EXPERIMENTAL ANALYSIS OF DIFFERENT HEAD COMBUSTION CHAMBER TO ENGINE PERFORMANCE FOR TWO-STROKE SMALL ENGINE.

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (mechanical and manufacturing) WITH HONOURS

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ABSTRACT

This project is about the study on two-stoke small engine. In today's automobile technology, there are a variety of engine designs to choose from, including rotary engines, rotax engines, and many others. Because of their design and technology, these engines have their own priority use. The most common type of engine on the market is a piston engine, which can be either four-stroke or two-stroke. Because of the advantages of these engines, such as their ease of construction and suitability in many aspects, they can reduce marketing costs and maintenance costs indirectly. However, each of these engines has its own set of advantages and disadvantages, and they were created with a variety of conditions in mind. As an example, two-stroke engines are typically used in motorcycles, marine engines, and small engines such as lawn mowers, chainsaws, and other small engines, but four-stroke engines are typically used in larger engines such as cars, trucks, and buses. However, it continues to use four-stroke engines in its motorcycles. It's due of the engine's efficiency, such as fuel consumption efficiency. However, many research and development efforts have been made to improve the two-stroke engine. Some engineers, for example, have exploited power valve innovation to boost engine performance. The purpose of the power valve is to modify the exhaust duration to match the RPM range. In comparison to an engine that does not use a power valve, the engine will operate well at low RPM until it reaches higher RPM. This innovation is typically found in engines with extremely high RPMs. However, the purpose of this project is to conduct research into various combustion chambers that can be used in engines and which will generate the best performance and emissions.

ABSTRAK

Projek ini adalah kajian mengenai enjin kecil dua lejang. Dalam teknologi automobil masa kini, terdapat pelbagai reka bentuk enjin untuk dipilih, termasuk enjin wankel, enjin rotax, dan banyak lagi yang lain. Kerana reka bentuk dan teknologinya, enjin ini mempunyai keutamaan penggunaannya sendiri. Jenis enjin yang paling biasa di pasaran adalah enjin omboh, yang boleh berupa empat-lejang atau dua lejang. Kerana kelebihan enjin ini, seperti kemudahan pembinaan dan kesesuaiannya dalam banyak aspek, mereka dapat mengurangkan kos pemasaran dan kos penyelenggaraan secara tidak langsung. Namun, setiap enjin ini mempunyai kelebihan dan kekurangannya sendiri, dan mereka diciptakan dengan mempertimbangkan pelbagai keadaan. Sebagai contoh, enjin dua lejang biasanya digunakan dalam motosikal, mesin marin, dan mesin kecil seperti mesin pemotong rumput, gergaji besi, dan mesin kecil lain, tetapi enjin empat lejang biasanya digunakan pada mesin yang lebih besar seperti kereta, trak, dan bas. Namun, ia terus menggunakan enjin empat lejang pada motosikalnya. Ini disebabkan oleh kecekapan enjin, seperti kecekapan penggunaan bahan bakar. Namun, banyak usaha penyelidikan dan pengembangan telah dilakukan untuk memperbaiki enjin dua lejang. Sebilangan jurutera, misalnya, telah memanfaatkan inovasi injap kuasa untuk meningkatkan prestasi enjin. Tujuan injap kuasa adalah untuk mengubah jangka masa ekzos agar sesuai dengan julat RPM. Jika dibandingkan dengan enjin yang tidak menggunakan injap kuasa, mesin akan beroperasi dengan baik pada RPM rendah sehingga mencapai RPM yang lebih tinggi. Inovasi ini biasanya terdapat pada mesin dengan RPM yang sangat tinggi. Walau bagaimanapun, tujuan projek ini adalah untuk menjalankan penyelidikan ke dalam pelbagai ruang pembakaran yang boleh digunakan dalam mesin dan yang akan menghasilkan prestasi dan pelepasan terbaik.

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LIST OF SYMBOLS AND ABBREVIATIONS

RPM	-	Revolution per minute
ICE	-	Internal combustion engine
CI	-	Compression ignition
SI	-	Spark ignition
TDC	-	Top dead centre
CA	-	Crank angel
NO_x	-	Nitrous oxide
NO	-	Nitric oxide
O	-	Oxygen
N	-	Nitrogen
TKE	-	Turbulence kinetic energy
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
HC	-	Hydrocarbon
PM	-	Particulate matter
CC	-	Cubic centimetre
CDI	-	Capacitor discharge ignition
CNC	-	Computerized numerical control
kW	-	Kilowatt
N/m	-	Newton/meter
Hp	-	Horsepower

CHAPTER 1

INTRODUCTION

1.1 Title

Experimental analysis of different head combustion chamber to engine performance for two-stroke small engine.

1.2 Background

The two-stroke engine is very simple. It is because this type of engine needs to complete the power cycle with two strokes (up and down movements) of the piston during only one crankshaft revolution which is at the end of the combustion stroke and the beginning of the compression stroke happen simultaneously with the intake and exhaust functions occurring at the same time. Compared to four-stroke engine that need to complete a power cycle with four strokes which are intake, compression, combustion, and exhaust with two crankshaft revolutions.

The first commercial two-stroke engine involving in-cylinder compression is attributed to Scottish engineer Dugald Clerk who patented his design in 1881. However, German inventor Karl Benz produced two-stroke gas engine on 31 December 1879 and received a patent in 1880 in Germany. Meanwhile, the first truly practical two-stroke engine is attributed to Yorkshireman Alfred Angas Scott with his twin-cylinder water-cooled motorcycles in 1908. Two-stroke engine are widely used on lightweight or portable applications like small machines and motorcycles.

1.3 Problem Statement

The two-stroke engine from the manufacturing usually designed as a standard specification. Therefore, by modifying it will improve the engine to be better performances such as the acceleration and top speed and give better torque and horsepower. Besides, it also can improve the emission efficiency of the engine.

1.4 Research Objective

The primary goal of this research is to study about two-stroke engine performance. Specifically, the objectives are as follows:

- To analyse different head combustion chamber to engine power and torque.
- To analyse different head combustion chamber to engine emission.

1.5 Scope of Research

Following the background of two-stroke engine developer, every of the engine have their own characteristic to get the best efficiency and the power output from the engine. It is because of the technological advances and make them do more research and development to improve the engine. As the example, some of them have research and used the power valve system to the exhaust port that can control the suitable exhaust port duration and area to the certain R.P.M. So, the scope of this research are as follows:

- Use difference head combustion chamber.
- Investigation of using different combustion chamber performance and emission.
- Comparison of the suitable combustion chamber design.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

People nowadays put a high priority on automotive technology to assist them in moving through one position to another in a reasonable timeframe. Because of their importance in human life, automotive technology is rapidly evolving. There are many types of engine designs in automotive technology nowadays such as rotary engine, rotax engine and many more. These engines have their own priority use based on their design and technology. Commonly designed engine in market is piston engine either four-stroke or two-stroke engine. It is because of the advantages of these engine such as easy to build and more suitable from many aspects indirectly can less the marketing price and the maintenance. However, all these engines have their own pros and cons and designed with many of condition use. As the example, the two-stroke engine usually designed for motorcycles, marine engine and small engine like lawn mower, chain saw and others while the four-stroke engine more designed for bigger engine like for car, lorry, and bus. But it is still having the motorcycles build from four-stroke engine. It is because of the efficiency of the engine such the efficiency of fuel consumption.

Talk about the fuel consumption we know that the four-stroke engine is more efficient compared to the two-stroke engine. If we go through more depth in the engine system, we can know the aspects that affecting this issue. So, nowadays the production of two-stroke engine getting lesser because of this issue especially for motorcycles. But the two-stroke engine still involve in production for the small engine. It is because two-stroke engine is more suitable for small engine because of some factors such as easy to build and low maintenance cost. So, there is still have the production of two-stroke engine in automotive technology for certain use. Therefore, it is proved that every design or types of engines have their own pros and cons characteristics.

2.2 Engine classification

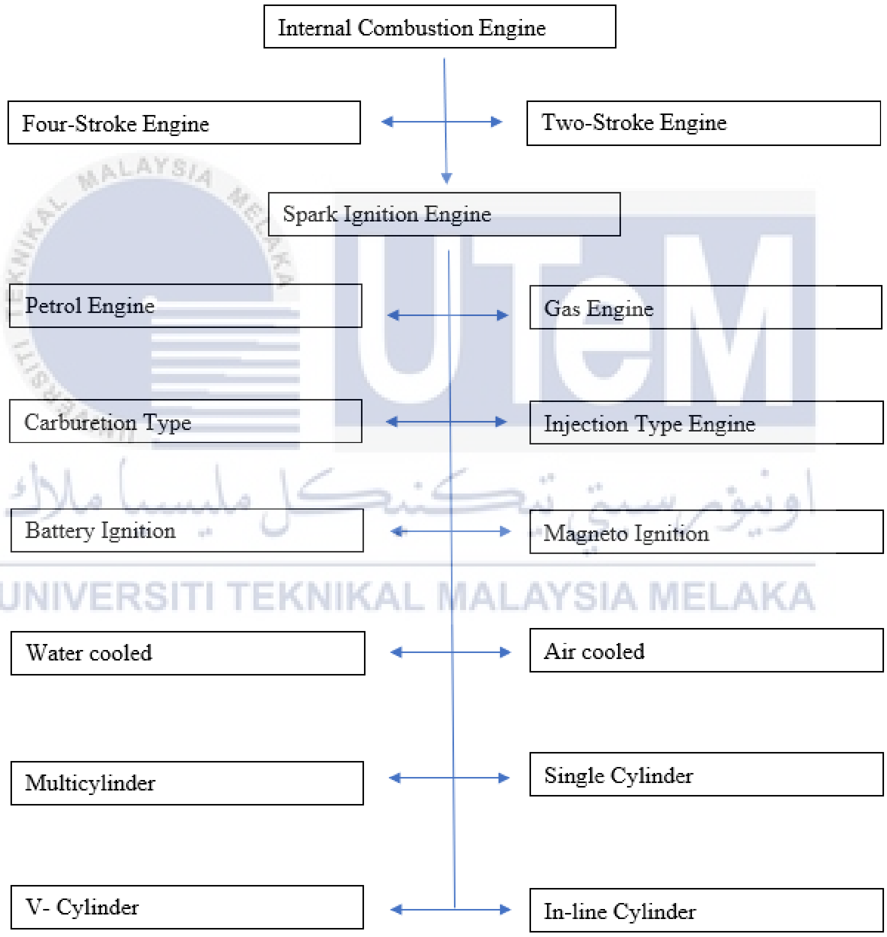


Figure 2.1 Engine Classification.

An internal combustion engine (ICE) is a heat engine in which a fuel is burned in a combustion chamber that is part of the working fluid flow circuit with an oxidizer (air)(Wikipedia, no date). The expansion of the high-temperature and high-pressure gases created by combustion acts directly on a part of an internal combustion engine. The force is applied typically to pistons, turbine blades, a rotor, or a nozzle. The part is moved over a distance by this force, which converts chemical energy into useful work. For applications where engine weight or size are significant, this has replaced the external combustion engine. **Étienne Lenoir** invented the first commercially internal combustion engine about 1860 and **Nicolaus Otto** invented the first modern internal combustion engine in 1876(Wikipedia, no date). Internal combustion engines, such as the more common four-stroke and two-stroke piston engines, as well as variations such as the six-stroke piston engine and the Wankel rotary engine, are commonly referred to as internal combustion engines. Continuous combustion gas turbines, jet engines, and most rocket engines are examples of a second class of internal combustion engines, all of which operate on the same principle as previously mentioned. Firearms are a type of internal combustion engine, but one that is so advanced that it is sometimes regarded as a distinct category. Natural gas or petroleum products such as gasoline, diesel fuel, or fuel oil are commonly used to power ICEs. Compression ignition (CI) engines use renewable fuels like biodiesel, whereas spark ignition (SI) engines use bioethanol derived from bioethanol.

The amount of air and gasoline that can reach the engine cylinders determines carburettor and fuel injection output (CarsDirect, 2012). The pistons and combustion chambers in the cylinders are where energy is released from the combustion of gasoline. Fuel and air will be fed into the engine through the carburettor and fuel injection system. Jets in the carburettor will drive the gas into the combustion chambers. The amount of fuel that can pass through these jets is entirely dependent on how much air can be drawn into the carburettor. The biggest problem with using a carburettor to get the best output is that it can't control the air to fuel ratio for each individual cylinder. This would not be a problem if each cylinder had its own carburettor. For the best efficiency, the best fuel to air ratio for each cylinder is approximated with a carburettor (CarsDirect, 2012). On the other hand, last longer than fuel injection systems and are thus chosen in motorsports. Since there are no electrical components or return lines to the fuel tank, carburettors are often much easier to mount than fuel injection systems. Electronic fuel injection systems are much more costly than carburettors.

