly BTDC and terminated a little ATDC.

Combustion process occurred in a closed constant-volume increase pressure and temperature in cylinder. The very high pressure generates the power stroke or expansion stroke process 3-4 Figure 2.1. High pressure on the piston face forces the piston back towards BDC and produces work and power output of the engine.

Near the end of power stroke of a real engine cycle, the exhaust valve is opened and the cylinder experiences exhaust blow down process 4-5 Figure 2.1. A large amount of exhaust gas is expelled from cylinder, reducing pressure to exhaust manifold. The exhaust valve opens BBDC to allow finite time of blow down to occur. The pressure within the cylinder at the end of exhaust blow down has been reduced to about one atmosphere.

The exhaust stroke process 5-6 Figure 2.1 occurs as the piston travel from BDC to TDC. The process occurs at constant pressure due to the open exhaust valve.

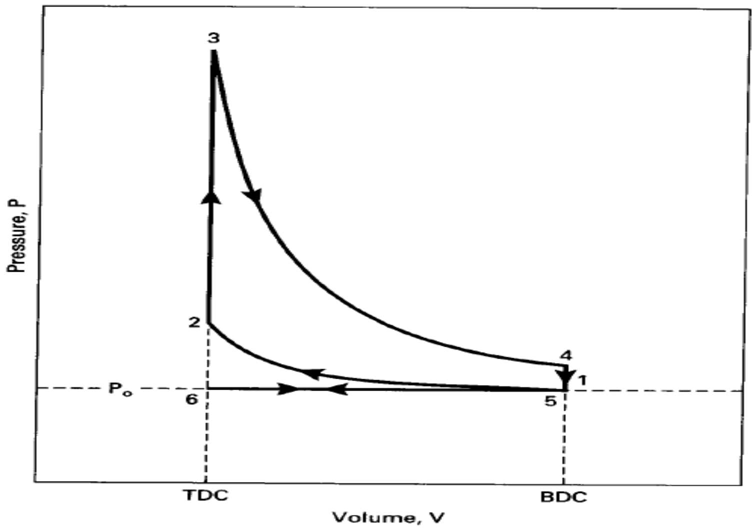


Figure 2.1: Otto cycle P-V diagram

Source: Pulkrabek,1997

2.3 INTAKE SYSTEM

The object of the intake system is to deliver the proper amount of air and fuel accurately and equally to all cylinders at the proper time in the engine cycle. Flow into an engine is pulsed as the intake valves open and close, but can generally be modeled as quasi-steady state flow. The intake system consists of an intake manifold, a throttle, intake valves, and either fuel injectors or a carburetor to add fuel. Fuel injectors can be mounted by the intake valves of each cylinder, at the inlet of the manifold, or in the cylinder head. The primary components of the automotive intake system are: intake manifold, throttle body/carburetor, and air induction components such as air cleaner and ducting.

Air cleaners filter the air before it reaches the engine. They remove abrasive particles which cause wear and damage. The filter must stop minute particles without restricting air-flow. Most air cleaners trap abrasive particles using a pleated dry paper element, but some use the dust-attracting property of oil. The air cleaner on a multi-point fuel injected engine uses a dry-type element. It is connected to the throttle body by a duct. For optimum performance, it needs to be supplied with cool, clean air.

The intake manifold carries the air of the air-fuel mixture to each cylinder. In spark-ignition engines, fuel is either mixed with the air at the entrance to the manifold, or injected close to the cylinder head.

To maintain ideal combustion conditions and reduce emissions, many air cleaners include a system to maintain air-intake temperature, regardless of outside air temperature.

2.3.1 Intake Valve

Intake valve of most internal combustion engines are poppet valves that are spring loaded closed and pushed open by the engine camshaft. Most of the valve are made form a hard alloy steel (Pulkrabek,1997).

The distance which the valve opens is called valve lift Figure 2.2. Due to the constant opening and closing of the valves, the cross sectional area through which the flow passes through changes. This area is referred to as the effective area. This area is defined as in Eq. (2.1).Where A_c is curtain area and C_d is discharge coefficient.

$$A_e = A_c (q) C_d(q) \tag{2.1}$$

The curtain area, A_c, can be defined in several ways. A simple definition of the curtain area is given by Eq. (2.2). Where D_v is diameter of the valve and L_v is valve lift.

$$A_c = 3.14159 \text{ x } D_v L_v \tag{2.2}$$

The lift and the discharge coefficient both vary with the crank angle. The discharge coefficient is determined experimentally. This coefficient accounts for the real gas flow effects.

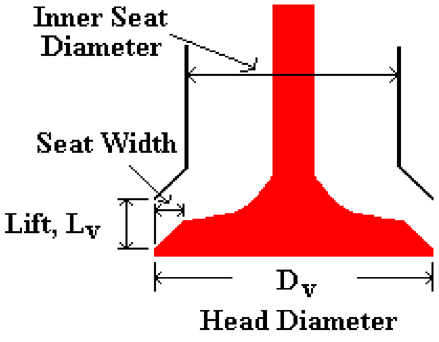


Figure 2.2: Schematic of the poppet valve

Source: Taylor

2.3.2 Disc valve

The disc valve design is emanated from East Germany in the 1950s (Blair, 1996). Most disc valve has timing characteristic and is usually fabricated from spring steel.

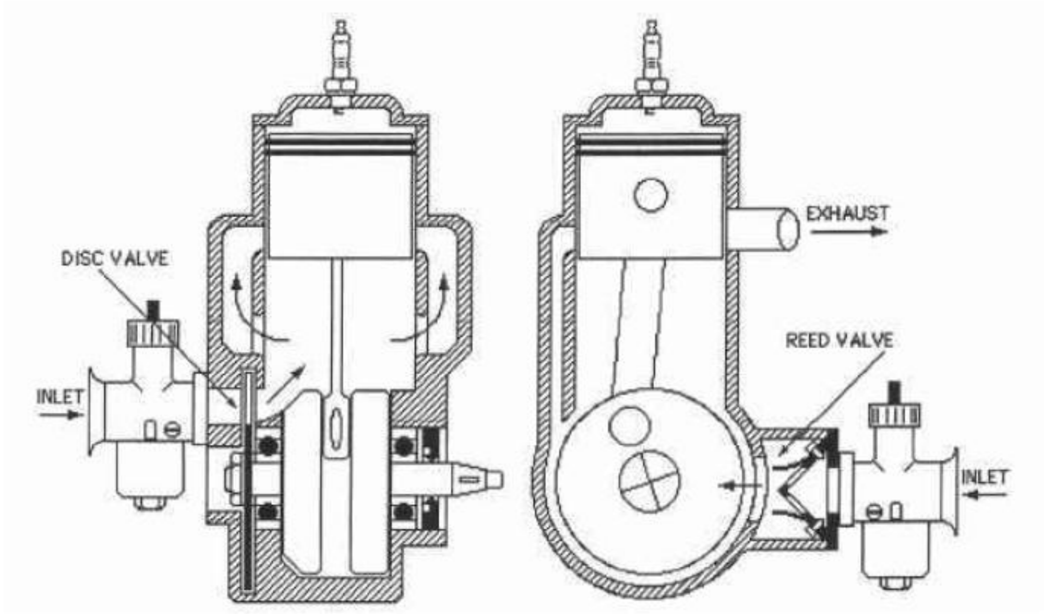


Figure 2.3: Disc valve and reed valve control of the inlet system

Source: Blair, 1996

2.3.3 Reed valve

Reed valve Figure 2.4 have and elastic reed that rest on a basic body. It controls gas transfer in the intake port. Most reed valve is design as V-block Figure 2.3 and the material used for the reed petals are either spring steel or composited material.

The reeds are self acting and open when vacuum builds in the engine crankcase so that the air or fresh mixture can enter freely. As the pressure increased in the crankcase up to pressure in the intake manifold, the reeds automatically close, thus preventing backflow of the induced charge.

Figure 2.4: Reed valve

Source: A. Angeletti

2.4 EXHAUST SYSTEM

During engine operation, each time the exhaust valve opens pulses of hot exhaust gases are forced into the exhaust manifold. These hot, rapidly expanding gases produce a lot of noise, some of it at very high frequency. The exhaust system does several jobs. It has to reduce the noise of the exhausting gases to acceptable levels. It has to discharge the gases safely, far enough away to prevent them re-entering the vehicle.

Some of these gases are highly poisonous. In an enclosed space, carbon monoxide can cause death in minutes. It is odorless and colorless, which makes it difficult to detect, and removing it is especially important. In modern vehicles, it also keeps harmful emissions to a minimum.

The exhaust system is designed to enhance engine operation. A well-designed system can improve drivability and performance. In this simplified model, burned gases exit the cylinder through the exhaust port and pass into the exhaust manifold.

The first pipe is usually called the engine pipe. It is connected to the outlet of the manifold which carries the exhaust gases to the muffler, which reduces exhaust noise. Exhaust gases are then discharged through a tail pipe, usually at the rear, or sometimes, to the side or above the vehicle.

The primary components of the automotive exhaust system are: exhaust manifold, engine pipe, catalytic converter, exhaust brackets, muffler and components such as the resonator and tail pipe. The exhaust manifold collects exhaust gases as they leave each cylinder and directs them into the exhaust system. The exhaust pipe carries the hot exhaust gases to where they can be discharged into the atmosphere.

2.5 INTAKE AND EXHAUST FLOW

The intake and exhaust system are important because these system govern the air flow into the engine cylinders. The higher the air flow, the larger the amount of fuel that can burn and greater the power produced. The importance parameters are volumetric efficiency for four-stroke engine or scavenging and trapping efficiencies for two-stroke engine.

Mass flow through the intake valve into a cylinder is shown in Figure 2.5. Reverse flow can result when valve overlap occurs near TDC. Reverse flow out of the cylinder will also occur at lower engine speeds as the intake valve is closing ABDC, as previously explained. Intake valves normally start to open somewhere between 10° and 25° BTDC and should be totally open by TDC to get maximum flow during the intake stroke. The higher the speed for which the engine is designed, the earlier in the cycle the intake valve will be opened. In most engines valve timing is set for one engine speed, with losses occurring at any lower speed or higher speed. At lower than design speed the intake valve opens too early, creating valve overlap that is larger than necessary. This problem is made worse because low engine speeds generally have low intake manifold pressures. At higher than design speeds, the intake valve opens too late and intake flow has not been fully established at TDC, with a loss in volumetric efficiency.

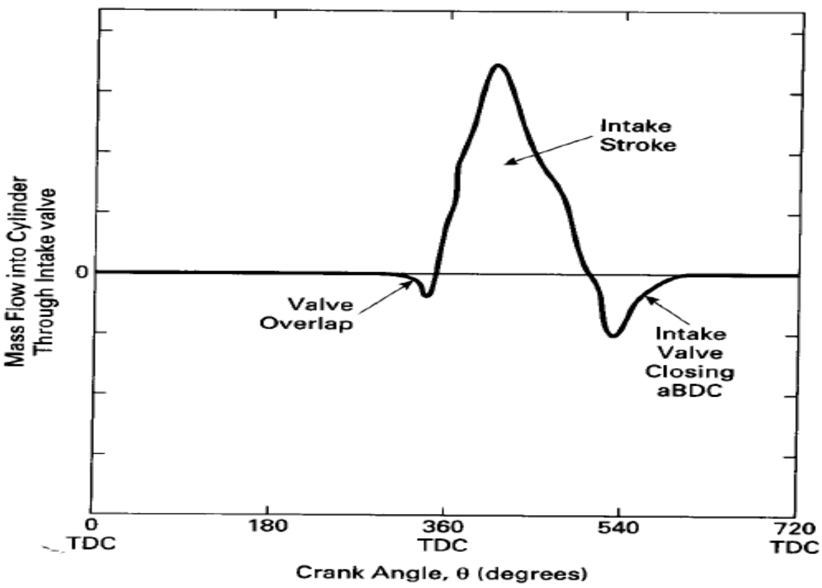


Figure 2.5: Flow of air-fuel mixture through the intake valve into engine cylinder

Source: Pulkrabek,1997

Figure 2.6 shows the flow of gases through the exhaust valve out of the cylinder. When the valve is first opened, blow down occurs with a very high flow rate due to the large pressure differential. Choked flow will occur at first, limiting the maximum flow rate. By the time the piston reaches BDC, blow down is complete, and flow out of the exhaust valve is now controlled by the piston during the exhaust stroke. The piston reaches maximum speed about halfway through the exhaust stroke, and this is reflected in the rate of exhaust flow. Towards the end of the exhaust stroke, near TDC, the intake valve opens and valve overlap is experienced. Depending on engine operating conditions, a momentary reverse flow of exhaust gas back into the cylinder can occur at this point.