For those who want the best performance from their engines, fuel injection systems are becoming more common. Fuel injection is divided into two types which are port fuel injection and direct injection (CarsDirect, 2012). The most widely used fuel injection system is port fuel injection, while direct fuel injection is the most recently created fuel injection system. This device was created with four or two stoke engines in mind. The major advantage of direct injection is that the volume of fuel and air can be precisely released and pumped into the cylinder based on the engine load conditions. The system's electronics can measure and adjust this data on a regular basis. Higher power output, higher fuel consumption and lower emissions are all benefits of this form of managed fuel injection. One of the main problems is that these devices are complex and would cost significantly more than a carburettor. Since it uses an electrical part, and a custom cylinder head setup and installation is more difficult.

Engineers in the automobile sector sought efficiency in power generation, fuel economy, and dependability, and these are the same things that engineers in the tractor and stationary gas-engine industries are looking for today.

Following the creation of the vehicle engine, engineers were tasked with devising a method for starting and lighting autos. Mechanical and air-pressure starters were tried and found to be inadequate, thus electric starting and lighting systems entered the market and have since become widely accepted. These, on the other hand, not only add significantly to the initial cost of the car, but also require a significant payment for its maintenance. As a result, it's only logical that the automaker looked for ways to cut costs in other areas to counterbalance, at least in part, the increased cost of electric starting and lighting equipment. Why not a battery ignition system with a storage battery as a source of current, one would argue? The outcome has been widespread adoption of battery-ignition systems, particularly among lower-cost vehicles. However, the independent high-tension magneto is still widely used in higher-priced vehicles. In terms of battery ignition, 58 models use high-tension magneto ignition, and 137 models use battery ignition this year. Trucks, on the other hand, are virtually always fitted with high-tension magnetos.

The switch from magneto to battery ignition has given the public the impression that the latter is just as excellent as high-tension magneto ignition, even though an investigation of the case reveals that the switch was made solely for commercial motives(International and Transactions, 1917). In our engineering work, we've always kept in mind the significant differences between driving circumstances for cars and driving circumstances for tractors. The trac- tor resembles the vehicle solely in the sense that both have a gasoline engine, transmission, and differential, but the similarities end there. Automobiles are built to be as light as possible, run-on pneumatic tyres on good firm roads, carry comparably little weights, and are equipped with engines that are likely to be driven at tiny throttle openings for 95% of the time. They are only ever relied upon to generate their maximum output of power for a few minutes at a time, and even then, only for a few minutes at a time, because they are pleasure cars with no regard for fuel economy.

We know that in Internal Combustion Engines, the combustion of air and fuel takes place inside the engine cylinder, resulting in the production of hot gases. The temperature of the gases will be between 2300 and 2500 degrees Celsius(Sagar, Singh and Agarwal, 2015). This is an extremely high temperature, and it may cause the oil film between the moving parts to burn, resulting in seizing or welding. As a result, the temperature must be decreased to around 150-200°C, which is the most efficient operating temperature for the engine. It's also not a good idea to cool too much because it affects thermal efficiency. As a result, the cooling system's goal is to maintain the engine working at its most efficient temperature. It should be remembered that the engine is highly inefficient while it is cold, thus the cooling system is constructed in such a way that it stops cooling while the engine is warming up, and then it begins cooling once the engine has reached its maximum efficient operating temperature (Sagar, Singh and Agarwal, 2015).

Small engines with a power output of up to 15-20 kW, as well as aeroplane engines, typically use an air-cooled system (Sagar, Singh and Agarwal, 2015). Fins or expanded surfaces are supplied on the cylinder walls, cylinder head, and other surfaces in this system. Heat generated by combustion in the engine cylinder will be transmitted to the fins, and heat will be dispersed to air as air passes over the fins. The quantity of heat dissipated to air is determined by the volume of air passing through the fins, the fin surface area, and the thermal conductivity of the metal used to make the fins. The air-cooled engine has a straightforward design. Due to the lack of water jackets, radiators, circulating pumps, and the weight of the cooling water, it is lighter than water-cooled engines. Because of that it is cheaper to manufacture and needs less care and maintenance. This cooling technique is especially useful in areas with extreme climate conditions, such as the arctic, or where water is scarce, such as deserts. However, because the engines are directly exposed to air, this type of system is less efficient.

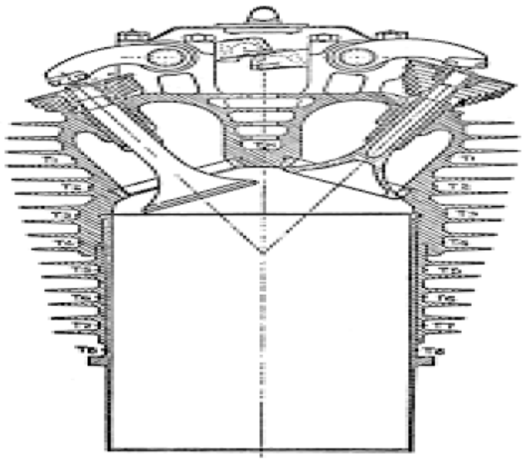


Figure 2.2 Air Cooling System.

The water-cooling system in an engine has two purposes which are removes excess heat generated in the engine and prevents it from overheating, and it keeps the engine at operating temperature for efficient and economical operation(Tri-State Generation and Transmission Association Inc, 2000). Direct or non-return systems, thermo-syphon systems, hopper systems, and pump or forced circulation systems are the four types of cooling systems available. Non-return water cooling systems are best suited for large installations with abundance of water(Tri-State Generation and Transmission Association Inc, 2000). The engine cylinder receives water directly from a storage tank. The hot water is not cooled before being discharged instead; it is just discharged. A good example is the low-horsepower engine combined with the irrigation pump. Thermo-syphon water cooling works on the idea that hot water rises, and cold water falls because heated water is lighter (Tri-State Generation and Transmission Association Inc, 2000). The radiator is elevated above the engine in this design to allow for easy water flow towards the engine. Heat is transferred to the water jackets, where it is thermal radiation removed by the circulating water. The water jacket rises to the top of the radiator as it heats up. The system is set up by replacing the rising hot water with cold water from the radiator, which creates a water circulation (Tri-State Generation and Transmission Association Inc, 2000). This aids in maintaining the engine's operating temperature. However, the pace of circulation is very slow. Only when there is a significant temperature differential can circulation begin. When the water level goes below the top of the radiator's delivery pipe, circulation stops. As a result of these factors, this system is no longer in use. The thermo-syphon system and the hopper water cooling system both work on the same basis.

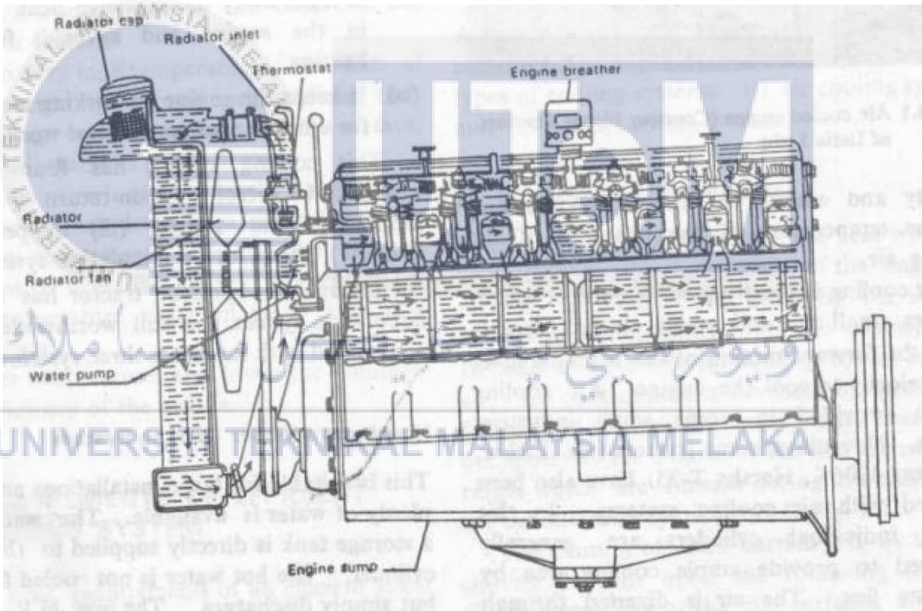


Figure 2.3 Water Cooling System.

There is a hopper on a jacket that contains water and surrounds the engine cylinder in this(Tri-State Generation and Transmission Association Inc, 2000). Water is replaced with cold water as soon as it begins to boil with this technique. This device prevents an engine from running for more than a few hours without being refilled with water. The force circulation water cooling system, on the other hand, is built similarly to the thermo-syphon system except it uses a centrifugal pump to circulate the water throughout the water jackets and radiator. The centrifugal pump transports water from the lower area of the radiator to the engine's water jacket. When the circulating water returns to the radiator, it loses its heat due to the radiation process. This system is used in automobiles, trucks, tractors, and other vehicles.

2.3 Two-stroke engine system

Two-stroke engine commonly found in small engine application such as lawn and garden equipment, dirt bikes, mopeds, jet skis and small outboard motors (Abd Majid, 2007). Since two-stroke engine does not have valve and any component like four-stroke engine such as camshaft, rocker arm and others that making it more complicated. This factor makes this engine lighter, simpler, and less expensive to manufacture. Two-stroke engines fire once every evolution while four-stroke engine fire once with two evolution that makes two-stroke engines a significant power boost. This is because of the compression and intake phase occur simultaneously at the first stroke and then the combustion and exhaust phase occur simultaneously at the second stroke that making it a complete cycle or revolution with only two strokes.

2.4 Two-stroke process

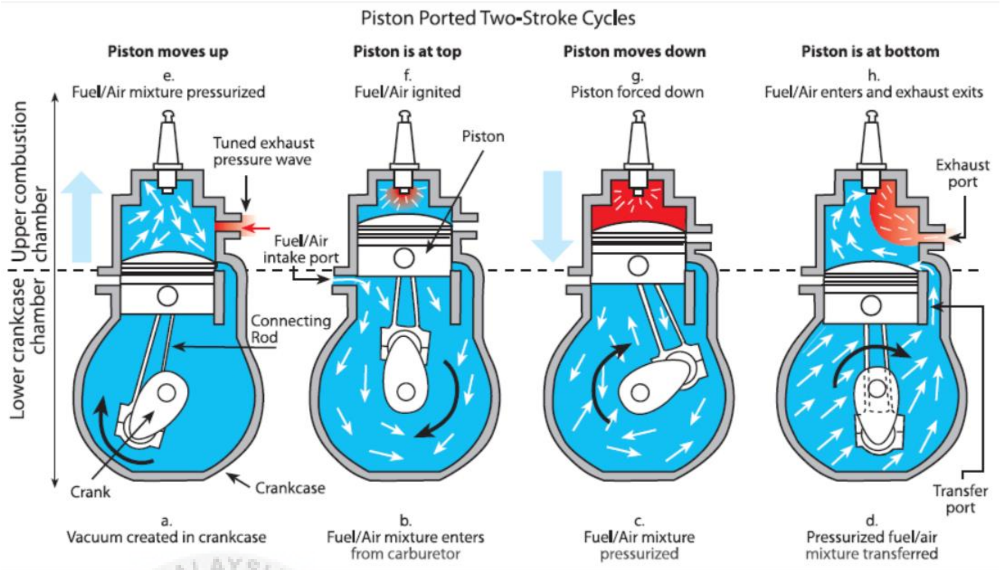


Figure 2.4 Two-stroke Process

The image shown in **Figure 2.4** depicts a crankcase vacuum intake. When the piston moves from A to B, the stroke process occurs (AvStop.Com, 2014). The upward stroke of the piston draws a vacuum in the crankcase, creating a positive suction in the intake system. This causes the fuel-air mixture to enter the crankcase via the carburettor intake valve system. When the piston reaches its highest position (Top Dead Centre), fuel and air mixture will be allowed to flow into the transfer port via the lower piston skirt (TDC). Most of the fuel and air combination has been mixed into the crankcase at this stage. compression stroke piston then moves downward (b to c). When the piston is on the downward stroke, a mechanical rotary valve shuts, a pressure valve is pushed closed by the increasing crankcase pressure, or the pressure valve closes in the cylinder (AvStop.Com, 2014). When the fuel mixture is compresses during the downward stroke of the piston, it's compressed in the crankcase. lowest part of the crankcase moves, or the exhaust is ejected (d). The high-pressure of fuel and air mixture in the crankcase passes around the piston into the main cylinder when the piston is at the bottom of its stroke. As the piston is at its lowest position, the exhaust port is open, and new fuel is being mixed, this promotes exhaust scavenging (AvStop.Com, 2014). Because some of the new fuel mixture leaks out the exhaust port, the two-stroke engine uses more gasoline. When the piston is in the upward position, the cylinder begins to compress (AvStop.Com, 2014).