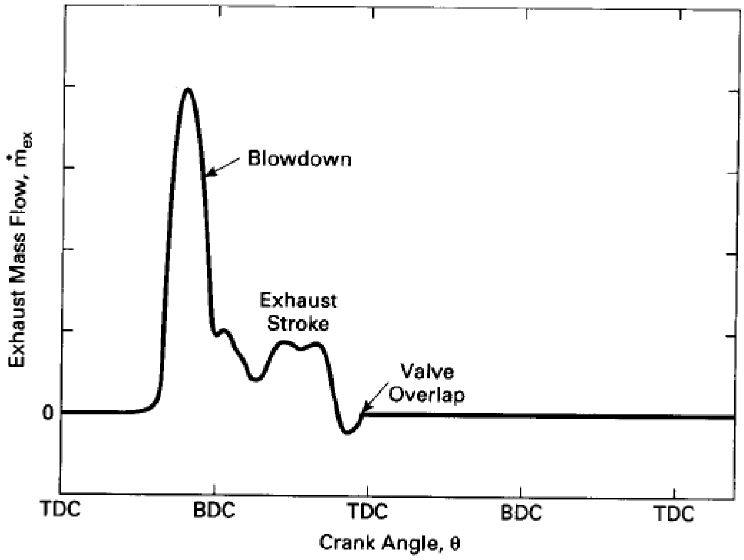


Figure 2.6: Exhaust gas flow out of cylinder through exhaust valve

Source: Pulkrabek,1997

2.4.1 Variation with speed, and valve, area, lift, and timing

Volumetric efficiency depends on the velocity of the fresh mixture in the intake manifold, port, and valve. Since the intake system and valve dimensions scale approximately with the cylinder bore, mixture velocities in the intake system will scale with piston speed. Hence, for different engines it should be compare with same mean piston speed.

The shape of volumetric efficiency versus mean piston speed curves can be explained in the Figure 2.7. This figure shows the effect on volumetric efficiency at difference phenomena. Charge heating in the intake manifold and cylinder drops curve A to curves B. The induction ram effect, at higher engine speeds, raises curves D to curve E. Late inlet valve closing increased charging at high speeds and at low speed, volumetric efficiency is decease due to the backflow.

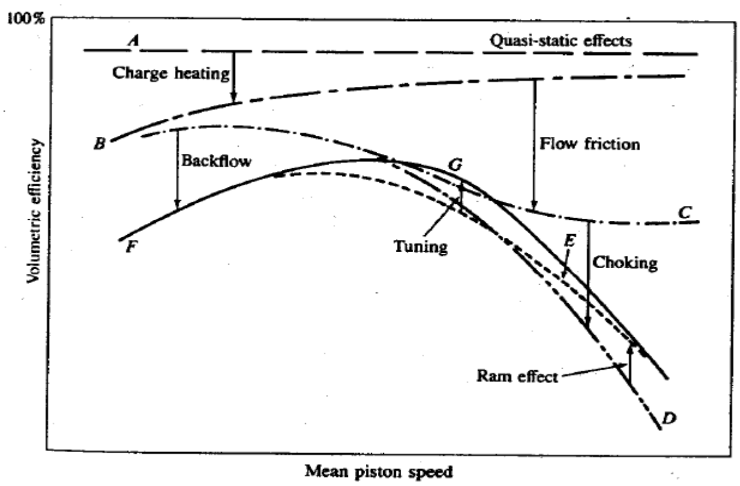


Figure 2.7: Effect on volumetric efficiency at difference phenomena

Source: Heywood, 1988

Figure 2.8 shows effect of on the volumetric efficiency of tuning the intake manifold runner. The 34 cm length produces desirable volumetric curves with increased low-speed air flow and flat mid-speed characteristic. The longest runner increase low speed air flow and flat mid speed characteristic. The longest runner increase volumetric efficiency but at high speed it unacceptable.

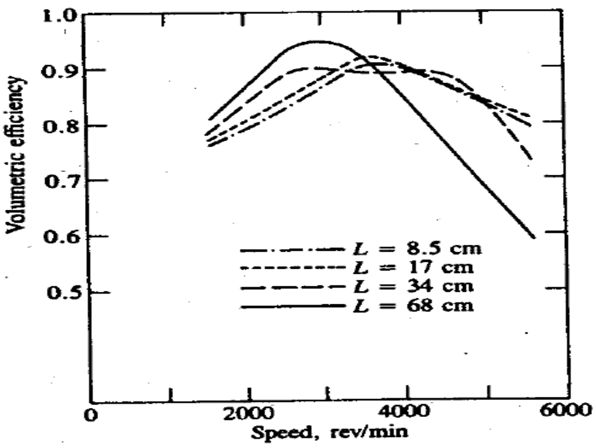


Figure 2.8: Effect of intake runner length on volumetric efficiency versus speed

Source: Heywood, 1988

Figure 2.9 shows effect of varying valve timing and valve lift on the volumetric efficiency versus speed curve. Low valve lift restricts engine breathing over the mid speed and high speed operating ranges. Above the critical valve lift, it is no longer a major constrain on effective valve open area.

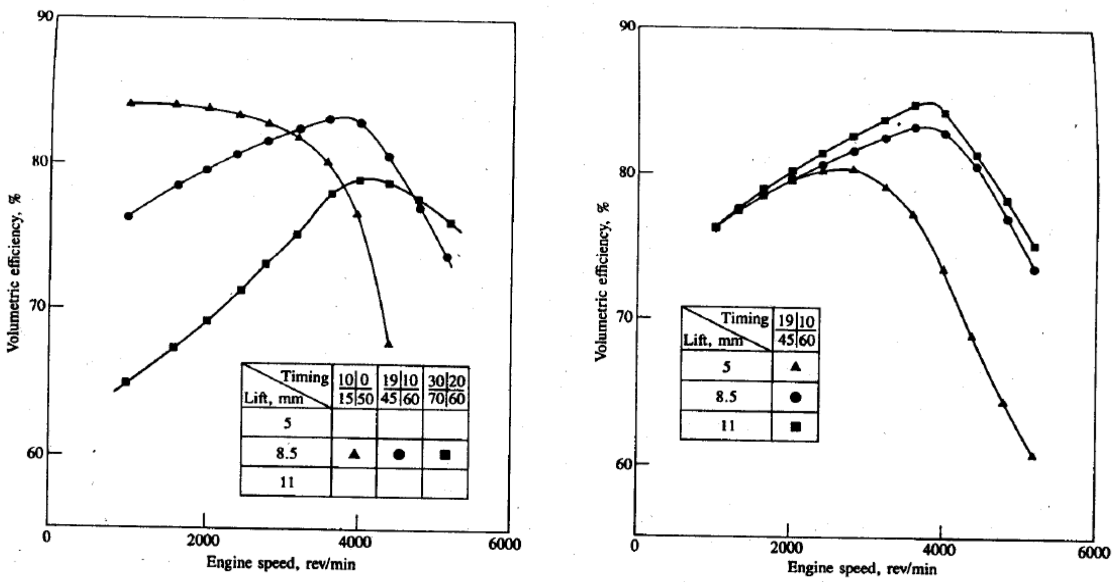


Figure 2.9: Effect of valve timing and valve lift on volumetric efficiency versus speed

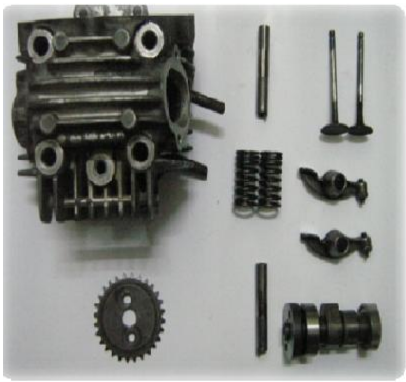
Source: Heywood, 1988

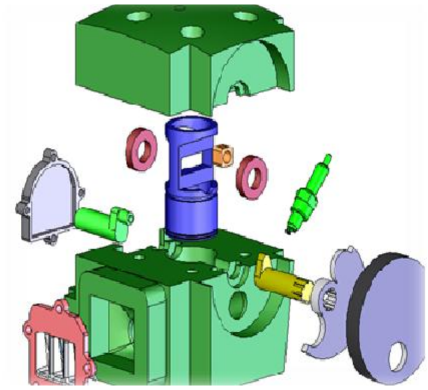
2.6 NOVEL CYLINDER HEAD

In an internal combustion engine, the cylinder head sits above the cylinders on top of the cylinder block. It consists of a platform containing part of the combustion chamber and the location of the poppet valve and spark plugs.

The new novel cylinder head concept had been design. These new designs of cylinder head are different from the original cylinder head. The original cylinder head consist of poppet valve and spark plug and it had been use in most type of vehicle.

The new design of cylinder head is base on the design of Baere. It's using a beare head. This engine work with two pistons, which the main piston create 4-stroke and the additional 2-stroke makes it 6-stroke engine. Beare designs cause an incensement of power from the transmitted power via the timing chain to the crankshaft. The new design cylinder head work with intake and exhaust port just like two stroke engine and with the special design of piston, it able to open and closing the intake port. The crank arm which is connects to piston move it up and down.





Original New design

Figure 2.10: Cylinder head original 110cc and novel cylinder head concept

Source: Kaharudin, 2008

The new cylinder head design give a positive result in term of performance and more environmentally theoretically. It increase the performance up to 34.8% in power, 15.5% for compression ratio and 7.5% in torque by theoretical.(Kaharudin, 2008)

2.6.1 Intake

The intake for the novel cylinder head is difference from the original design. Novel cylinder head used the reed valve as in the 2-stroke engine. The reed valve is place at the cylinder head. The reed valve only allows the flow to go in one direction. It reduces the reverse flow to the intake during running at low speed.

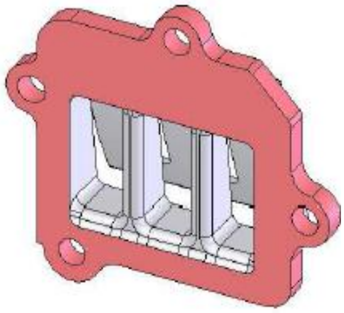


Figure 2.11: Reed valve design

Source: Kaharudin, 2008

2.6.2 Exhaust

Exhaust for the novel cylinder head design is use an exhaust port like the 2-stroke engine exhaust system. The opening and closing of the intake port is with the movement of the upper piston in the cylinder head.