At the moment the piston begins to rise, a pressurised wave of gas passes from the expansion chamber to the exhaust port to limit the amount of fuel that would have escaped from the exhaust port if it were not for the piston and the pressurised wave of gas. Finally, the cylinder is compressed by the piston which has travelled from its lower (e to f) to upper (g to h) position (AvStop.Com, 2014). Piston raises, compressing the fuel mixture in the combustion chamber. This piston compression operation is taking place at the same time as the crankcase vacuum intake procedure mentioned previously. Therefore, it is possible to accomplish four procedures with just two strokes. This is referred to as the cylinder power stroke because the piston goes from the bottom to the top of the cylinder (AvStop.Com, 2014). The fuel mixture is ignited by the spark plug and power is imparted to the piston when the piston rises during the power stroke of the engine. Once the piston moves down (from G to H), the cylinder power stroke occurs and exhaust enters the combustion chamber (AvStop.Com, 2014). The whirling motion of the fuel mixture drives the exhaust out the exhaust outlet.

2.5 Engine Components

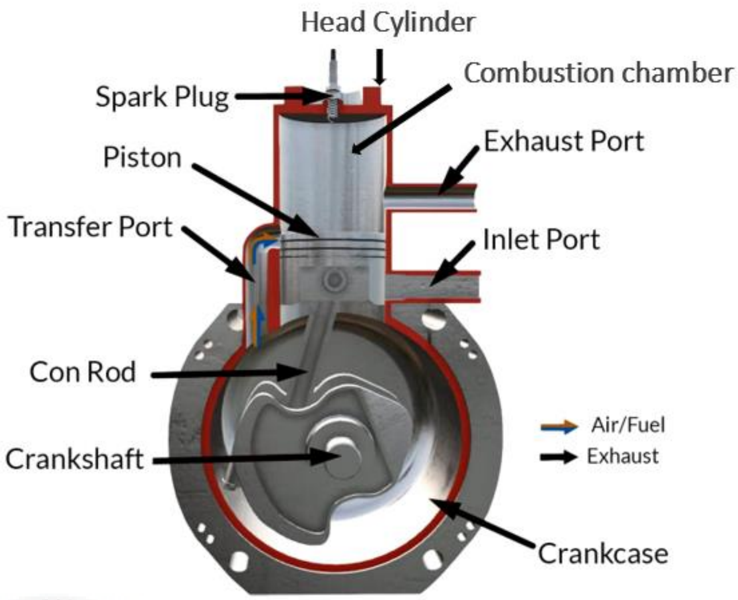


Figure 2.5 Engine Components.

The **Figure 2.5** shows the main component in a two-stroke engine. We can see that the spark plug has located at the centre of the head combustion chamber. The function of the spark plug is giving the spark to the combustion chamber to make an explosion that give power to the engine. A good combination design of head cylinder and block cylinder will produce a good power for the engine. The part that needs to be emphasized in head cylinder are the angel of the squish band, area of the squish band and the volume of the head which will determine the compression ratio of the engine. Other than that, two-stroke block cylinder have various of port transfer such as main transfer port, secondary transfer port and booster port. All this port has their role that making the engine can run more stable from the acceleration and speed. The function of this port is to transfer the intake fuel to the combustion chamber.

Many aspects need to be considered for this port to get a good performance of the engine such as the port duration, port angle and port area. Then, not forget to the exhaust port which the most important for an engine to get the power. The exhaust port is very sensitive to make some modify on it. The important in exhaust port are the area and duration measurement. If the measurement is too wide and does not follow as the tuning specification it can cause the engine performance to be drop. To counter the mistaken, we can bore up the size of the cylinder until the measurement that has been done will be match with the piston cylinder size or maybe the sleeve of the cylinder is oversize nothing can be done with the block cylinder except replace it to the new block cylinder.

Furthermore, the connecting rod and the crankshaft also have a big role to the engine. This is because it is functional to transfer the power from the combustion to the engine gearbox and then move the drive shaft. The length of the connecting rod also can be slightly affecting the duration of the cylinder block. Meanwhile, a great crankshaft is very important to be place in a high rev engine because it will be the main aspect of the vibration during the engine was running. A good crankshaft needs to produce very low vibration to make sure the engine can run smoothly during the heavy-duty performances.

Table 2.1 Engine component.

Components	**Figure**	**Function**
Head cylinder		• Combustion chamber. • Determine the engine power output.
Spark plug		• Give spark to the combustion chamber. • Ignition source.
Block cylinder		• Where the cylinder / piston works. • As the transfer flow port from crankcase to the combustion chamber.

Piston/Cylinder		• Transfer the energy from the combustion chamber to the connecting rod.
Piston pin		• To connect the piston and connecting rod
Piston ring		• To seal the compression.

Piston bearing		• To decrease the friction of piston pin and connecting rod.
Crankshaft		• Transfer energies receive from the combustion to the rotational energy.
Connecting rod		Connect the piston to the crankshaft.

2.6 Combustion chamber design

The two-stroke cylinder head may not seem interesting, but its design has a significant impact on how effectively your engine runs. The exterior forms and cooling fin patterns used by the manufacturers vary, but the essential requirement is that the cooling area be big enough to properly cool the engine. The geometry of the combustion chamber and the placement of the spark plug are the most significant factors (Bell, 1999). Many different combustion chamber designs have been attempted throughout the years, but only a few are suitable for a dependable high horsepower engine.

Researchers discovered that the gases at the combustion chamber's extreme outside boundaries, known as the 'end gases,' self-ignite to produce explosion. The surrounding metal of the piston crown and combustion chamber, as well as the heat emanating from the advancing spark-ignited flame, heat these terminal gases. These end gases will not have enough time to heat up enough to self-ignite and precipitate explosion if the spark flame reaches the outside borders of the combustion chamber fast enough.

Making the combustion chamber as tiny as feasible and then placing the spark plug in the centre of the chamber is the most apparent way to meet the second criterion. In a tiny combustion space, the combustion flame will naturally reach the terminal gases faster than if the chamber were twice as large (Bell, 1999). Then, if we position the combustion chamber as near to the piston crown as feasible, no combustion will occur around the chamber's borders until the piston is far beyond TDC (Top Dead Centre). Because of the squish band around the chamber's edge, it's known as a squish-type combustion chamber. Originally, the squish band's purpose was to compress gasoline from the cylinder's edges toward the spark plug (Bell, 1999). The fast-moving gases collide with the spark plug and transport the combustion flame rapidly to the combustion chamber's extremity, avoiding detonation. For a long time, engine designers have been aware of these issues. As a result, the optimal combustion chamber will have a squish design. You'll also note that these engines have a narrow diameter compared to their stroke, which lowers the size of the combustion chamber and the area of the piston crown exposed to the combustion flame.

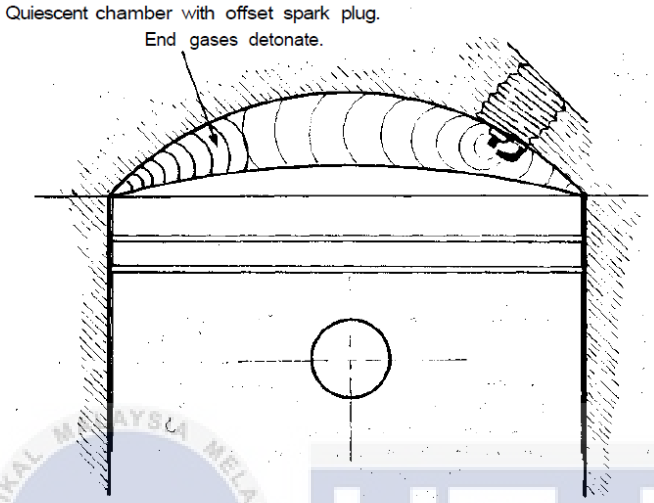


Figure 2.6 Offset Spark Plug.

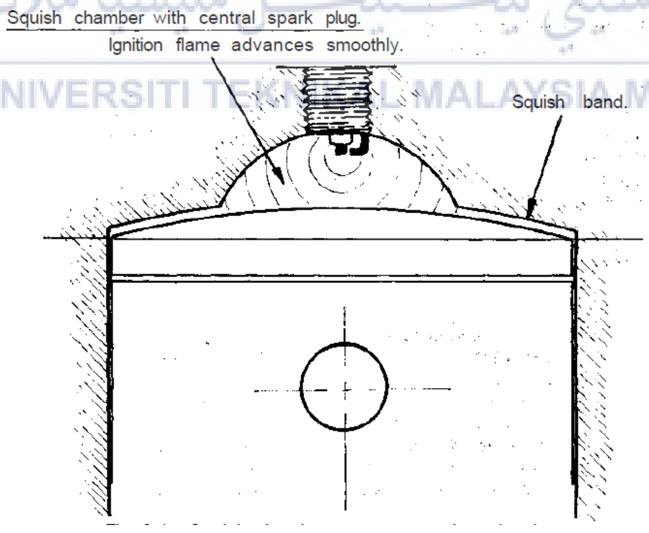


Figure 2.7 Central Spark Plug.

2.7 Combustion Chamber and Performance

2.7.1 Theory

Throughout the years, many of various combustions chamber designs have been created, but only a handful are appropriate for a dependable, high horsepower engine. The one thing a strong two-stroke doesn't need is a combustion chamber that promotes detonation, which is the bane of all racing two-strokes. To figure out what kind of combustion chamber you need, you must first understand what detonation is and how to avoid it. Detonation occurs when a part of the fuel/air combination starts to burn spontaneously after normal ignition. This scenario's flame front ultimately collides with the spark plug-ignited flame. The engine's internal components are hammered by the following explosion, producing a fast and severe build-up of pressure. The two-stroke tuner should be on the watch for a variety of tell-tale signs left after detonation. A sandblasted piston crown around the edge is the most obvious indication. Bike cylinders made of plated aluminium have a similar sandblasting appearance around the top lip of the bore. A shattered (not melted) spark plug insulator may also signal detonation. A detonating engine will ultimately seize or have a hole punched through the top of the piston if left running.

2.7.2 Parameter involved

To minimise cylinder and piston distortion, some manufacturers have opted to use an offset squish type combustion chamber. Illustration 2.8. The exhaust side of a two-stroke cylinder and piston is always the hottest, despite the fact that cooling air flow is much greater here than on the rear (inlet side) of the engine. This is due to several reasons, all of which are linked to the passage of very hot exhaust gas (630°C) through the exhaust port (Bell, 1999). The departing gas heats the exhaust port and cylinder wall, as well as the side of the piston. In rare instances, this may cause the piston to expand abnormally, causing it to seize. The manufacturer may choose to enhance piston to cylinder clearance to accommodate for this risk. Additional clearance, on the other hand, may not be desirable since it may increase leakage beyond the rings, resulting in greater piston wear. It is safer to move the combustion chamber to the head region (Bell, 1999). If this is done, the squish surface protects the front of the piston crown from the combustion flame. Because the front of the piston was originally considerably colder, it will not expand as much during the exhaust stroke.

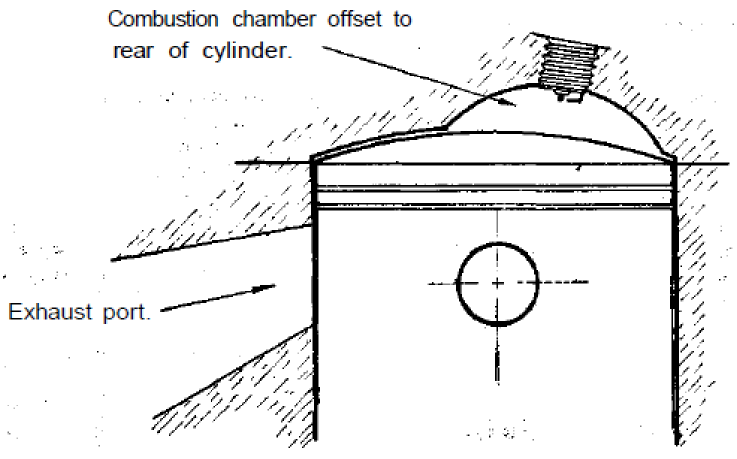


Figure 2.8 Offset Combustion Chamber.