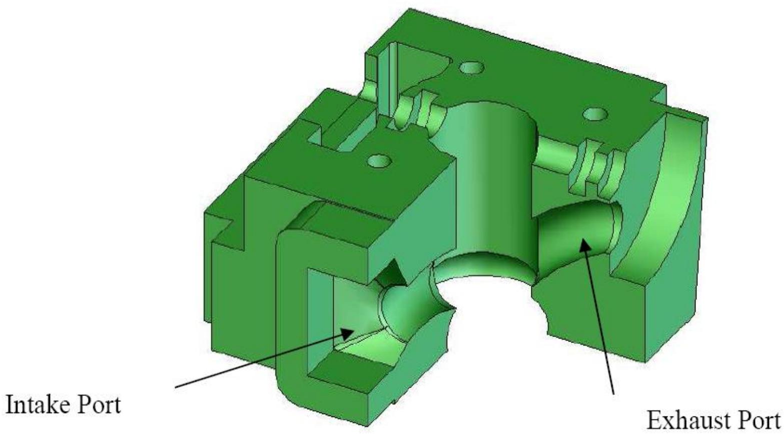
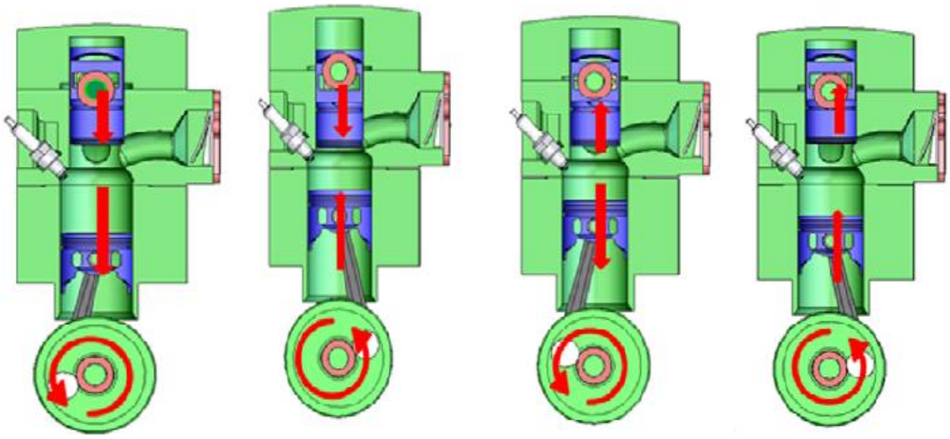


Figure 2.12: Main cylinder head

Source: Kaharudin, 2008

2.6.3 Novel Cylinder Head Operational



(a) (b) (c) (d)

Figure 2.13: Novel cylinder head engine cycle operation

Source: Kaharudin, 2008

Intake stroke operation Figure 2.11(a) the main piston moves from TDC to BDC. During this stroke the intake valve is open. The upper piston move half of it stroke from BDC to TDC.

Figure 2.11(b) shows compression stroke. At this time main piston moves from BDC to TDC. Both intake and exhaust valve close. Upper pistons complete another have of it stroke and reach TDC for the compression stroke.

Figure 2.11(c) shows power stroke operation. After the spark ignited, combustion occurs and the pressure in the combustion chamber increases and forces both piston move cause as the power stroke.

Figure 2.11(d) shows exhaust stroke. The upper pistons move from half of stroke to TDC and open the exhaust port. The main piston is move from BDC to TDC.

2.7 ONE DIMENSIONAL SIMULATION

One of the major areas of development in the internal combustion engine is the development of computer simulations of various types of engines. Their economic value is in the reduction in time and costs for the development of new engines and their technical value is in the identification of areas that require specific attention as the design study evolves. Computer simulations of internal combustion engine cycles are desirable because of the aid they provide in design studies, in predicting trends, in serving as diagnostic tools, in giving more data than are normally obtainable from experiments, and in helping one to understand the complex processes that occur in the combustion chamber(AL-BAGHDADI, 2004).

2.8 GT-SUITE

GT-Suite is an integrated set of computer-aided engineering (CAE) tools develop by Gamma Technologies, Inc. for design and analysis of engines, power train, and vehicles. It contain of six solvers (GT-Power, GT-Drive, GT-Vtrain, GT-Cool, GT-Fuel, and GT-Crank), a powerful processing package (GT-Post), and collection of supporting tools.

2.8.1 GT-Power

GT-Power is a 1-D engine simulation tool. It is a mathematical tool that uses advanced methodology to simulate the thermodynamic, fluid mechanic, and chemical processes that define real Internal Combustion engine behavior. The heart of the software is designed around a series of icons and connectors that define engine components and a logical interface for their use. These are shown in a schematic of what is referred to by GT-Power as the Project Map. Icons in the Project Map can be energized to reveal related information such as assigned values, formulas, etc., and methodology to edit input data as needed. At the heart of the software are two operating domains called GT-Ise and GT-Post. GT-Ise builds, executes, and manages the simulation process while GT-Post, a post-processing tool, provides access to computed results and plots. GT-Power is also important in determining the performance of an engine.

2.9 ENGINE PERFORMANCE PARAMETER

The engine parameters that need to determine in the project are volumetric efficiency. The engine parameter is important and need to state in the project to help in focusing the result. (Heywood, 1988, Pulkrabek,1997)

2.8.1 Volumetric Efficiency

The parameter is use to measure the effectiveness of an engine's induction process. It is define as the volume flow rate of air into the intake system divided by the rate at which volume is displaced by the piston. Eq. (2.3)

$$\eta v = \frac{2\dot{m}a}{\rho VdN} \tag{2.3}$$

Volumetric efficiency is affected by fuel, engine design, and engine operating variables.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter presents the specification and the descriptions of novel cylinder head used to model in GT-power 1-d simulation software. The investigation method to find the flow characteristic also describe in this chapter. Simulation of GT-power is run with a variation of intake, exhaust port and inlet, outlet runner length.

3.2 FLOW CHART DESCRIPTION

The project of one-dimensional simulation of a 4-stroke SI engine employing novel cylinder head concept: intake and exhaust flow investigation start with the background study or literature review of intake, exhaust and 1-D simulation. With the knowledge from literature review, the project continues to modelling of novel cylinder head in GT-power. The model is simulated and result obtain. The investigation run with various intakes and exhaust port size and difference inlet and outlet runner.

Intake and Exhaust Flow Investigation

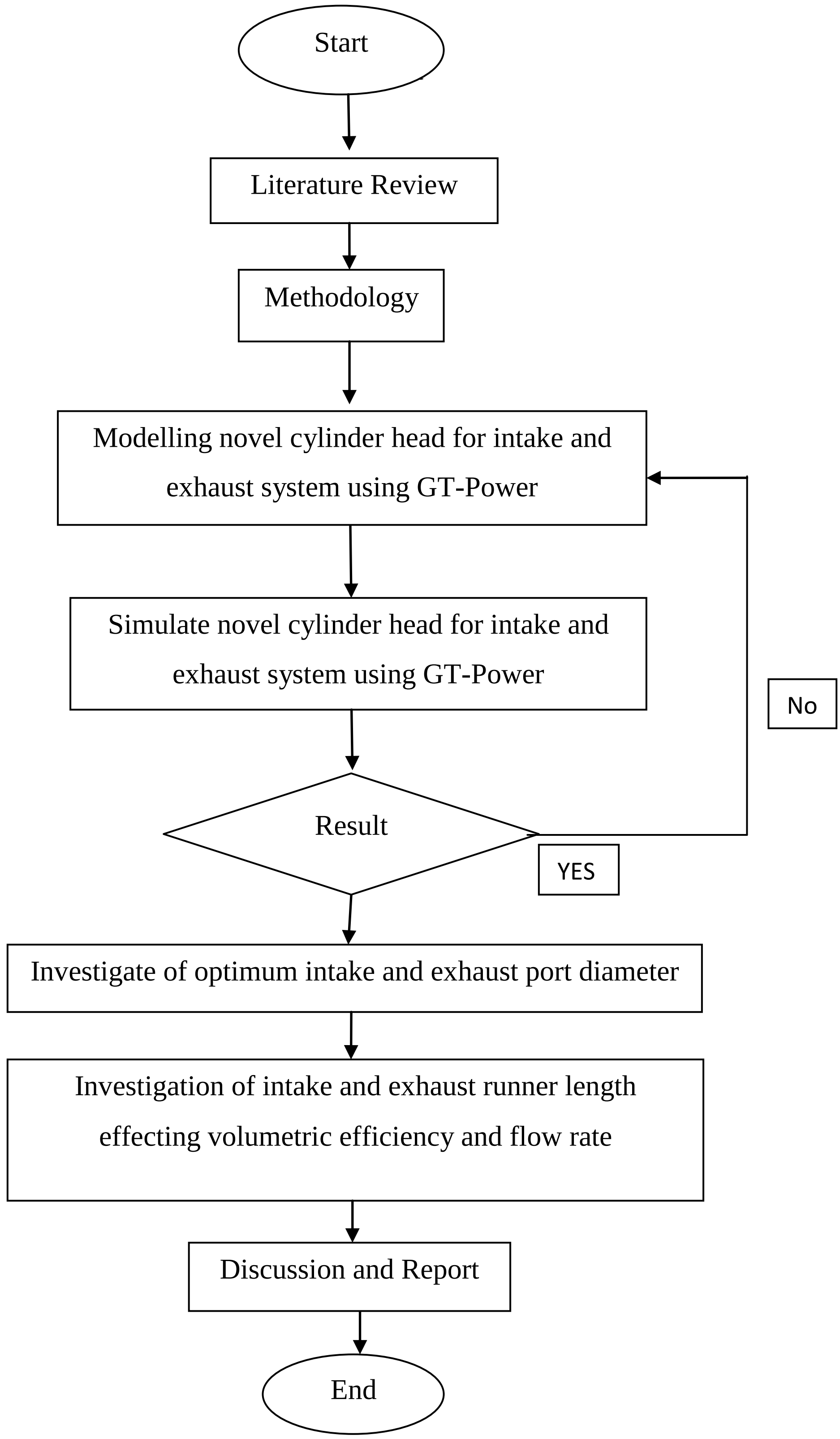


Figure 3.1: Flow Chart

3.3 MODELING NOVEL CYLINDER HEAD

Novel cylinder head is model in GT-Power software. After determining the specification of novel model, the right template need to be selected according suitability and output that needed. After selecting template, insert template data to determine object and model it in the project map. Run simulation and the output is produce in the GT-Post.

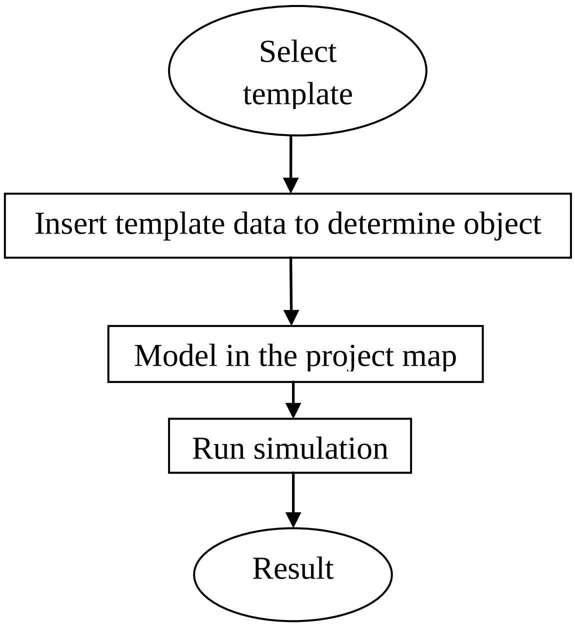


Figure 3.2: GT-Power simulation flow

3.4 ENGINE SPECIFICATION OF NOVEL CYLINDER HEAD

Table 3.1 shows the specification of novel cylinder head engine (Kaharudin, 2008). Novel cylinder head has two pistons which is the main and upper piston. Upper piston with a bore size of 34.6 mm and stroke 29.7 mm is smaller than main piston. Main piston has a bore of 53 mm and stroke 50.6 mm which is the original size of engine 110cc. The torque of this engine is 10Nm and power 8.9kW.

Table 3.1: Specification of novel cylinder head

	Piston	Bore(mm)	Stroke(mm)	Volume(cc)
Novel Cylinder Head	Main Piston	53.0	50.6	110
	Upper Piston	34.6	29.7	27.5

Item	Novel Cylinder Head
Compression Ratio	10.4:1
Torque	10 Nm
Power	8.9 kW

Source: Kaharudin, 2008

Comparison between novel cylinder head design engine and original 110cc shows in Table 3.2**.** Design engine have the same size of bore and stroke for main piston and smaller size of bore and stroke on the upper piston. Compression ratio of novel cylinder head is bigger than original engine. This can lead to a batter output performance of the engine.