If your motorbike is just used for pleasure, like many motocross motorcycles are, a large squish clearance isn't necessary. You won't get peak power, but you probably won't notice the difference. It's also improbable that you'll ever ride your bike hard enough to set off an explosion. If you want maximum power and no danger of explosion, the squish clearance, on the other hand, must be closed (Bell, 1999). A broken squish band is worse than having no squish band at all since it consumes a portion of your fuel charge. Less horsepower is the result of a squandered fuel charge. Consider the example of a TZ250 Yamaha Road racer to get an idea of how much horsepower you're potentially losing. The bore of these engines is 54mm in diameter, with an offset crush chamber (Bell, 1999). The trapped charge is compressed into a volume of 8.8cc based on the uncorrected compression ratio of approximately 15:1. The trapped charge will not be burned until long after TDC if the squish clearance is 1.7mm, which is too late to generate any power. 1.94cc is equivalent to 22% of the lost intake charge. The charge loss is decreased to 0.92cc (10.5%) when the squish clearance is lowered to 0.8mm. On paper, it seems to be a simple method to get 11.5 percent more horsepower, however losses limit the gain to around 5-6 percent on the dyno. As a result, maximum power increases from 52 to 55 hp. The midrange power may increase by as much as 10%, making the bike easier to ride and preventing detonation. To maintain an appropriate compression ratio, the combustion chamber must be carved further into the head, as previously stated. If you wish to keep the compression ratio the same as before, machine the combustion chamber twice as deep as the amount scraped off to reduce squish clearance (assuming a 50% squish band) (Bell, 1999). As a result, removing 0.9mm will need making the combustion chamber 1.8mm deeper. Figure 2.9 shows a 50 percent squish band with an area equal to half the cylinder bore size. For example, an engine with a 54mm bore would have an 8mm wide squish band.

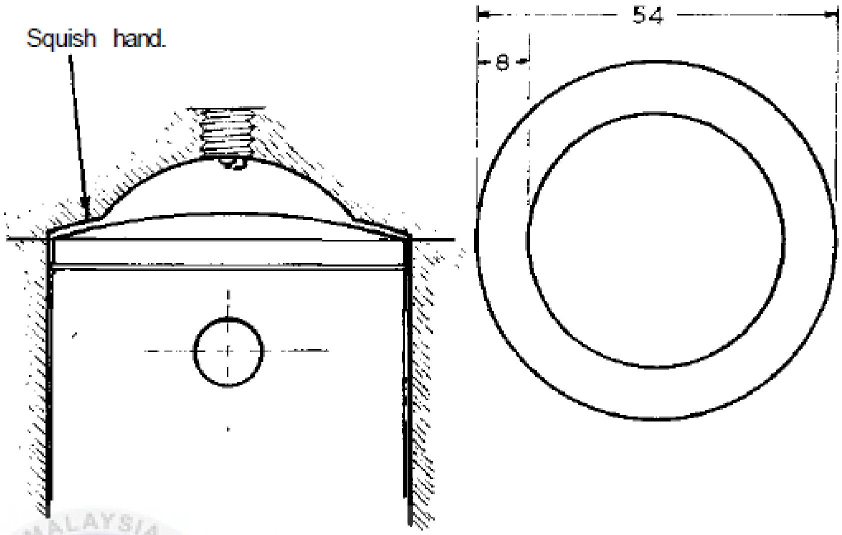


Figure 2.9 50% Squish of band.

Most people like to see the compression ratio pushed up as high as possible. High compression has always been equated with high horsepower (Bell, 1999). I agree that the compression ratio should be made as high as practicable, but often the manufacturer has already found the limit and built his engines accordingly. In this case, all you can do is make sure that production tolerances haven't dropped the ratio below what the manufacturer intended. When working with two-stroke engines, keep in mind that increasing the compression ratio will not produce the same amount of power as a four-stroke engine (Bell, 1999).

2.8 Combustion Chamber and Emission

2.8.1 Theory

The **Figure 2.10** illustrates how the temperature is distributed throughout a cylinder when combustion chambers are changed. The intensity of the flame increases in direct proportion to the speed of laminar flow, however, turbulence has almost little impact on the flame kernel (Wu et al., 2016). The spark plug discharge has less fuel ahead of the chemical reaction, which allows it to be one of the primary drivers in determining the rate of flame propagation. For much of the early phase, turbulence intensity has minimal effect on flame production, although turbulence does play a significant role in the process of flame propagation. The amount of turbulence in the flame propagation process is almost certain to increase. At 725 degrees Celsius, the spread direction and pace of flame may be observed in **Figure 2.10**. It can be found by investigating the 725 CA flame propagation's gradation. The first combustion chamber (where the flame is slow to start) has a temperature distribution that gradually raises the flame, while the second (where the flame has just begun to expand) has a temperature distribution that steeply rises the flame, and the third (where the flame has already started to expand) has a temperature distribution that presents a rapid increase in flame temperature. This argument makes sense, since it is easier to build a bigger squeezing area, which in turn allows for greater turbulence in the second and third combustion chambers (Wu et al., 2016). By significantly increasing the kinetic energy of local turbulence, this will greatly enhance the speed at which flames spread, which will speed up the combustion process. In this research, only NOx emissions were examined. The three most important elements to NO production in combustion processes are the oxygen enrichment, high temperature, and duration of O and N. The NOx is produced in the burnt region of **Figure 2.10**, as it is indicated. The number of NOx production around the spark plug is at its highest because of the temperature surrounding the spark plug (Wu et al., 2016). While a rapid turbulent flow speed in the third combustion chamber contributes to increasing the combustion speed in the cylinder, it is also an appropriate reason because the increased NOx production that results. Due to the more even distribution of TKE in the second combustion chamber, second combustion-chamber cylinder combustion is more harmonic, resulting in a lower NOx production. Other scientists have discovered related research. This chamber's NOx reduction to 20% is very effective.

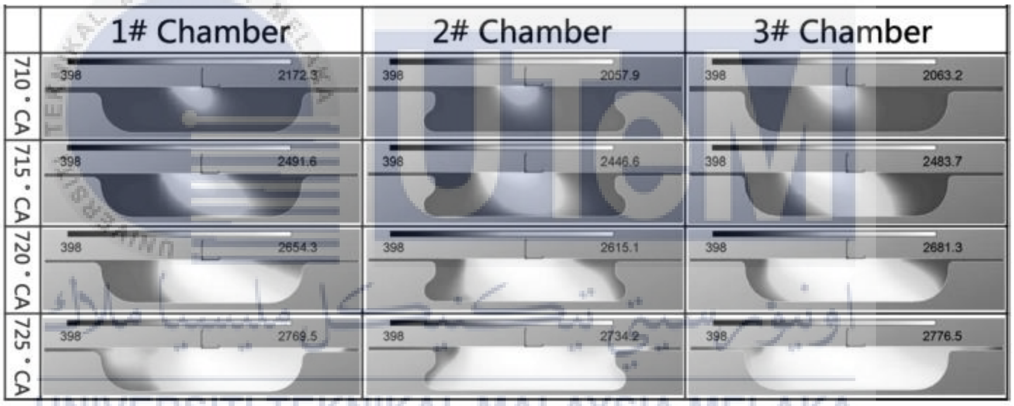


Figure 2.10 Temperature distribution in cylinder.

2.8.2 Parameter Involved

In spark ignition engines, the flame development and quick combustion periods are split into the combustion phase, which is a time frame that contains the period during which a spark is applied to the mixture, and the total combustion period, which is the sum of the flame development and quick combustion periods in the fuel chemical energy released 90% (90% burnt mass percentage) (Wu et al., 2016). In other words, by doing a simulation that includes three distinct combustion chambers, parameters in the combustion process such as flame surface density distribution may be measured. The various combustion chamber times scales, when it comes to the growth of a flame, are comparable, but when it comes to the creation of a flame, the time scales vary. The correct rationale is that the lower limit of the extent of turbulence is found during the flame kernel's development period, when there is little turbulence, and the flame expands with laminar flow speed. In the rapid combustion period, turbulence is more widespread, and the flame spreads with turbulent flame speed. The greater turbulent flow speed helps increase the flame propagation speed during fast burning (Wu et al., 2016). The flame surface density distribution is shown in **Figure 2.11**.

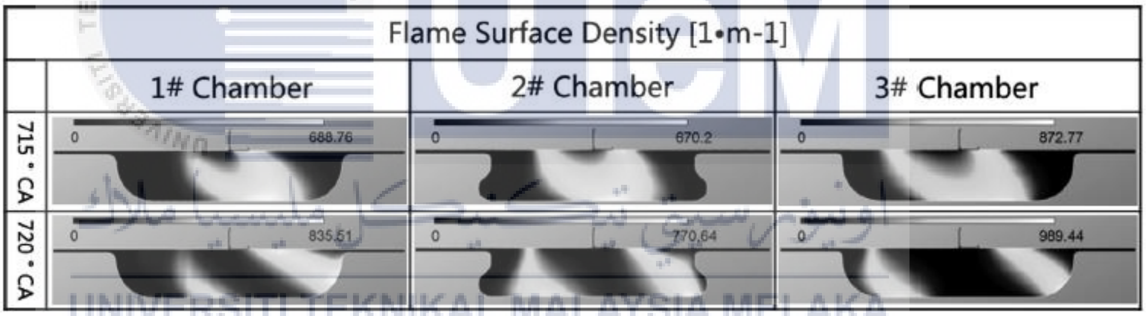


Figure 2.11 The Flame Surface Density.

The **Figure 2.11** graphically depicts the findings that in the third combustion chamber, maximum flame surface density was found, which implied that the propagation speed of the flame in the third chamber was the quickest, while in the first chamber the propagation speed of the flame was the slowest. This may be shown to be true since the TKE plays a major role in bringing about the effect (Wu et al., 2016). Spark ignition engines are known to cause turbulence in the flammable-non-flammable fuel mixture at the flame front. This may increase the interchange of flammable and non-flammable compounds near the flame, and extend the size of the flame front, improving the flame propagation speed.

2.9 Power, torque, and emission for two-stroke small engine

Two stroke vehicles are used for high efficiency output (Abhilash and Kumar, 2020). The fact that a two-stroke engine has one rotation per rev and one running stroke each rev is the major advantage. We utilise mechanical devices to capture that power because of the greater pickup and high thermal efficiency afforded by that working stroke. To work efficiently and to analyse how a charge is imparted, we primarily employ proper fuel engines. When compared to other fuel vehicles, gasoline emits fewer carbon particles. We basically use proper fuel engines to perform efficiently and analyse how a charge is imparted. Gasoline emits fewer carbon particles than other types of fuel vehicles. Aside from that, pollutant emissions linked with the conversion of chemical energy obtained from fuel into thermal energy, as well as the release of toxic gases such as NOx, CO, HC, and PM, have been a prominent issue affecting engine performance (Khoa and Lim, 2019). Because the combustion process has a significant impact on engine performance and emission characteristics, lean-burn mixes were used to improve combustion quality.

Effect of exhaust temperature on carbon monoxide (CO) emissions in different load sand ethanol percentages are depicted in **Figure 2.12**. CO will be produced from the partial oxidation of carbon-containing compounds, it forms when there is not enough oxygen to produce carbon dioxide (CO2) (Ghazikhani *et al.*, 2014). Carbon monoxide burns and produces carbon dioxide in the presence of oxygen. It is self-evident that when engine speed rises, exhaust temperature rises as well, and the needed time for combustion decreases, resulting in an increase in CO. **Figure 2.12** shows that increasing the exhaust temperature greatly increased CO2 emissions. This increase is higher for 15% ethanol than other percentage which is approximately a 30% increase in 50% full load. When the engine speed increases, fuel and air ratio decreases, so oxygen in the mixture increases and consequently hydrocarbons (HCs) decrease by increase in exhaust temperature (Ghazikhani *et al.*, 2014).

This fact is shown in **Fig 2.13** which is 30% on an average. Also, some of the fuel–air combination "hides" from the flame in the crevices formed by the piston ring grooves in piston engines. A faint flame and low combustion temperature may also exist in some areas of the combustion chamber. HCs are created when unburned fuel is expelled from a combustor. HCs released by test engines at various exhaust temperatures, loads, and ethanol concentrations percentages are presented in **Fig 2.13**. These figures confirm that using ethanol reduces the HCs level in all cases and for each 5%ethanol, HCs decreased by approximately 6%. Nitric oxide (NOx) will be produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures (Ghazikhani *et al.*, 2014). As shown in **Fig. 2.13**, ethanol additives have the greatest impact on NOx emissions, which can be the most significant benefit of ethanol because it reduces NOx emissions by roughly 83 percent when used in high percentages (15%) and high-speed engines, and by 38 percent on average. Because ethanol has an oxygen molecule in its chemical composition, it improves combustion and reduces NOx emissions when added to gasoline. Furthermore, ethanol makes a lower combustion temperature than gasoline and NOx mostly form in high temperature.

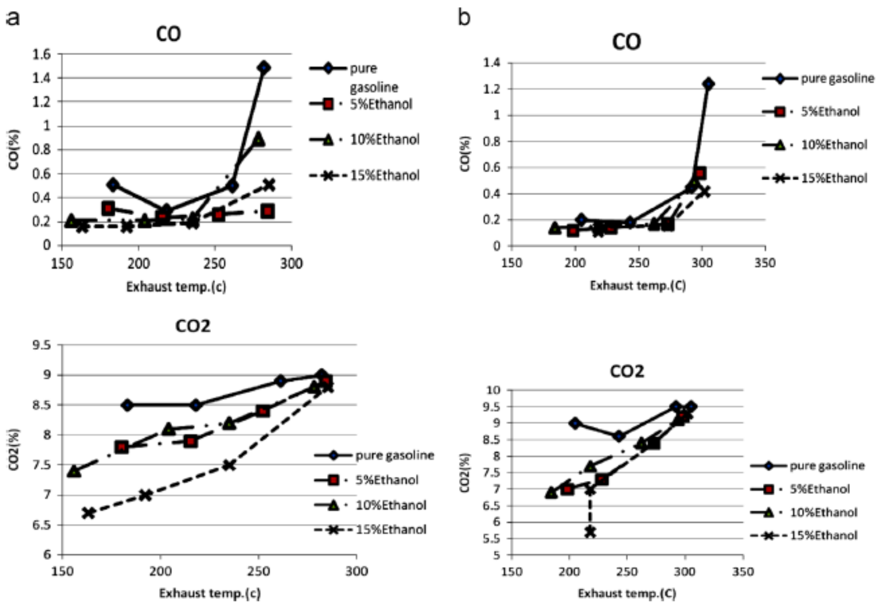


Figure 2.12 Effects of exhaust temperature and CO and CO2 emissions.

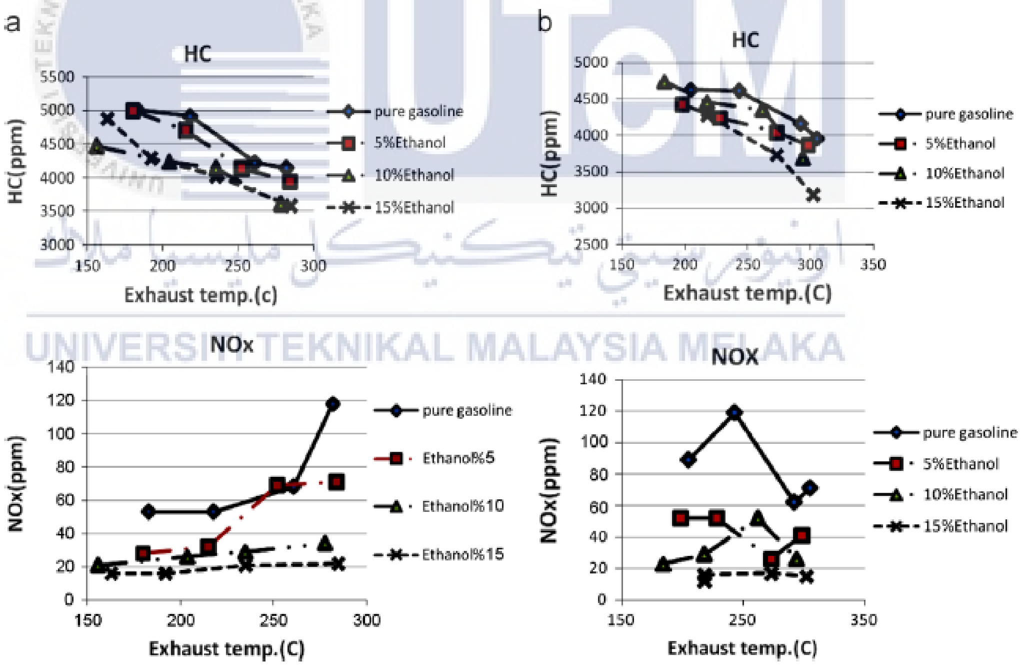


Figure 2.13 Effects of exhaust temperature and HC and NO_x emissions.

CHAPTER 3

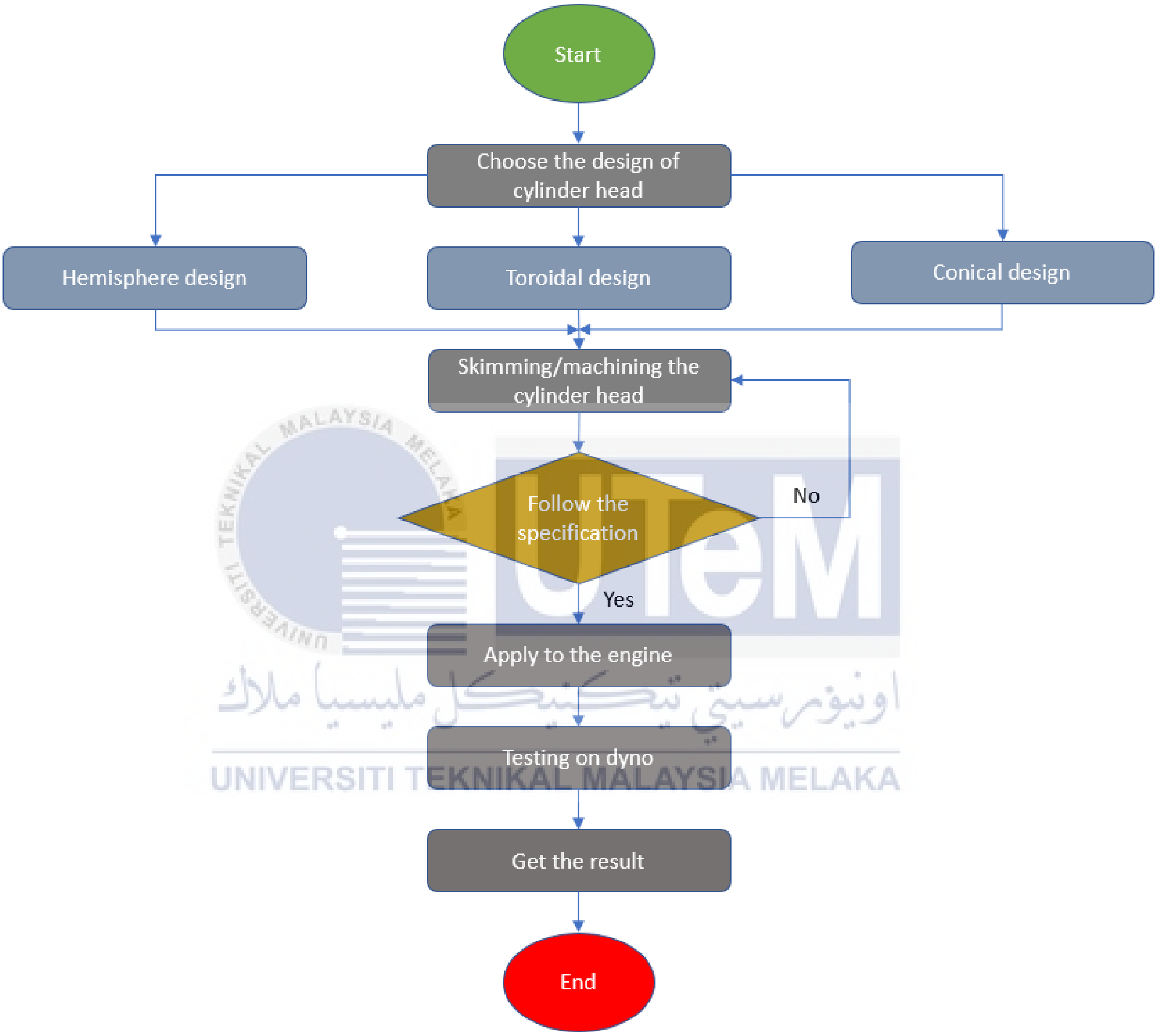
METHODOLOGY

3.1 Introduction

In general, the performance of an engine is depending on many aspects such as the engine capacity(cc), the parts and technology that were involved in the engine based on the production specification who is build up the engine. Typically, the most powerful engine is referring to the bigger capacity and directly use more of fuel consumption. But nowadays the technology is more advance based on the research and development from the professional engineers. They were done many of research to get the maximum power output in a small engine. As example, the turbocharger and supercharger which are the advance technology that can enhance the engine performance. Both technologies are having a same function which is to give more air by compressing it before the air going inside the combustion chamber. This is because the more air enters in the combustion, the more powerful explosion can be done and directly give more power to the engine.

So, this also including to the two-stroke engine which is many research and development have done to improve the engine. As example, some engineers have used the power valve innovation to improve the engine performance. The power valve function is to adjust the exhaust duration that suitable with the RPM range. So, the engine will run with a great performance at low RPM until the higher RPM compared to the engine does not use power valve. This innovation generally uses in very high RPM engine. However, this project is to make research about a different combustion chamber that apply to the engine, and which one will produce a great performance and emission.

3.2 Process Flow Chart



3.3 Experiment Design

This project is to study about the shape of combustion chamber of two-stroke engine. In this study three different shape of combustion chamber was used to get three different data in terms of the horsepower, torque, and emission. To get the result a two-stroke motorcycle will be test on dyno to get more efficient data. The aim for this study to determine which one of the different combustion chamber shapes will produce a great performance in terms of horsepower, torque and has a good of emission to surrounding.

3.3.1 Experiment Layout

Refers to **Figure 3.1** this is the model of motorcycle that will be used for this study.

Figure 3.1 Yamaha 125ZR motorcycle model.

Stock Specification

Table 3.1 Stock engine specification.

Displacement	124.3cc
Maximum power	17.1 hp
Maximum torque	16.1 Nm
Engine type	Two-stroke, Single cylinder
Exhaust pipe	Single exhaust
Bore X Stroke	53.8mm x 54.7mm
Drive type	Chain drive
Compression ratio	6.5:1
Clutch type	Wet, Multi-plate
Cooling system	Air cooled
Gear box	6-speed
Transmission type	Manual

Current Test Specification

Table 3.2 Testing engine specification.

Displacement	144.54cc
Maximum power	xx.xx hp
Maximum torque	xx.xx Nm
Engine type	Two-stroke, Single cylinder
Exhaust pipe	Single exhaust
Bore X Stroke	58mm x 54.7mm
Drive type	Chain drive
Compression ratio	6.95:1
Clutch type	Wet, Multi-plate
Cooling system	Air cooled
Gear box	6-speed
Transmission type	Manual

Table 3.3 Fuel and Ignition.

Ignition system	CDI
Start option	Kick starter
Fuel type	Petrol

3.4 Combustion Chamber Design

The combustion chamber is come from the standard specification which is the original part from Hong Leong Yamaha Sdn Bhd. So, the material or others aspect of the combustion chamber are same only different in term of shape. The parameter of the chamber like the diameter, squish band width and squish angel are not changed due to get the perfect result. It is because when one of the parameters has been changed it can cause some side effect or disturb the performance of the engine. **Figure 3.2** shows the parameter of the combustion chamber.