Table 3.2: Comparison between 110cc engines with novel cylinder head engine

Part	110cc	Design engine
Bore(mm)	53.0	Main piston : 53.0
		Upper piston : 34.6
Stroke(mm)	50.6	Main piston : 50.6
		Upper piston : 29.7
Displacement volume(cc)	110	137.5
Clearance volume(cc)	14.7	13.8
Clearance height(mm)	6.2	6.6
Compression ratio	9.0	10.4

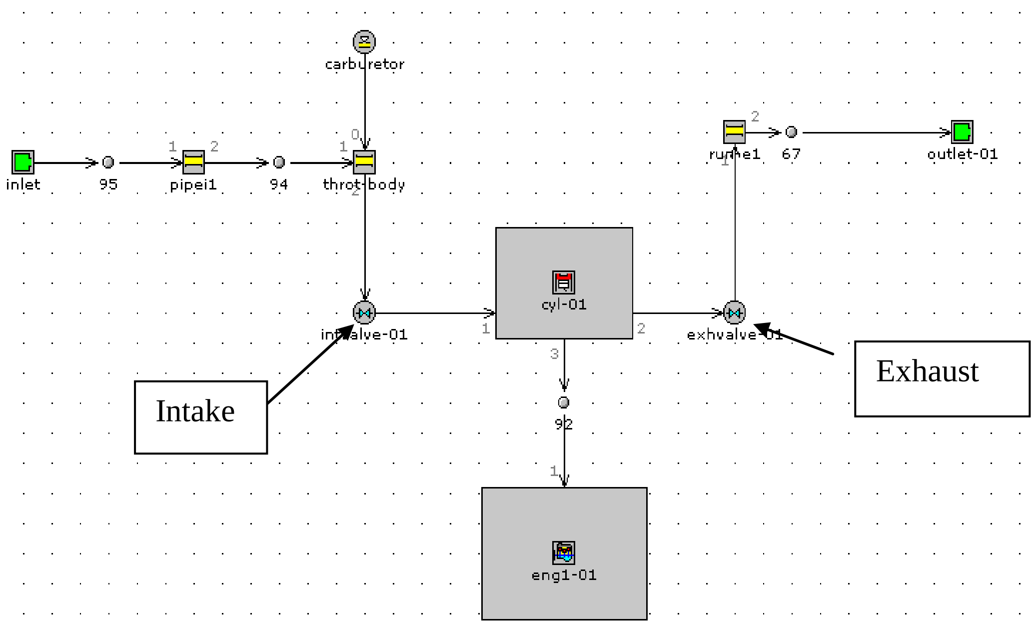


Figure 3.3: Model 110cc engine in GT-power

Figure 3.3 shows the model of 110cc engine. Original engine use intake and exhaust poppet valve and it is describe using template “ValveCamConn” in GT-power.

The 1-d simulation engine model of novel cylinder head is modeled with a total volume in GT-Power software. Total volume of novel cylinder head is equal to 137. 5cc @ 0.000138m^3

$$r_c = (V_c + V_d) / V_c \quad (3.1)$$

In Eq. (3.1) r_c is compression ratio, V_c is clearance volume, and V_d is displacement volume. From calculation the combustion chamber in novel cylinder head is 14.7cc and the clearance height is 6.6 mm.

Figure 3.4 shows the drawing of model diagram of novel cylinder head. Bore size in the diagram for simulation is 53.0 mm and stroke is 50.6 mm. The clearance height is from calculation and applied in the model which is 6.6 mm. The intake system in the diagram is using reed valve as in two-stroke and exhaust system using reed valve and exhaust port.

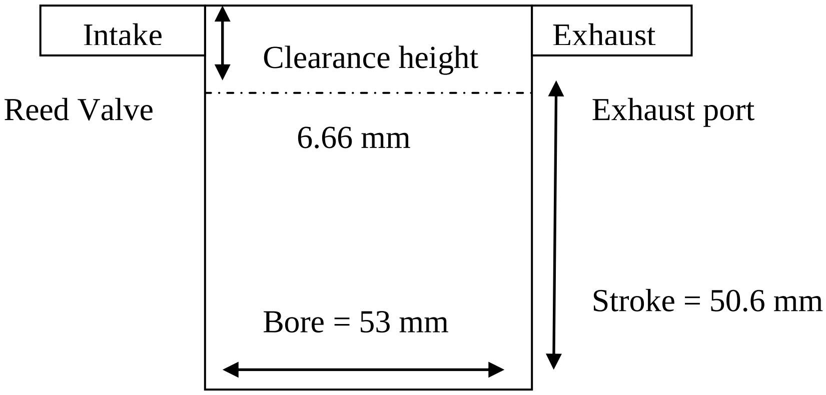


Figure 3.4: Model diagram of novel cylinder head

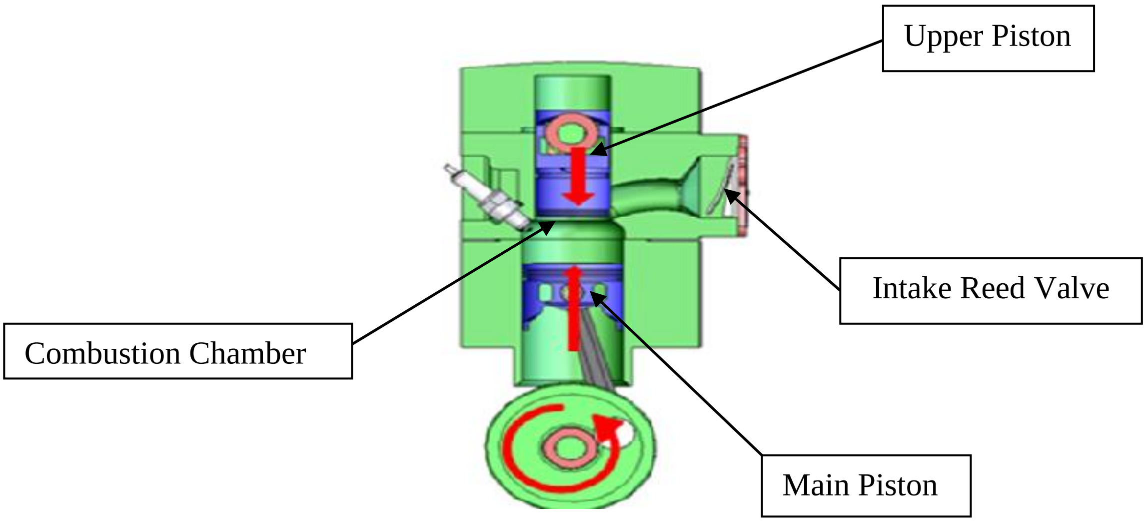


Figure 3.5: Novel Cylinder Head

Source: Kaharudin, 2008

Figure 3.5 shows picture of novel cylinder head during compression stroke. The upper piston functions as open and close of port of intake and exhaust similar with valve system. The model of novel cylinder head in Figure 3.3 is a diagram of novel cylinder head during compression stroke. During this condition the volume in cylinder is constant.

Table 3.3: Intake and exhaust system valve of novel cylinder head

Novel Cylinder Head model		
1	Intake	Reed valve Intake Port
2	Exhaust	Exhaust port

Source: Kaharudin, 2008

Geometry of reed valve, intake and exhaust port is determined from the drawing of novel cylinder head. Table 3.4 shows the dimension of part used as input in GT-power.

Table 3.4: Diameter and length of Intake and exhaust

Object	Dimension	Value
Reed Valve	Reference diameter	24 mm
Intake port	Diameter	22 mm
	Length	41 mm
Exhaust Port	Diameter	20 mm
	Length	48 mm

Source: Novel cylinder head drawing

Novel cylinder head works in four-stroke cycle. The intake and exhaust system for novel cylinder head is difference with ordinary four-stroke engine. Table 3.2 shows the intake and exhaust system used in a novel cylinder head. For intake it uses reed valve and intake port. For exhaust in used exhaust port.

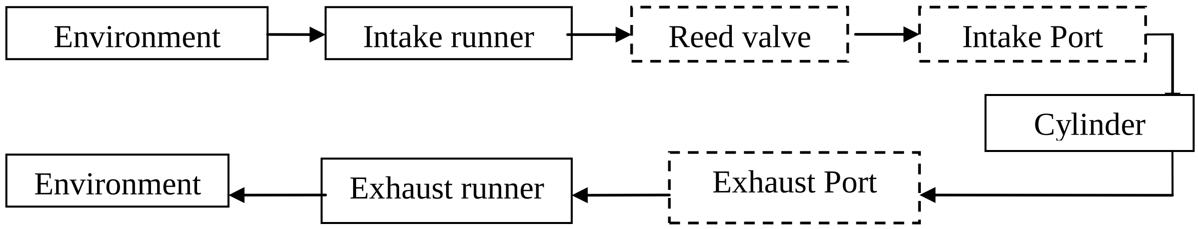


Figure 3.6: Novel Cylinder head flow diagram

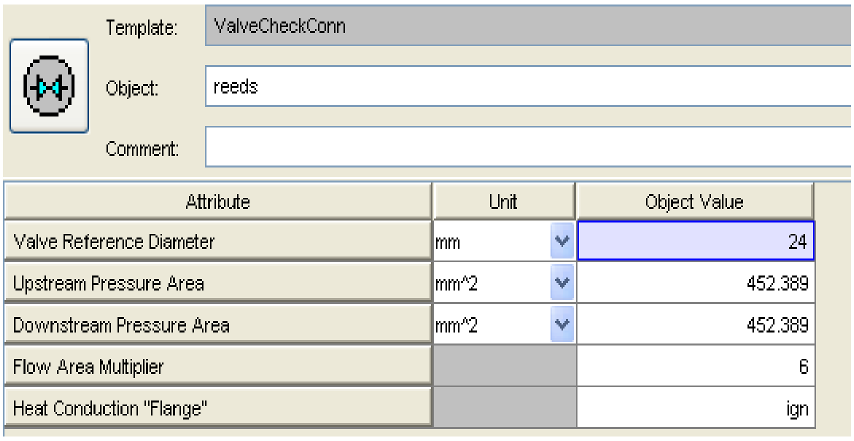
Figure 3.6 shows the flow diagram of novel cylinder head engine. The difference between original design engine and novel cylinder head engine is in the intake and exhaust system. The air in novel cylinder head flow through reed valve, intake port, into engine cylinder and out to exhaust port difference of original four stroke engine which flow through poppet valve for intake and exhaust.

3.4.1 Modeling template in GT-power

Template is an object to describe real part of an engine in a GT-power. Template is chosen depend on condition of engine and different investigation method. Template use in GT-Power to describe intake and exhaust are "ValveCheckConn" for reed valve and "ValvePortConn" for intake and exhaust port.

Object: ValveCheckConn

Template 'ValveCheckConn' Figure 3.7 is been use in modelling novel cylinder head engine to represent reed valve. The valve is defined such that high pressure at the valve inlet as defined by the linking arrows causes the valve to open and high pressure at the valve outlet causes the valve to close. Therefore, the valve acts to prevent backflow in the reverse direction of the linking arrow. The properties are such as reed valve.



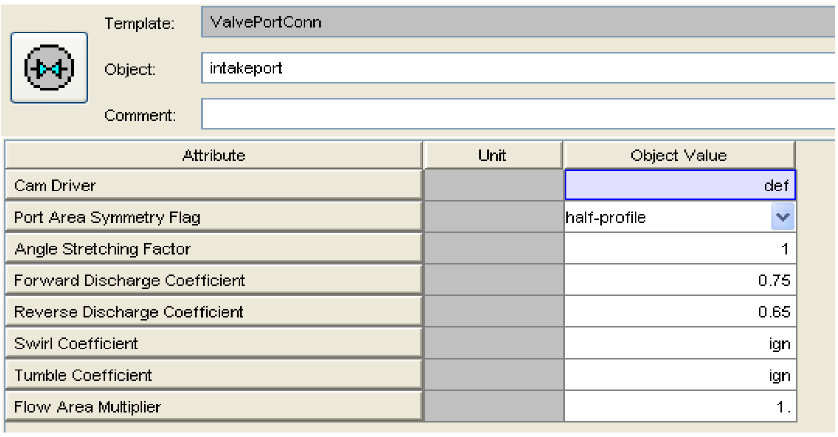
Template: ValveCheckConn
Object: reeds
Comment:

Attribute	Unit	Object Value
Valve Reference Diameter	mm	24
Upstream Pressure Area	mm^2	452.389
Downstream Pressure Area	mm^2	452.389
Flow Area Multiplier		6
Heat Conduction "Flange"		ign

Figure 3.7: ValveCheckConn object

Object: ValvePortConn

Template that use to present exhaust port is ‘ValvePortConn’ Figure 3.8. This object defines the characteristics of a ported valve for two-stroke engines including valve area and flow coefficients. The code calculates the flow through the valves in each direction using "effective area" which is the product of the actual area and the discharge coefficient, CD. The user may model the flow properly in a ported valve by either: 1) entering the actual geometric area of the port in the area array and specifying the two discharge coefficients; or 2) entering the effective area in the area array and setting the discharge coefficients to 1.



Template: ValvePortConn
Object: intakeport
Comment:

Attribute	Unit	Object Value
Cam Driver		def
Port Area Symmetry Flag		half-profile
Angle Stretching Factor		1
Forward Discharge Coefficient		0.75
Reverse Discharge Coefficient		0.65
Swirl Coefficient		ign
Tumble Coefficient		ign
Flow Area Multiplier		1.

Figure 3.8: ValvePortConn object

Object: EngCylinder

This template is used to specify the attributes of engine cylinder. The data for this template is from the specification of novel cylinder head in table 3.1. Figure 3.9 shows the specification of the engine cylinder main attribute.

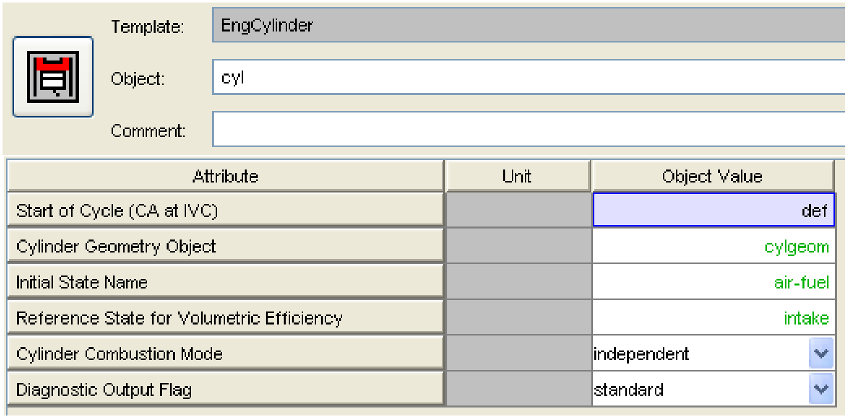


Figure 3.9: EngCylinder object

Object: EngCrankTrain

This object specifies the attributes of an engine's crank train. The crank train models the crank slider mechanisms and crankshaft, which translate the torques generated directly from the pressure acting on each piston in the cylinders into the crankshaft output torque. Figure 3.10 shows the specification of engine crank train.

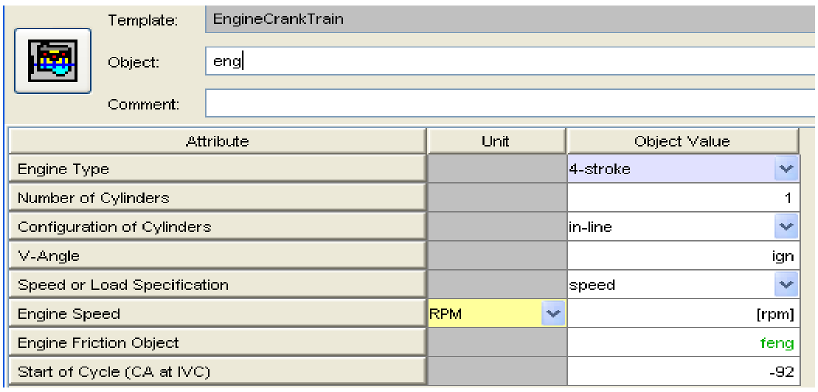


Figure 3.10: EngCrankTrain object

3.4.2 Novel cylinder head project map in GT-power

Selected object for modeling novel cylinder head is placed in project map and link it together. Figure 3.11 shows the model of novel cylinder head in a project map. The model is ready to run and produce the result needed.

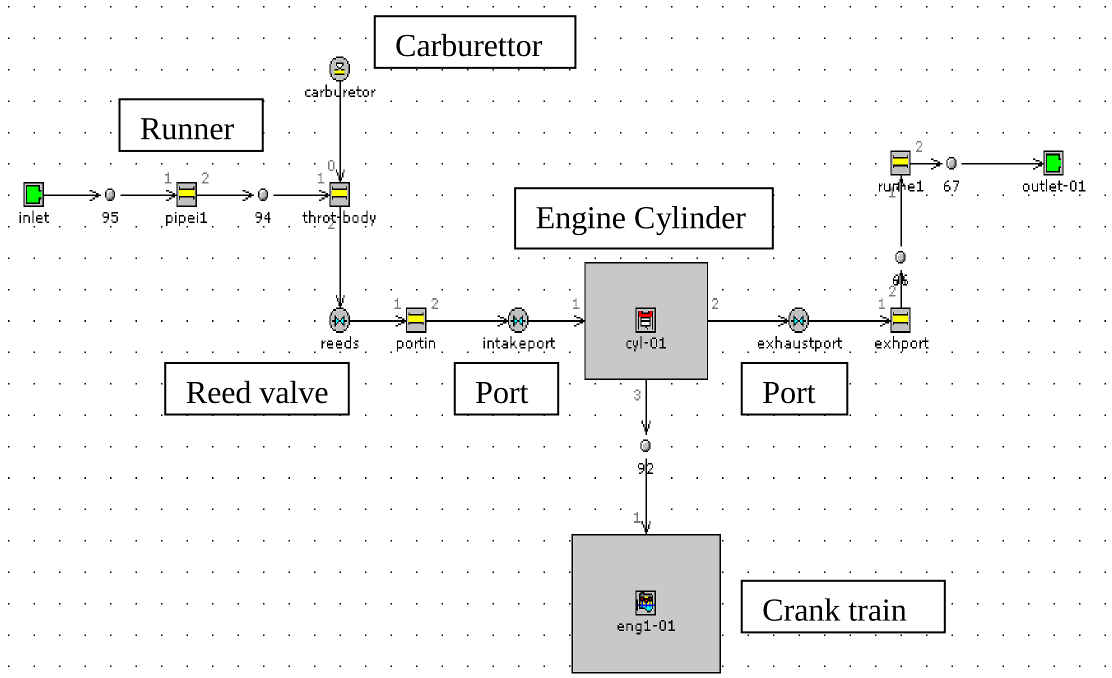


Figure 3.11: GT-power model project map

3.5 INVESTIGATION OF OPTIMUM INTAKE AND EXHAUST PORT DIAMETER

The investigation is varies with difference intake and exhaust port diameter. Engine speed also varies from 800 rpm to 4000 rpm. The variation of port size is not exceeding 70% size of upper cylinder bore size. The intake and exhaust length is fix to its original length for this investigation.

The volumetric efficiency rate is determined from the simulation. The highest efficiency and the most suitable volumetric efficiency as it changes with engine speed are select as the optimum intake and exhaust port size.

Table 3.5 shows the input data for the investigation optimum intake port size. Intake port size is varies and exhaust port is fix to its original size.

Table 3.5: Difference intake port diameter

	Intake Port Diameter (mm)	**Exhaust Port Diameter (mm)**
1.	16	20
2.	18	20
3.	20	20
4.	22	20
5.	24	20

Table 3.6 is the input data for investigation of varies exhaust port size with similar intake port size. Intake port size is at its original size.

Table 3.6: Difference exhaust port diameter

	Intake Port Diameter (mm)	**Exhaust Port Diameter (mm)**
1.	22	16
2.	22	18
3.	22	20
4.	22	22
5.	22	24

Table 3.7 shows the investigation strategies with variation of intake and exhaust port size. The variation of size is according to the size use in Table 3.5 and 3.6.

Table 3.7: Intake and exhaust port diameter variation

	Intake Port Diameter (mm)	Exhaust Port Diameter (mm)
1.	16	16
2.	18	16
3.	20	18
4.	22	20
5.	24	22

3.6 INVESTIGATION OPTIMUM OF INTAKE AND EXHAUST PORT LENGTH

The investigation determined volumetric efficiency and to find the optimum length for intake and exhaust port. The length varies with increasing and decreasing of 0.2% of original length. Intake port and exhaust port is set to original geometry of novel cylinder head.

Table 3.8 shows the variation of inlet length. The port diameter used in the simulation is fixed as the length varies. The length is limit from cylinder head to the rear wheel of Modenas Kriss 110. The original length of exhaust length is 1050 mm and inlet is 90 mm.

Table 3.8: Variation of inlet length

	Inlet length (mm)	Exhaust length (mm)
1.	54	1050
2.	72	1050
3.	90	1050
4.	108	1050
5.	126	1050

Table 3.9 shows the investigation strategies with different exhaust length but same inlet length.

Table 3.9: Variation of exhaust length

	Inlet length (mm)	Exhaust length (mm)
1.	90	630
2.	90	840
3.	90	1050
4.	90	1260
5.	90	1470

Table 3.10 is the data used to simulate the investigation variation of inlet and exhaust length. The variation of data is base on the data use in Table 3.7 and 3.8.

Table 3.10: Inlet and exhaust length

	Inlet length (mm)	Exhaust length (mm)
1.	54	630
2.	72	840
3.	90	1050
4.	108	1260
5.	126	1470

CHAPTER 4

RESULT & DISCUSSION

4.1 INTRODUCTION

This Chapter is discussing the model of novel cylinder head engine in GT-Power. The result of investigation method from previous chapter to determine the optimum intake and exhaust port size is shows in this chapter. The result of optimum inlet and exhaust length also is shows in this chapter. The simulation result is display and analyze in GT-post before transfer to Microsoft excel.

GT-post is a powerful data analysis tool used to plot, view, and manipulate data generated either by a GT-suite simulation or by an external source. It offers a more efficient data analysis solution than standard spreadsheet software. By employing data pointers, the results viewed in GT-post are updated automatically and immediately when a model is changed and a simulation is rerun. Also, GT-post lends itself nicely to the development of portable, user-defined templates that control how results are presented. This manual describes the features of GT-post. It is assumed that the user is already familiar with GTISE, the GT-suite Graphical User Interface (GUI), and the process of building models in GT-suite.

4.2 NOVEL CYLINDER HEAD MODELING IN GT-POWER

The novel cylinder head engine is modeled base on the diagram of novel cylinder head design figure 3.3. The engine cylinder is model in total volume of novel cylinder head. The intake system of novel cylinder use reed valve and intake port. In GT-Power, the template use to describe reed valve Figure 4.1 (A) is ‘ValveCheckConn’ and intake port 'ValvePortConn' Figure 4.1 (C). Exhaust ports also use the same template as intake port. To describe the length and size of the port, 'pipe' Figure 4.1 (B and E) templates is used.

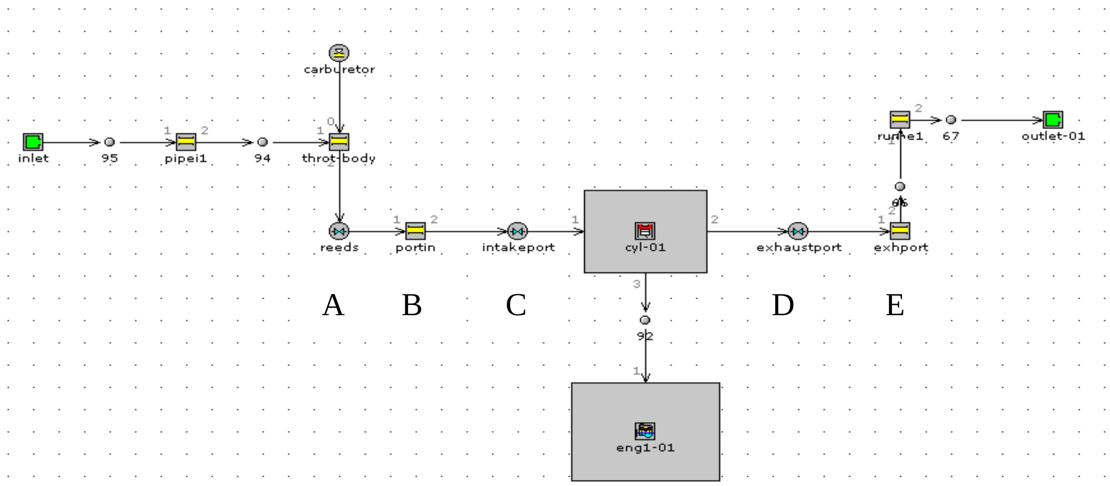


Figure 4.1: Novel cylinder head GT-power model

The real model of novel cylinder head is display in Figure 4.2. The comparesion between real and simulation component can be seen in Figure 4.1 and 4.2. (A) is the reed valve, (B) is intake port area, (C) is intake port runner length, (D) exhaust port runner length, and (E) is exhaust port area.