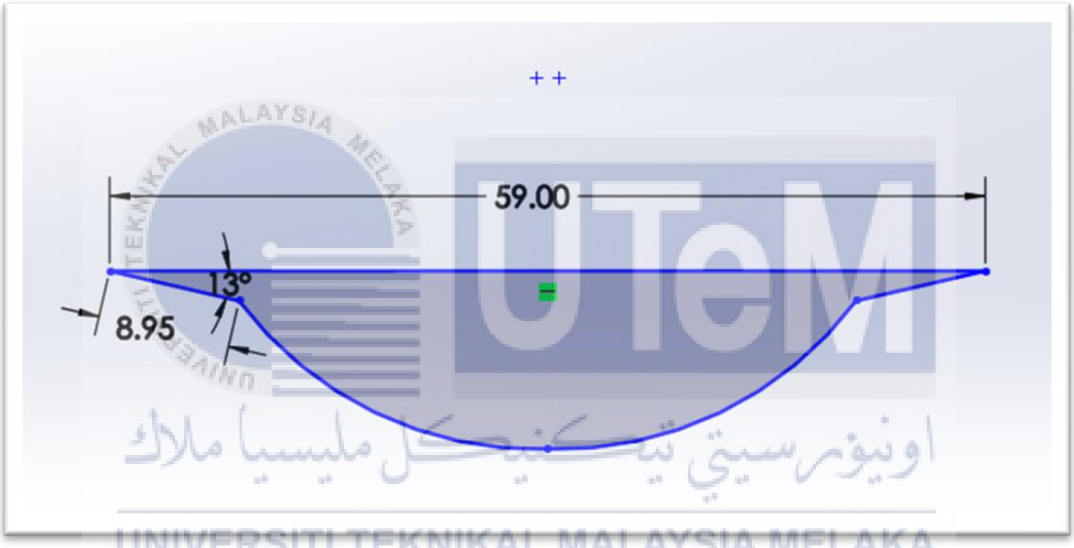


Figure 3.2 Combustion chamber parameter.

Other than that, the compression ratio used also will be same which is 6.95:1. So, this meaning even there are three different of combustion chamber will be use but the volume is still same to get the same compression ratio. It is because different combustion chamber also will affect the performance of the engine. To produce the shape of combustion chamber, a lathe machine will be use and then the volume will measure by using a burette or syringe. The following figure which are **Figure 3.3**, **Figure 3.4** for hemisphere design, then **Figure 3.5, Figure 3.6** for toroidal design and the last design are **Figure 3.7** and **Figure 3.8** for conical design.

a) Hemispherical Design

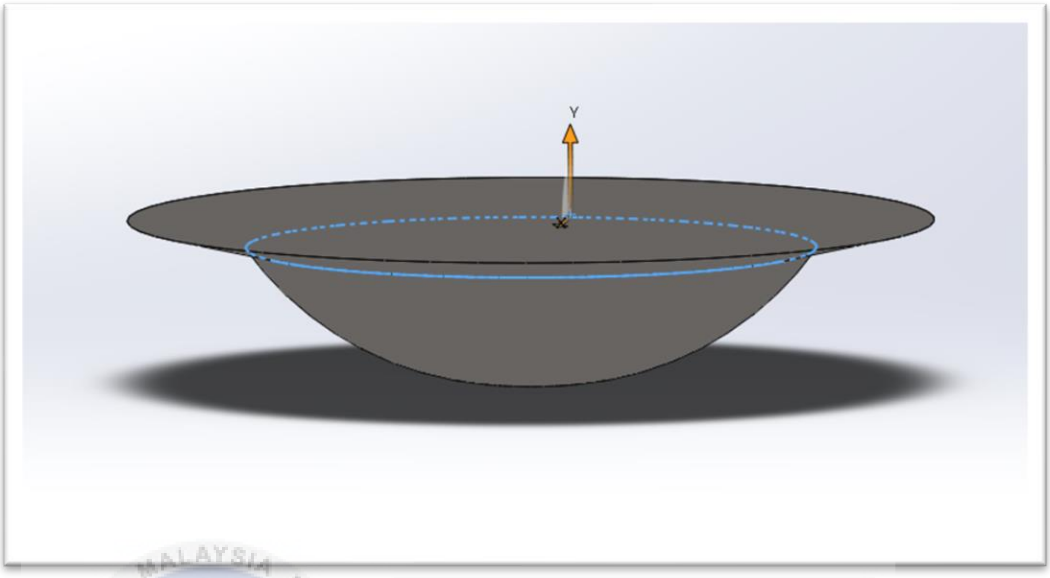


Figure 3.3 Hemispherical combustion chamber.

Figure 3.4 Hemispherical front view.

Figure 3.5 Hemispherical real testing design.

b) Toroidal Design

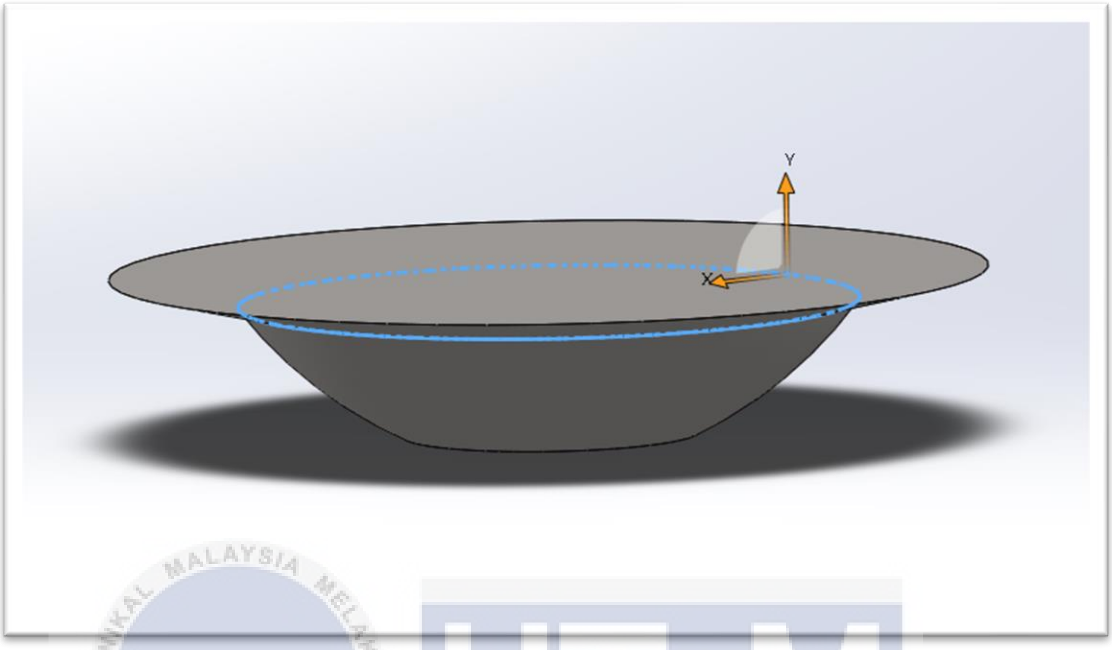


Figure 3.6 Toroidal combustion chamber.

Figure 3.7 Toroidal front view.

Figure 3.8 Toroidal real testing design.

c) Conical Design

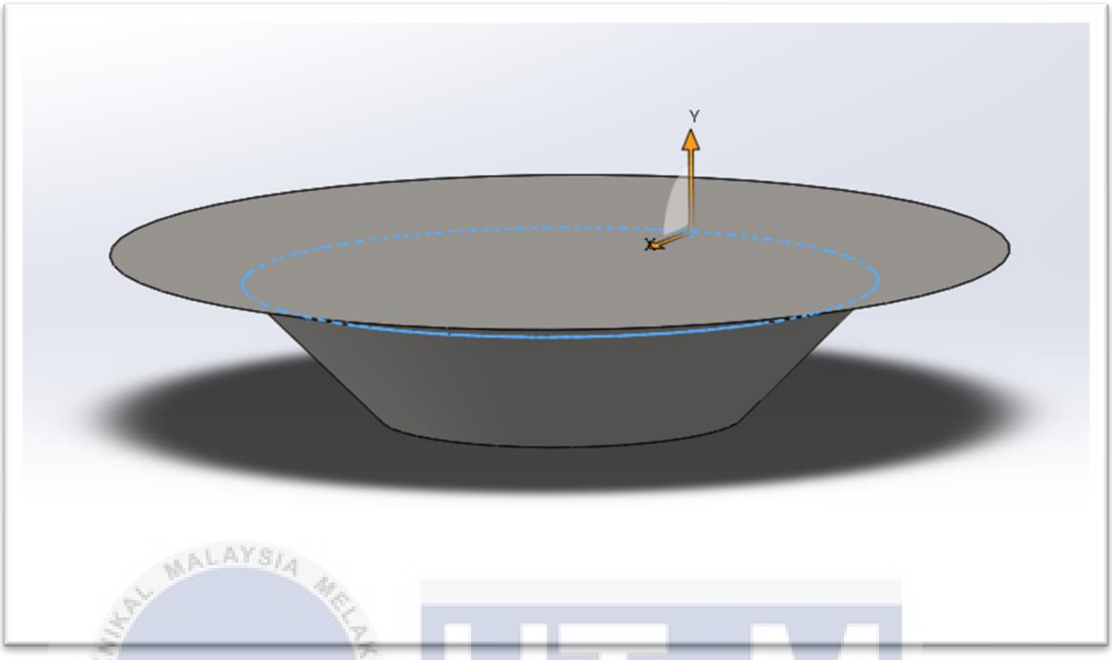


Figure 3.9 Conical combustion chamber.

Figure 3.10 Conical front view.

Figure 3.11 Conical real testing design.

3.4.1 Tools and Equipment

In this project many equipment and tools will be use. The equipment involved start from the beginning to making the combustion chamber shape until the engine will be test and get the result. As example the machining equipment, measurement, and the tools for open and install the head cylinder.

3.4.1.1 Machining

a) Dyno test

A dyno test is a short form for dynamometer. This device functional to measure the force, torque, and power for vehicle. A dyno test also can evaluate and giving the reading that indicates the amount of power in the engine. **Figure 3.9** shown the example of the dyno test.

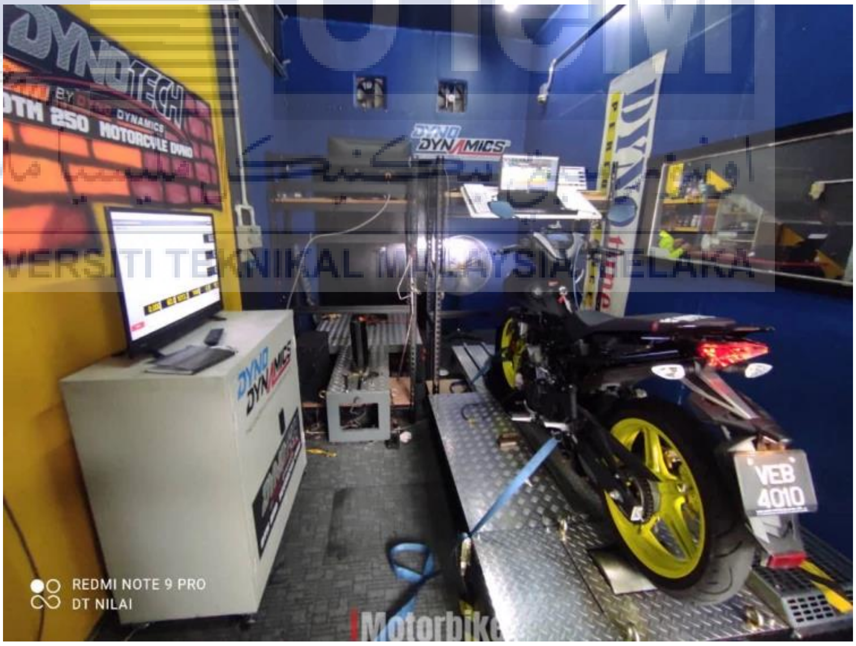


Figure 3.12 Dyno test.

b) Dyno test used

In this project the dyno machine that has been used was placed at Engineering Technology Faculty of University Technical Malaysia Melaka. The type of the dyno is DYNOmite Dynamometer which is made from USA. This dynamometer maximum limit of the measuring horsepower is about 800hp. DYNOmite Dynamometer was manufactured in the last 42 years ago for wide range of high performance and industrial applications. It also one of the world's fastest growing engine dynamometer manufactures. This dynamometer has got high demand in market. The Customers include US and foreign military branches, top NASCAR teams, OEM engine manufactures, machine shop and individual hobbyists. It is because this dynamometer has certified with the accurate result. The figure below is the dynamometer and the motorcycle that has been used and testing.

Figure 3.13 DYNOmite with testing motorcycle.

c) Dyno test procedure

Table 3.4 Dyno test procedure.