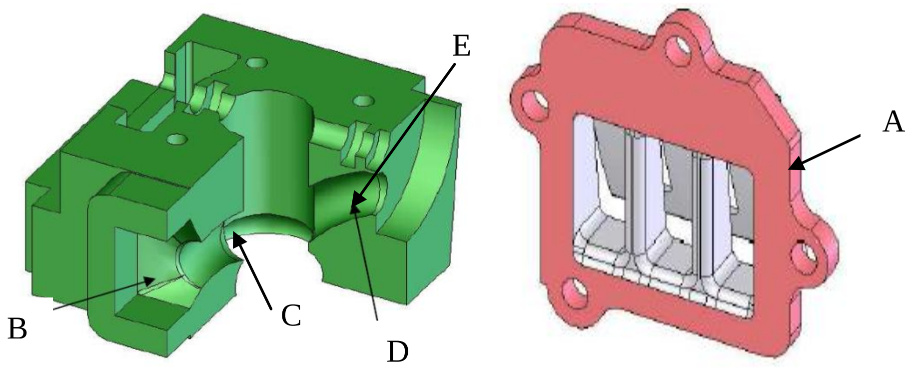
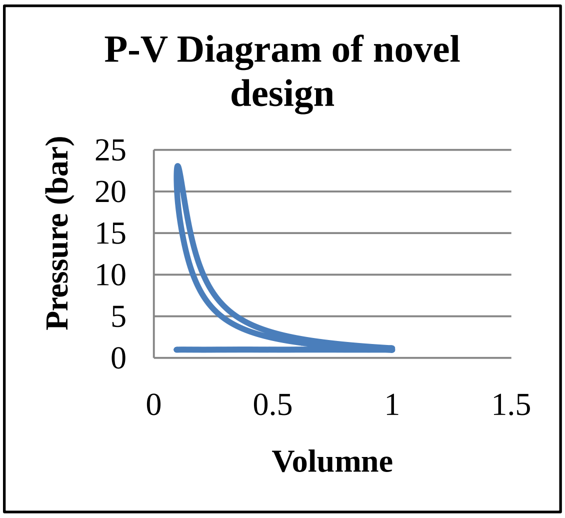


Figure 4.2: Novel Cylinder Head cross section and reed valve

Source: Kaharudin, 2008



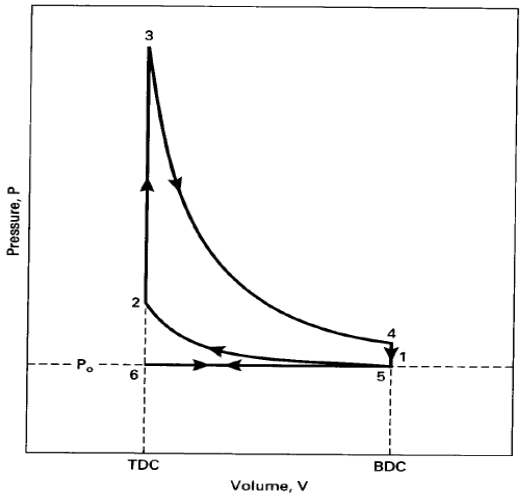


Figure 4.3: Comparision four-stroke P-V diagram of original and novel cylinder head

Figure 4.3 shows the compasrision pressure versus volume diagram of four stroke engine and novel cylinder head engine. The application of two stroke intake and exhaust system in a four stroke engine of novel cylinder head shows that it can be applied. This prove by the same pattern of P-V diagram of original and novel engine.

4.3 OPTIMUM INTAKE AND EXHAUST PORT DIAMETER

Investigations are using GT-power simulations and run in difference intake and exhaust port size. The best and optimum value is selected from the result. The engine speed is varies from 800 rpm to 4000 rpm.

4.3.1 GT-Power result of volumetric efficiency vs. mean piston speed

Figure 4.4, 4.5, and 4.6 shows graph of volumetric efficiency versus mean piston speed. Volumetric efficiency depends on the velocity of the fresh mixture in the intake manifold, port, and valve. Since the intake system and valve dimensions scale approximately with the cylinder bore, mixture velocities in the intake system will scale with piston speed. Hence, for different engines it should be compare with same mean piston speed.

Graph in Figure 4.3 is a result from simulation run in difference intake port size. Exhaust port diameter is 20 mm same as original design. Increasing of intake port size also increase the volumetric efficiency. Diameter of 24 mm shows the most efficient diameter to be chosen as an intake port diameter as the exhaust port in the original size.

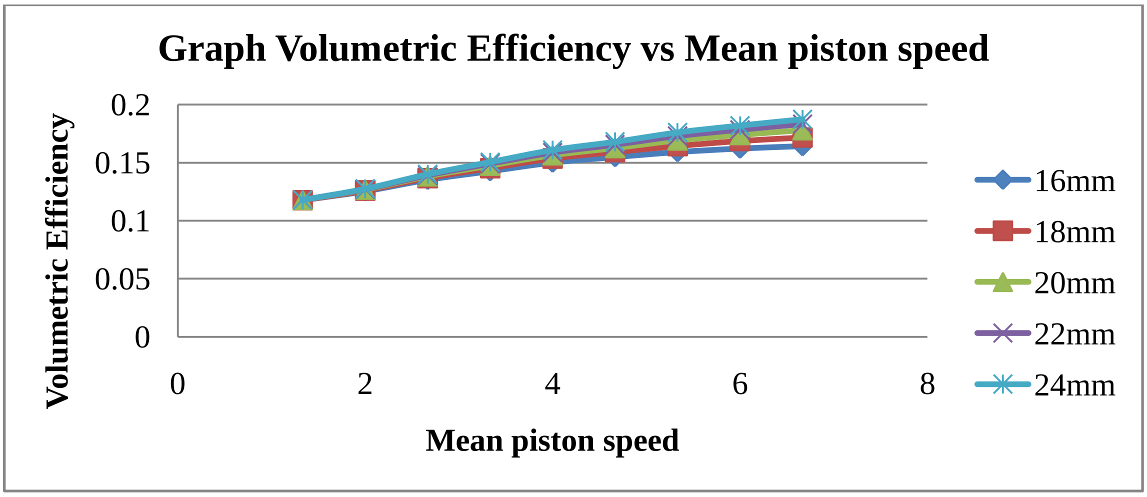


Figure 4.4: Volumetric Efficiency vs. Mean Piston Speed at difference intake port size

Figure 4.4 shows that at shorter length of exhaust port, engine will give it best performance. Volumetric efficiency is proportional to mean piston speed. At low mean piston speed, the volumetric efficiency at every exhaust port size is almost the same.

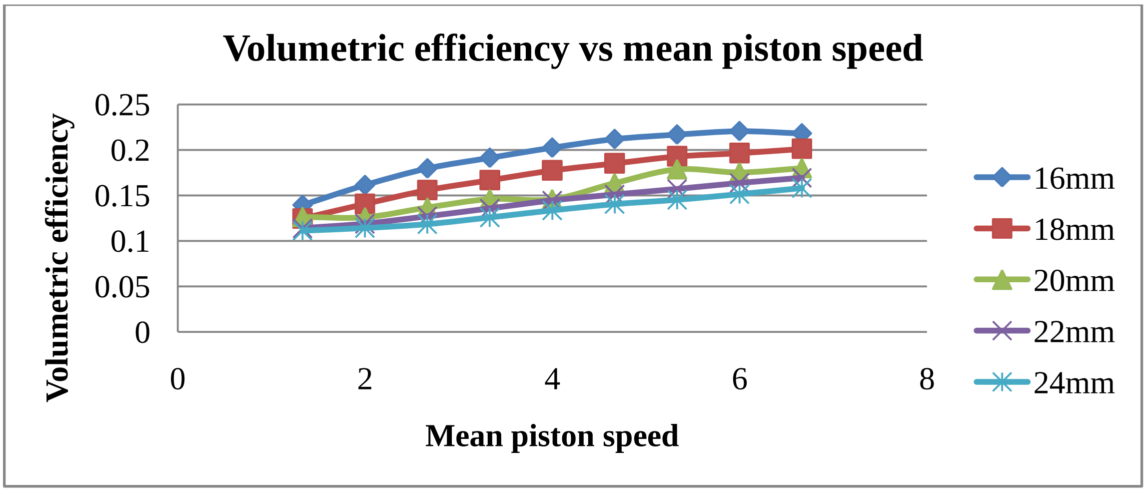


Figure 4.5: Volumetric Efficiency vs. Mean Piston Speed at difference exhaust port size

Figure 4.5 shows curves of volumetric efficiency versus mean piston speed from various geometry of intake and exhaust port. Table 3.7 shows the geometry of investigation. Combination of intake port diameter of 18 mm and exhaust port diameter of 16 mm has the highest efficiency.

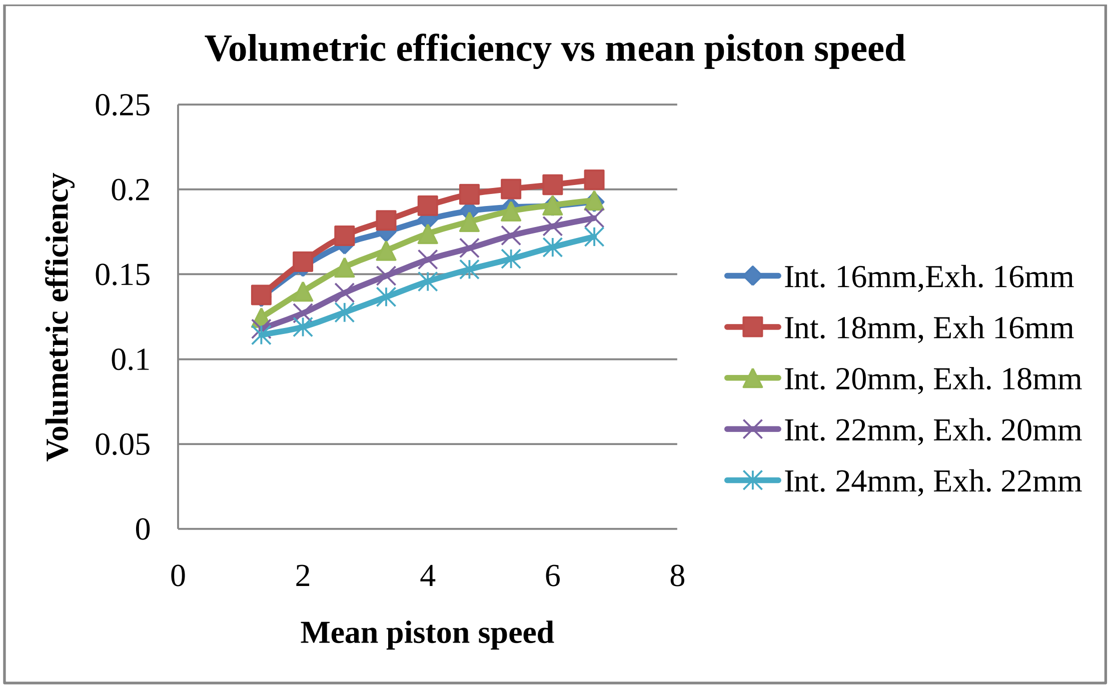


Figure 4.6: Volumetric Efficiency vs. Mean Piston Speed at various intake and exhaust port size

It is desirable to have maximum volumetric efficiency in the intake of any engine. One of the most important processes that shows how much power and performance can be obtain from an engine is getting the maximum amount of air into the cylinder during each cycle. More air means more fuel can be burned and more energy can be converted to output power. This will vary with the engine speed as shown in figure 4.3, 4.4, and 4.5, which represent the efficiency curve of different porting geometry. From figures, bigger intake port will give an efficient engine but compare to exhaust port, smaller geometry is more efficient than bigger geometry.