No	Description	Figure
1	A loader was used to put the testing motorcycle on the dyno. During the process make sure to get help from someone to guide from other side as the motorcycle not to fault. Put the loader away before the testing.	
2	Make sure the safety belt one at the front tyre and two for side hold was tighten. This belt needs to be tightened properly as it not going loose during the testing.	 

3	Then, make sure the tyre has aligned to the centre of the roller as the motorcycle was not tilted that can be dangerous during the test.	
4	Next, the main switch of the dyno was turned ON. The others switch such as the blower, ventilation fan and computer were turned ON too.	 

5	Lastly, make sure the ventilation fan and blower were functional well before starting the dyno test.	 

d) Lathe machine or CNC

To make the combustion chamber shape, a lathe machine will be use. But using the lathe machine we need to determine the volume manually using a burette or syringe compared to CNC which can give the exact value. However, using a lathe machine can be consider because of the low cost compared to CNC. **Figure 3.10** shown the lathe machine with cylinder head. During the process, the most important thing is the parameter which are the squish angel, squish value and the combustion chamber volume. Even the design is different, but the parameters cannot be change due to get the perfect result.

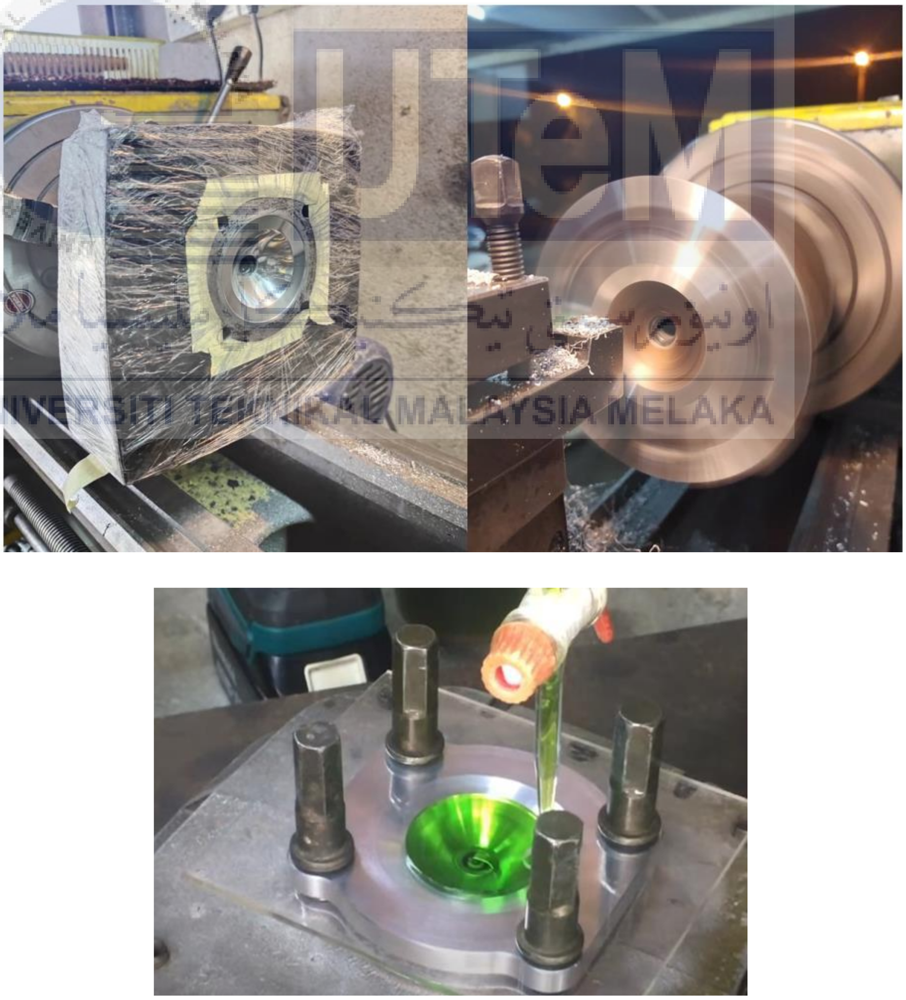


Figure 3.14 Cylinder head machining and volume measurement.

3.4.1.2 Measurement

Table 3.5 Measurement kit.

Equipment	**Figure**	**Function**
Burette or syringe		To measure the combustion chamber volume.
Vernier calliper		To measure the parameter of combustion chamber.

3.4.1.3 Tools

Table 3.6 Tools.

Tools	**Figure**	**Function**
Torque wrench		To tighten the bolt and nut during the opening and installation of the cylinder head. The force used around 17-23 N.m.
Screwdriver		To open and tighten the motorcycle cover set screw.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter present the results and the analysis on the experimental of different head combustion chamber to engine performance for two-stroke small engine. These main objectives for this experiment are to analyse different head combustion chamber to engine power, torque and emission. This research is based on the different combustion chamber that have in previous of two-stroke motorcycle engine from the early century of this engine manufactured until now. The example of the shape of the combustion chamber that have been design are conical and hemispherical shape. Mostly of the latest two-stroke engine was used the hemispherical shape design. The conical design is rarely to find and form for the two-stroke motorcycle in early 1990s like Yamaha TZM150 and Yamaha Y100 sport. Other than these shape, the toroidal shape design also one of the most popular designs that has been put on to the two-stroke engine. But this shape just found in the research and development website and never revealed and used by biggest company such Yamaha, Honda, Suzuki and many more. So, from this experiment we can get the result for each type of the combustion shape. The result will appear the characteristic of each combustion chamber based on the horsepower, torque and the emission at the certain RPM. From the result obtained we can know why this shape were designed for different engine and which of these combustions give the best output or results.

4.2 Testing Result

4.2.1 Hemispherical Design

Table 4.1 Hemispherical test 1.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	3.54	8.40	5.27	4.80	21.90
4000	3.62	6.40	2.05	4.70	21.90
5000	5.92	8.40	2.83	4.70	21.90
6000	10.54	12.50	2.71	4.80	21.90
7000	21.32	21.70	2.79	4.80	21.90
8000	23.79	21.20	5.27	4.70	21.90

Table 4.2 Hemispherical test 2.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	3.55	8.40	4.28	5.80	21.40
4000	3.64	6.50	2.42	5.00	21.40
5000	5.88	8.40	0.47	4.60	21.40
6000	10.98	13.00	0.35	4.50	21.40
7000	21.05	21.40	5.00	5.40	21.40
8000	24.97	22.30	2.35	5.00	21.40

Table 4.3 Hemispherical test 3.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	3.04	7.20	5.35	5.80	21.90
4000	3.65	6.50	2.79	4.80	21.90
5000	5.90	8.40	2.54	4.50	21.90
6000	8.87	10.50	2.7	5.70	21.90
7000	19.47	19.70	2.54	5.30	21.90
8000	25.77	23.00	3.65	5.00	21.90

Table 4.4 Hemispherical average test result.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	3.38	8.00	4.97	5.47	21.73
4000	3.64	6.47	2.42	4.83	21.73
5000	5.90	8.40	1.95	4.60	21.73
6000	10.13	12.00	1.92	5.00	21.73
7000	20.61	20.93	3.76	5.17	21.73
8000	24.84	22.17	3.44	4.90	21.73

4.2.2 Toroidal Design

Table 4.5 Toroidal test 1.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	2.29	5.40	6.27	4.80	21.90
4000	3.01	5.40	5.66	4.70	21.90
5000	5.01	7.10	6.30	4.70	21.90
6000	7.56	8.90	6.50	4.80	21.90
7000	18.14	18.40	5.61	4.80	21.90
8000	23.92	21.40	4.06	4.70	21.90

Table 4.6 Toroidal test 2.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	2.12	5.00	6.29	4.80	21.90
4000	3.12	5.50	5.22	4.70	21.90
5000	5.06	7.20	6.58	4.80	21.90
6000	7.52	8.90	5.49	4.80	21.90
7000	12.89	13.10	5.00	4.80	21.90
8000	25.40	22.80	4.85	4.70	21.90

Table 4.7 Toroidal test 3.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	2.07	4.90	3.87	4.80	21.90
4000	3.13	5.60	3.13	4.70	21.90
5000	5.05	7.20	3.59	4.80	21.90
6000	7.59	8.90	3.03	4.80	21.90
7000	12.09	12.60	3.39	4.80	21.90
8000	25.17	22.70	3.45	4.70	21.90

Table 4.8 Toroidal average test result

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	2.16	5.10	5.48	4.80	21.90
4000	3.09	5.50	4.67	4.70	21.90
5000	5.04	7.17	5.49	4.76	21.90
6000	7.56	8.90	5.01	4.80	21.90
7000	14.37	14.70	4.54	4.80	21.90
8000	24.83	22.30	4.30	4.70	21.90

4.2.3 Conical Design

Table 4.9 Conical test 1.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	1.92	4.50	5.27	5.70	21.90
4000	3.00	5.30	2.09	4.90	21.90
5000	4.80	6.80	4.72	4.50	21.90
6000	8.57	10.20	3.43	5.90	21.90
7000	18.08	18.30	2.09	5.30	21.90
8000	21.64	19.30	3.65	5.00	21.90

Table 4.10 Conical test 2.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	1.97	4.70	7.21	5.70	21.90
4000	3.12	5.50	5.99	4.80	21.90
5000	5.00	7.10	5.69	4.50	21.90
6000	8.36	9.90	5.73	5.80	21.90
7000	18.18	18.50	5.58	5.30	21.90
8000	22.49	20.10	5.61	5.00	21.90

Table 4.11 Conical test 3.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	2.02	4.80	5.27	4.80	20.80
4000	3.09	5.50	2.83	4.70	21.90
5000	5.00	7.10	3.48	4.70	21.90
6000	7.48	8.80	2.04	4.80	21.90
7000	12.60	12.80	3.65	4.80	21.90
8000	25.67	23.10	3.65	4.70	21.90

Table 4.12 Conical average test result.

Engine speed (RPM)	Engine power (Hp)	Torque (N.m)	CO (%)	CO2 (%)	O2 (%)
3000	1.97	4.67	5.92	5.40	21.50
4000	3.07	5.43	3.64	4.80	21.90
5000	4.93	7.00	4.63	4.57	21.90
6000	8.14	9.63	3.73	5.50	21.90
7000	16.29	16.53	3.77	5.13	21.90
8000	23.27	20.83	4.30	4.90	21.90

4.3 Overall testing result

Table 4.13 Engine performance.

Type of combustion chamber	Horsepower (Hp)		Torque (N.m)	
	Average	Max.	Average	Max.
Hemispherical	24.84	25.77	22.17	23.00
Toroidal	24.83	25.40	22.30	22.80
Conical	23.27	25.67	20.83	23.10

Table 4.14 Emission.

Type of combustion chamber	CO (%)		CO_2 (%)		O_2 (%)	
	Average	Max.	Average	Max.	Average	Max.
Hemispherical	3.08	5.35	5.00	5.80	21.73	21.90
Toroidal	4.92	6.58	4.76	4.80	21.90	21.90
Conical	4.33	5.92	4.33	5.40	21.84	21.90

4.4 Graph Analysis

4.4.1 Hemispherical Design.

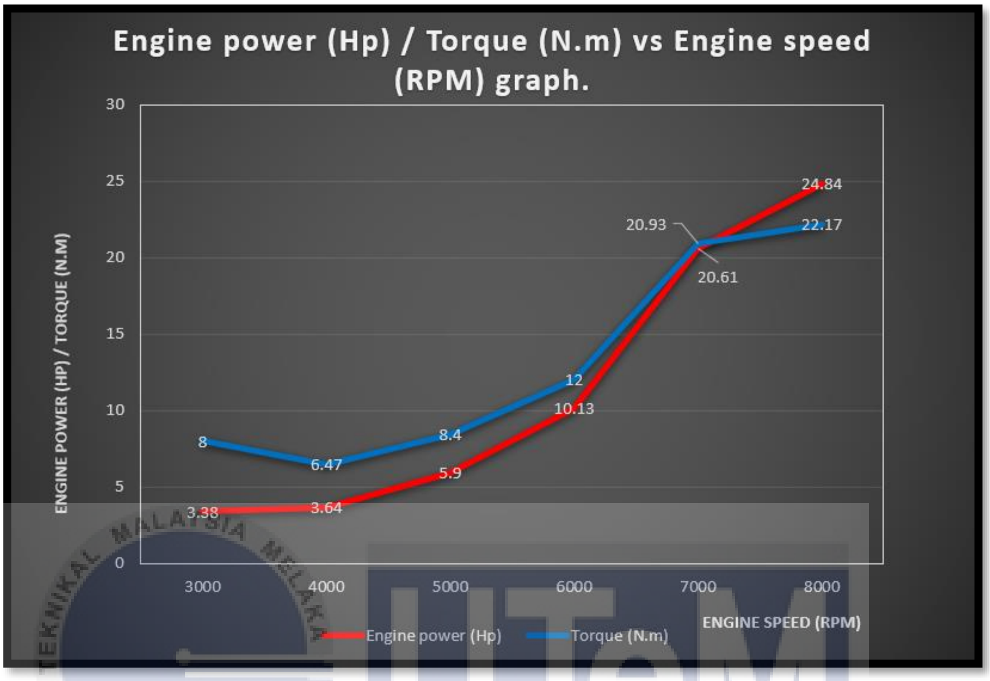


Figure 4.1 Hemispherical engine power and torque graph.