4.3.2 GT-Power result of volumetric efficiency vs. engine speed

In the previous result, the changes of porting geometry are displayed in volumetric efficiency versus mean piston speed. The mean piston speed is the average speed of the piston in a reciprocating engine. It is a function of stroke and RPM. There is a factor of 2 in the equation to account for one stroke to occur in 1/2 of a crank revolution.

Figure 4.7 shows the graph of volumetric efficiency versus engine speed at difference intake port size. Volumetric efficiency is increase as engine speed increase. Intake port with port size of 24 mm shows the most efficient geometry to choose as an intake port.

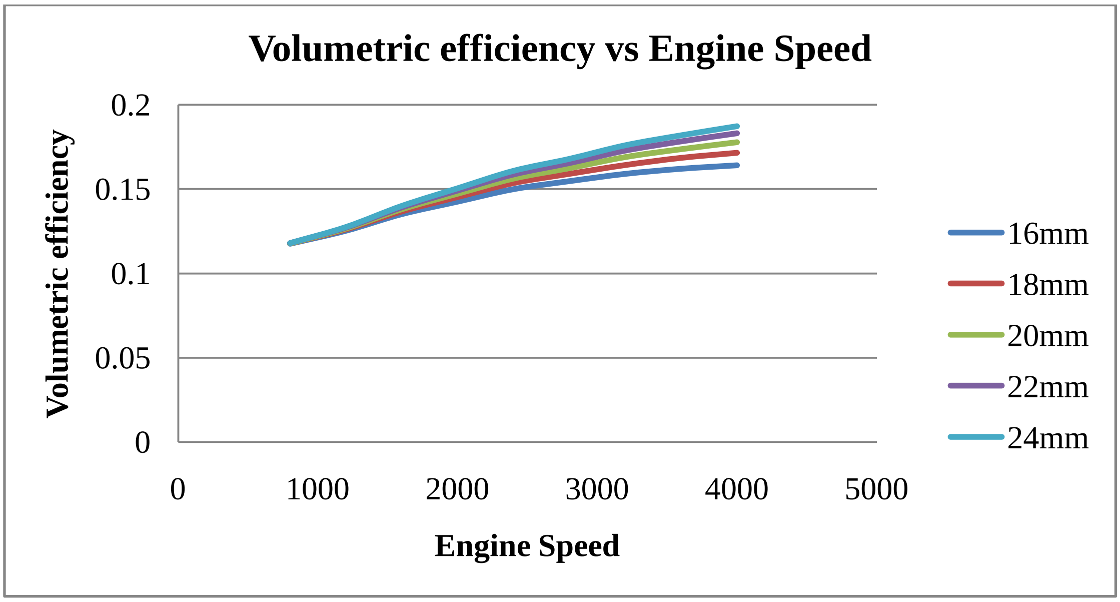


Figure 4.7: Volumetric efficiency vs. Engine Speed at difference intake port size

Figure 4.8 the graph of volumetric efficiency versus engine speed at difference exhaust port size. Comparison of exhaust port size shows that 16 mm which is the smallest diameter is the best size to choose as exhaust port due to highest and increasing of volumetric efficiency.

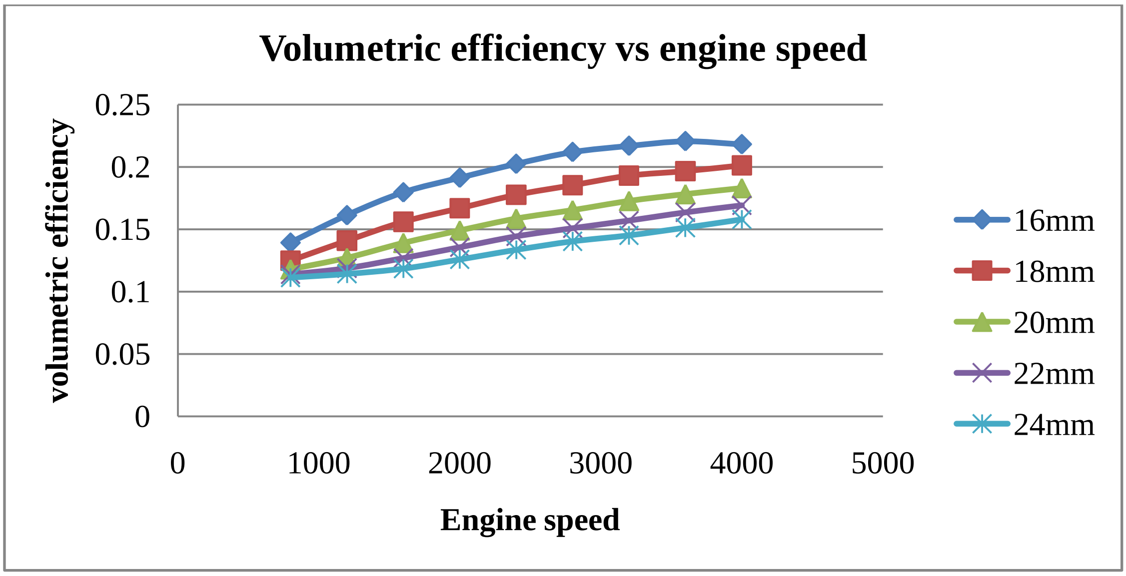


Figure 4.8: Volumetric efficiency vs. Engine Speed at difference exhaust port size

Figure 4.9 shows graph of volumetric efficiency versus engine speed at various intakes and exhaust port size. As the engine speed increase the volumetric efficiency also increase. Table 3.7 shows the data for this investigation. The differences of port size show a difference at low engine speed. No. 2 with intake port 18 mm and exhaust port 16 mm shows the best geometry to be choose.

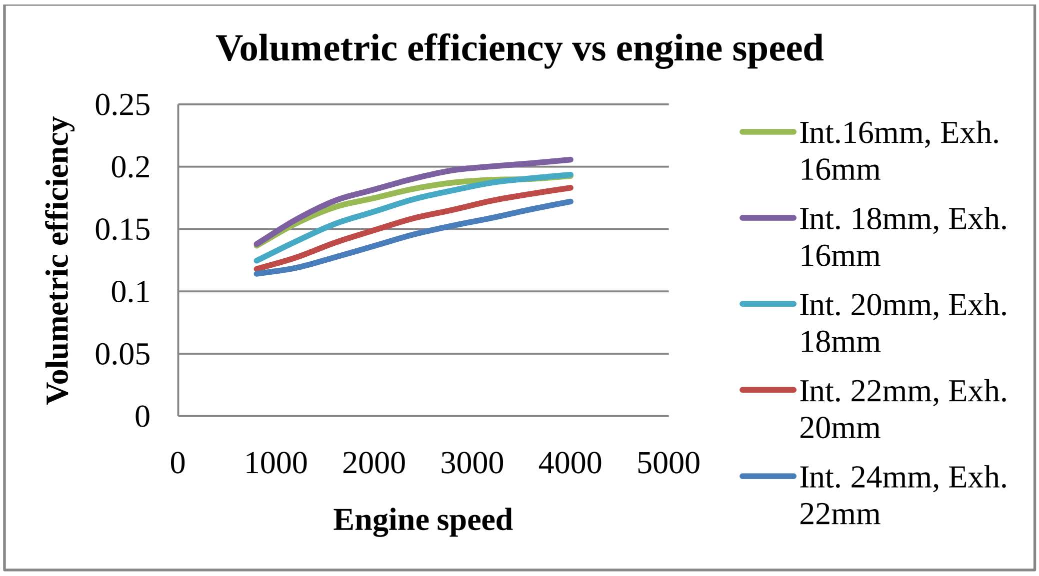


Figure 4.9: Volumetric Efficiency vs. Engine Speed at various intake and exhaust port size

Port size will affect power over the entire rpm range. If the port is too small it will restrict top end flow and if it's too large velocity will be reduced and it will hurt low end power. Since the intake valve is the most restrictive part of the intake system, the intake runners should be sized according to how well air can flow through the valve area.

4.4 INVESTIGATION OF INTAKE AND EXHAUST RUNNER LENGTH

Investigation of intake and exhaust runner length is to find the optimum intake runner and exhaust runner for a given rpm. The maximum length is limit to Modenas kriss 110 overall length. The simulation runs in three type of investigation. First simulations run at difference inlet length, second at difference exhaust length and third at various inlets and exhausts length.

Figure 4.10 show graph of volumetric efficiency versus engine speed with difference inlet length. The original length 90 mm shows the desirable intake length as it increase from low speed and flat mid speed characteristic.

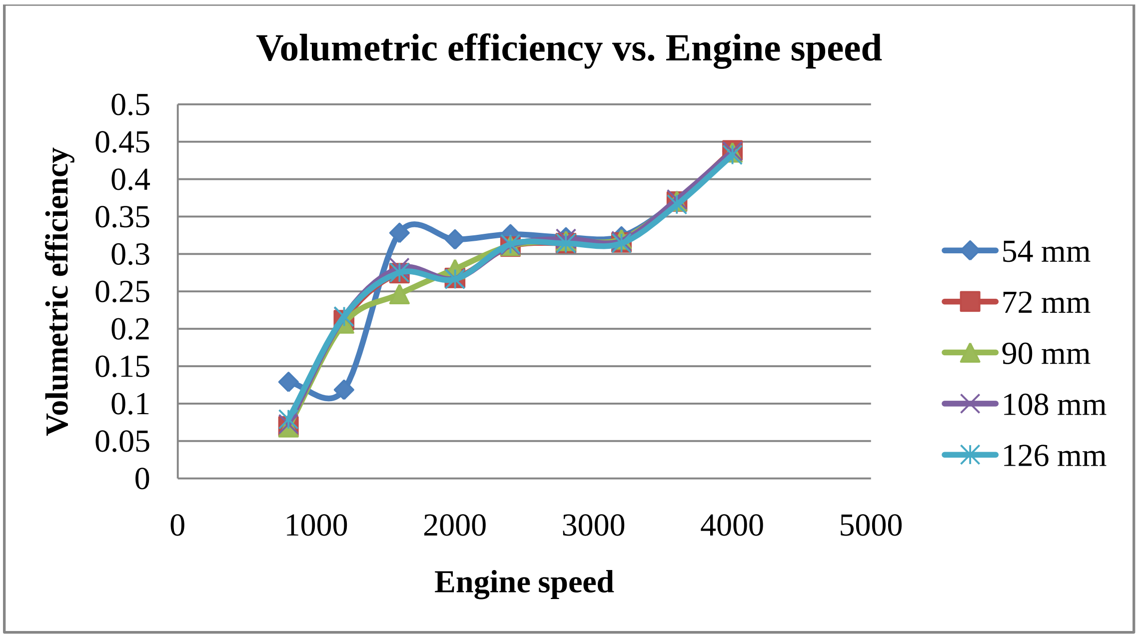


Figure 4.10: Volumetric efficiency vs. engine speed with difference inlet length

Figure 4.11 shows graph of volumetric efficiency versus engine speed with difference exhaust length. Exhaust length of 1470 mm has the highest efficiency but not increase proportional to engine speed. The change of volumetric efficiency as the speed increase is an unacceptable. The original length of exhaust runner is the best length. Changing the exhaust runner length also change the volumetric efficiency.

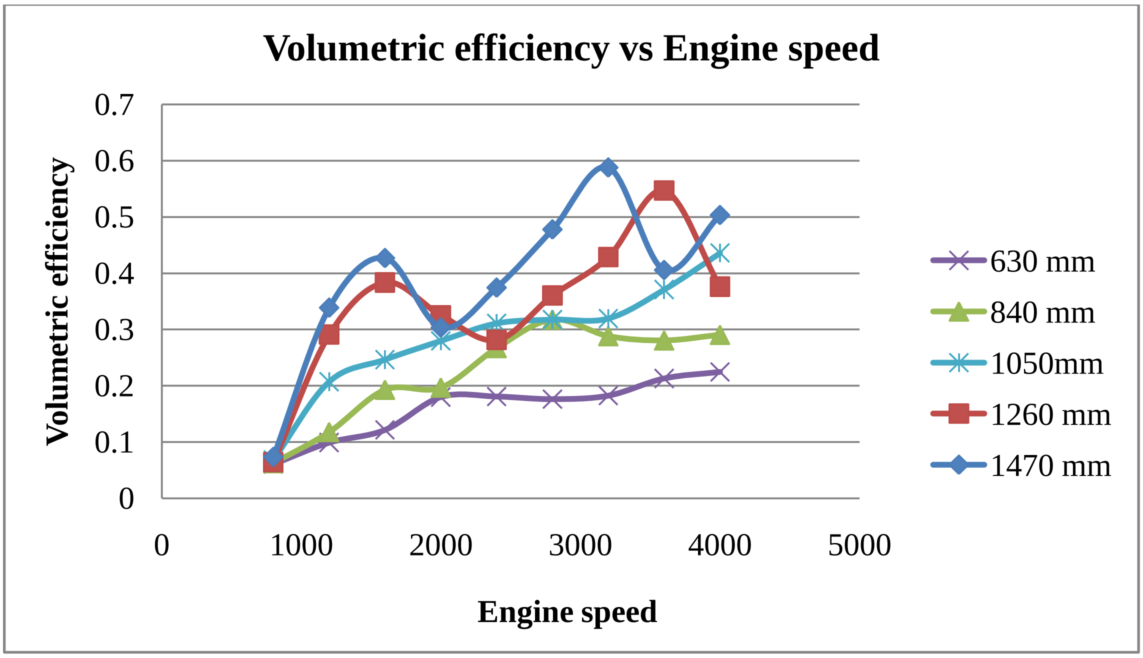


Figure 4.11: Volumetric efficiency vs. engine speed with difference exhaust length

Figure 4.12 is the graph of volumetric efficiency versus engine speed with various inlets and exhausts length. Combination of original inlet and exhaust give the best performance for the design simulation.

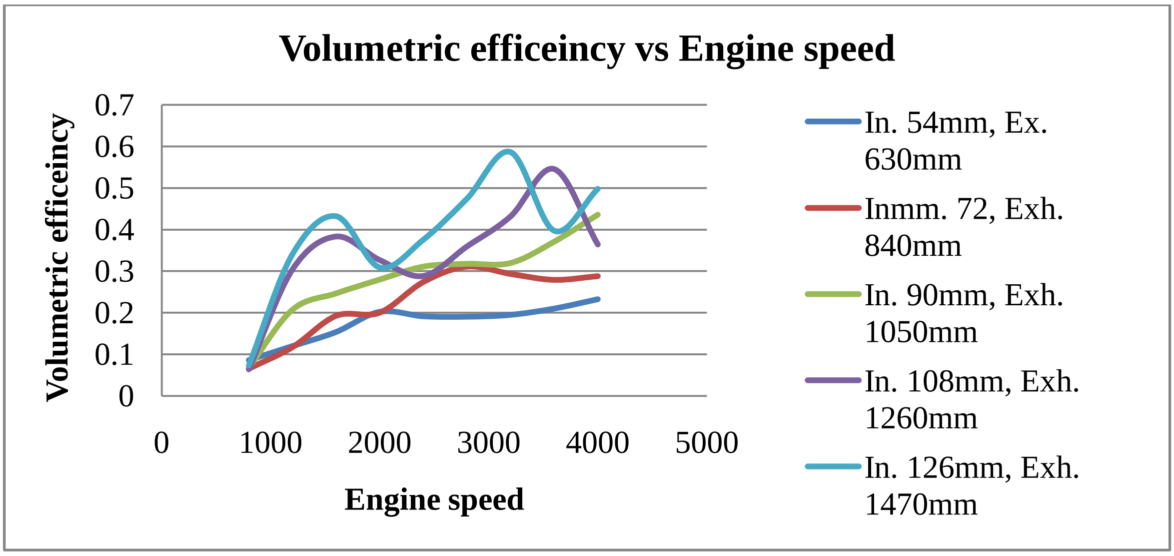


Figure 4.12: Volumetric efficiency vs. engine speed with various inlet and exhaust length

Elongation of the exhaust pipes offers an improvement potential of the engine efficiency.

4.5 OPTIMUM INTAKE AND EXHAUST LENGTH

The optimum port diameter for novel cylinder head engine is 24 mm and exhaust diameter is 16 mm. Runner lengths for intake and exhaust is the same as original length.

Table 4.1: Optimum intake and exhaust

	Intake	**Exhaust**
Port diameter	24 mm	16 mm
Runner length	90 mm	1050 mm

4.6 COMPARISON SIMULATION RESULT OF 110CC AND NOVEL CYLINDER HEAD ENGINE

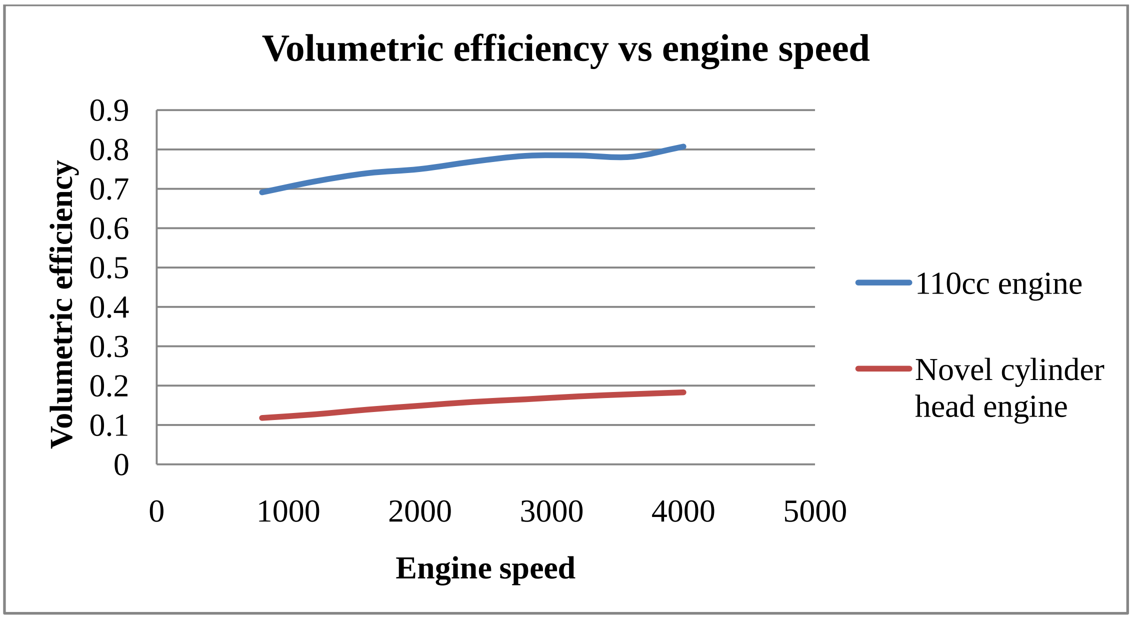


Figure 4.13: Graph comparison of volumetric efficiency versus engine speed between 110cc and novel cylinder head

Figure 4.13 shows the comparison of volumetric efficiency versus engine speed. There is a difference of volumetric efficiency between 110cc and novel cylinder head engine. The right setting for novel cylinder head engine is needed to obtain high volumetric efficiency as 110cc engine. The pattern of graph novel cylinder head is batter compare to 110cc engine. Volumetric efficiency for novel cylinder head is increase with higher speed compare to 110cc graph. Volumetric efficiency of 110cc is decease at 3000 until 4000 rpm.

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

An investigation of intake and exhaust system one dimensional simulation of a four stroke SI engine employing novel cylinder head is performed. Intake and exhaust system of two-stroke engine can apply in four stroke novel cylinder head engine. This prove by the same pattern of P-V diagram of novel cylinder head which use reed valve and exhaust port with original four stroke engine.

The optimum intake and exhaust port diameter is obtained. These investigations give information for proper sizing of inlet and exhaust length. The novel cylinder head had been simulating using GT-power simulation program.

Different port size and length give a difference characteristic of flow in term of volumetric efficiency performance. The optimum intake port size is 24 mm and exhaust port size is 16 mm. Original length of inlet and exhaust runner is the optimum length for the engine.

Volumetric efficiency is increase with difference intake and exhaust port and length. Bigger size of intake, smaller size of exhaust is necessary to allow best amount of air to enter and out from the cylinder.

5.2 RECOMMENDATION

The next step towards development of novel cylinder head engine is to find the optimize value and parameter for the best performance of novel cylinder head engine. Design the best and most efficient of intake and exhaust valve opening and closing for high and low engine speed.

Next is to find the spark timing of the base engine with new cylinder head. The study in the base engine spark timing according to the part open throttle and wide open throttle and determine the best spark timing for the design.

Finally is fabrication of novel cylinder head and employ it to original engine of 110cc and do the experiment of the intake and exhaust port of novel cylinder head using flow bench to find experimental value the design.

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APPENDIX A

GT-POWER SIMULATION TEMPLATE

Novel cylinder head model

Template: ValveCheckConn
Object: reeds
Comment:

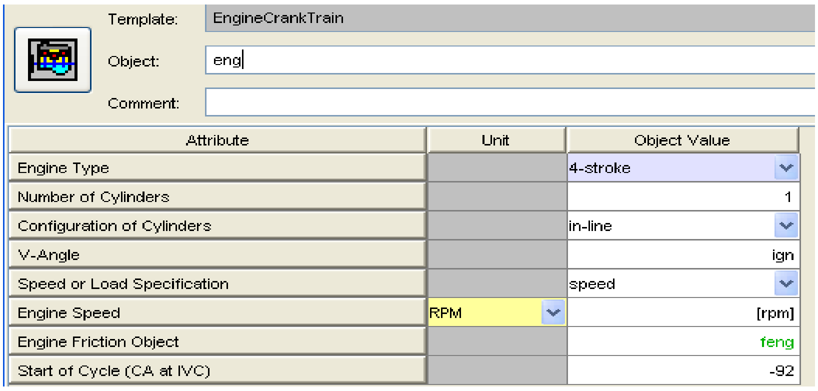
Attribute	Unit	Object Value
Valve Reference Diameter	mm	24
Upstream Pressure Area	mm^2	452.389
Downstream Pressure Area	mm^2	452.389
Flow Area Multiplier		6
Heat Conduction "Flange"		ign

Template: ValvePortConn
Object: intakeport
Comment:

Attribute	Unit	Object Value
Cam Driver		def
Port Area Symmetry Flag		half-profile
Angle Stretching Factor		1
Forward Discharge Coefficient		0.75
Reverse Discharge Coefficient		0.65
Swirl Coefficient		ign
Tumble Coefficient		ign
Flow Area Multiplier		1.

Template: EngCylinder
Object: cyl
Comment:

Attribute	Unit	Object Value
Start of Cycle (CA at IVC)		def
Cylinder Geometry Object		cylgeom
Initial State Name		air-fuel
Reference State for Volumetric Efficiency		intake
Cylinder Combustion Mode		independent
Diagnostic Output Flag		standard



Template: EngineCrankTrain
Object: eng
Comment:

Attribute	Unit	Object Value
Engine Type		4-stroke
Number of Cylinders		1
Configuration of Cylinders		in-line
V-Angle		ign
Speed or Load Specification		speed
Engine Speed	RPM	[rpm]
Engine Friction Object		feng
Start of Cycle (CA at IVC)		-92

Figure 3.9: EngCrankTrain object