This graph shown the engine power (Hp) and torque (N.m) of hemispherical head cylinder design. The horsepower increasing in steady state from 3000 RPM to 5000 RPM which 3.38 Hp to 5.9 Hp and when it reaches at 6000 RPM the horsepower increases in drastic condition to 7000 RPM which is increasing from 10.13 Hp to 20.93 Hp. The maximum horsepower is 24.84 Hp at 8000 RPM. Then, the torque for this design is 8 N.m at the beginning of 3000 RPM. When at 4000 RPM it dropped to 6.47 N.m and increasing steadily to 6000 RPM which is 6.47 N.m to 12 N.m. The torque increasing very drastic from 6000 RPM to 7000 RPM which is 12 N.m to 20.61 N.m and increasing steady to hit the maximum torque at 8000 RPM which is 22.17 N.m. Then, the horsepower and torque increase in drastic condition from 6000 RPM to 7000 RPM because of the flame propagation that resulting from the combustion in the combustion chamber.

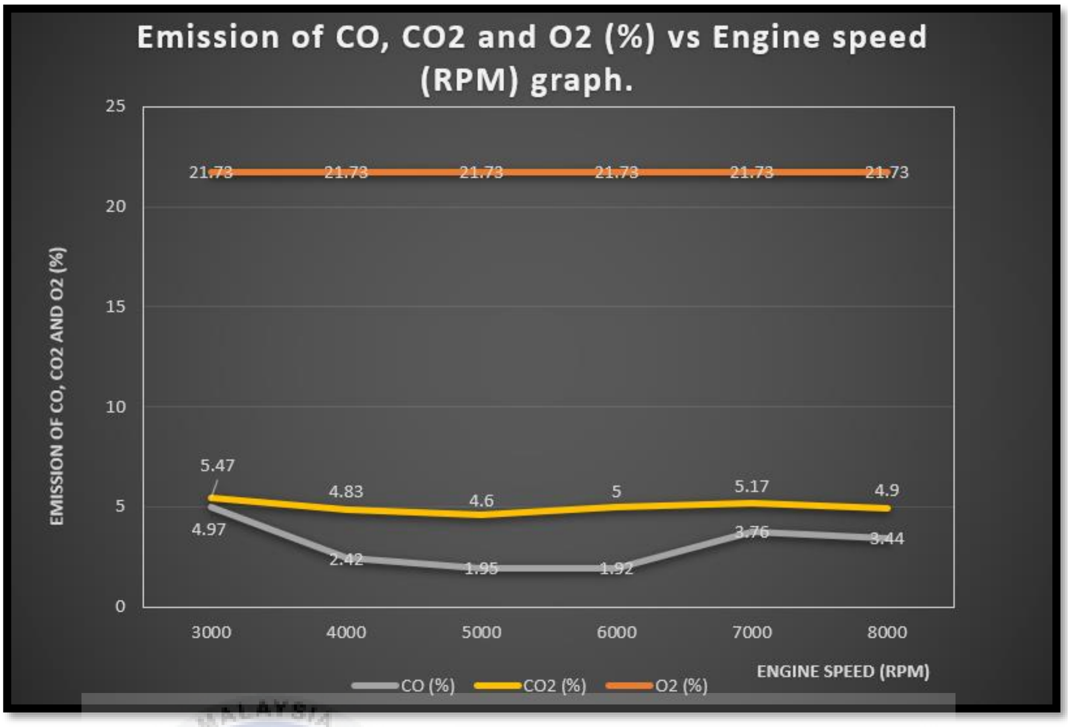


Figure 4.2 Hemispherical emission graph.

This graph shown the emission of hemispherical head cylinder design. The percentage of CO decrease steadily from 3000 RPM to 5000 RPM which is 4.97 (%) to 1.95 (%) and slightly decrease to 6000 RPM with 1.92 (%). Then, its raise to 3.76 (%) at 7000 RPM and decrease to 3.44 (%) at 8000 RPM. The percentage of CO2 decrease slightly from 3000 RPM to 5000 RPM which is 5.47 (%) to 4.6 (%) and slightly increase from 5000 RPM to 7000 RPM before its decrease again to 4.9 (%) at 8000 RPM. Meanwhile the amount of O2 is constant at 21.73 (%) from 3000 RPM to 8000 RPM. The amount of CO is the highest at 3000 RPM. This mean the combustion at that RPM is very poor combustion compared at other RPM. The greatest combustion happens when the engine reach at 6000 RPM because it produces the lowest amount of CO which is 1.92 (%). From the result it shown the combustion rate in the combustion chamber is different at variable RPM. So, it means that the flame propagation happen in the combustion chamber and the exhaust temperature is different when the engine goes at others RPM.

4.4.2 Toroidal Design.

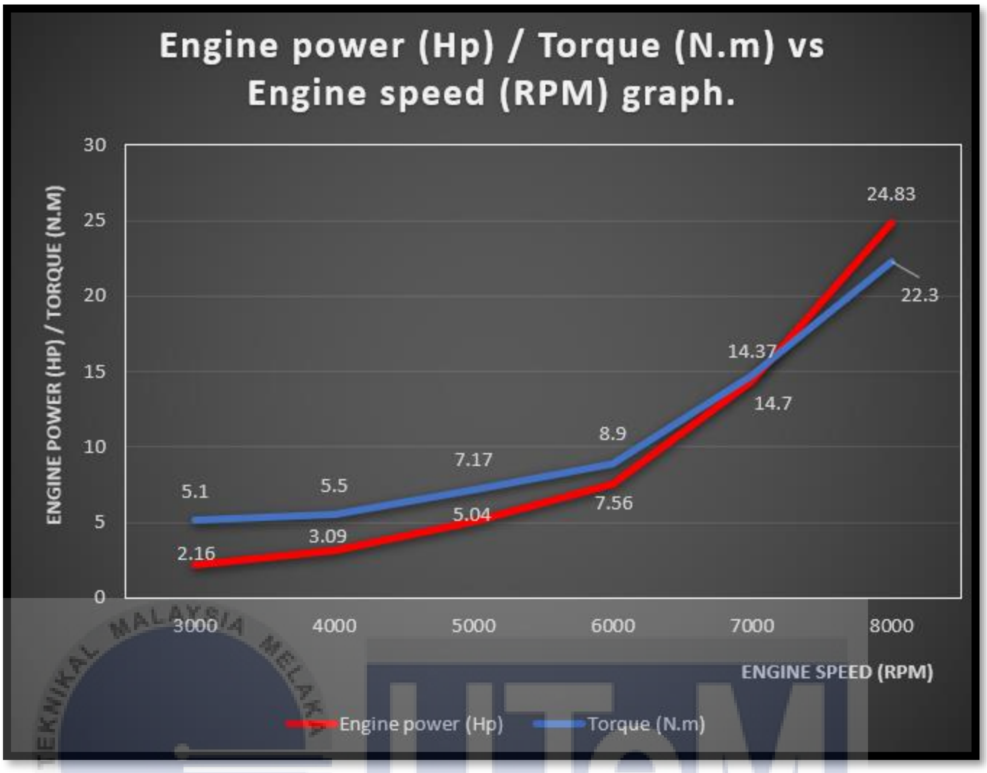


Figure 4.3 Toroidal engine power and torque graph.

This graph shown the engine power (Hp) and torque (N.m) of toroidal head cylinder design. The horsepower increasing in steady state from 3000 RPM to 6000 RPM which 2.16 Hp to 7.56 Hp and when it reaches at 6000 RPM the horsepower increases in drastic condition to 8000 RPM which is increasing from 7.56 Hp to 24.83 Hp. The maximum horsepower is 24.83 Hp at 8000 RPM. Then, the torque for this head cylinder design is slightly increase from 3000 RPM to 6000 RPM which is 5.1 N.m to 8.9 N.m. The torque increasing very drastic from 6000 RPM to 8000 RPM which is 8.9 N.m to 22.3 N.m. The maximum torque is 22.3 N.m at 8000 RPM. The horsepower and torque increase in drastic condition from 6000 RPM to 8000 RPM because of the flame propagation that resulting from the combustion in the combustion chamber. This means the flame propagation occur very fast at that RPM that making the engine can produce a lot of power in very short time.

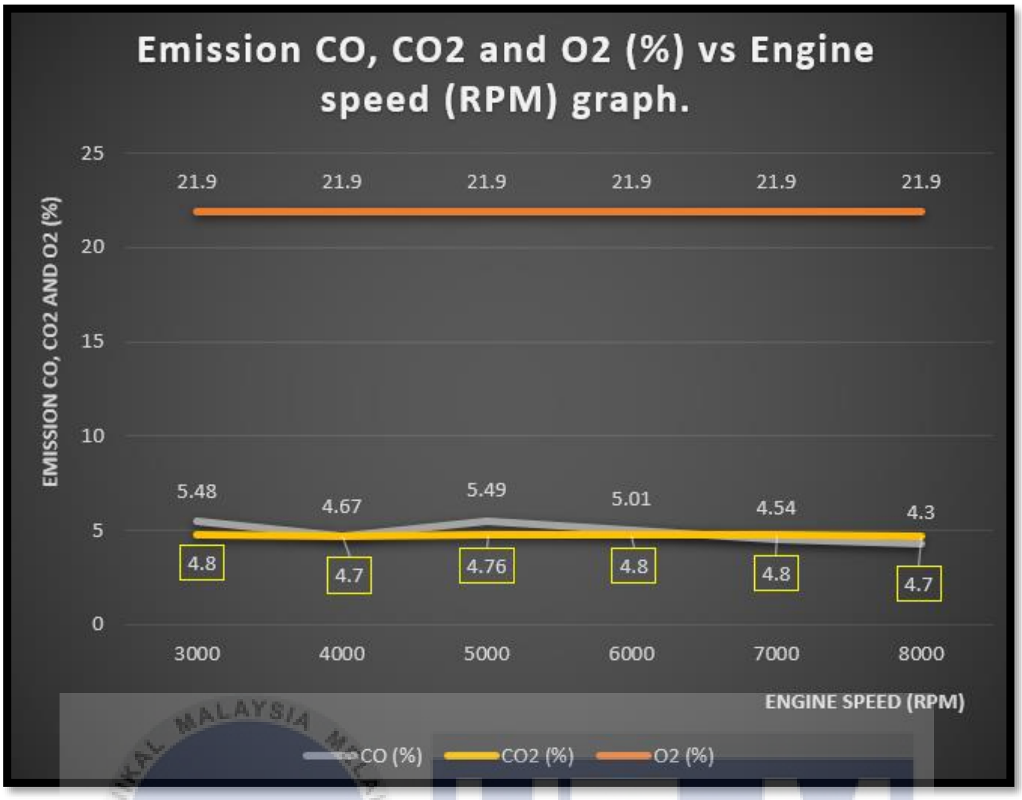


Figure 4.4 Toroidal emission graph.

This graph shown the emission of toroidal head cylinder design. The percentage of CO slightly decrease from 3000 RPM to 4000 RPM which is 5.48 (%) to 4.67 (%) and increase to 5.49 (%) at 5000 RPM. Then, its decrease in steady state from 5000 RPM to 8000 RPM which is 5.49 (%) to 4.3 (%). The percentage of CO2 just slightly drop from 4.8 (%) to 4.7 (%) at 4000 RPM and increase to 4.8 (%) at 6000 RPM until 7000 RPM then decrease again to 4.7 (%) at 8000 RPM. Meanwhile the amount of O2 is constant at 21.9 (%) from 3000 RPM to 8000 RPM. The amount of CO is the highest at 5000 RPM. This mean the combustion at that RPM is very poor combustion compared at other RPM. The greatest combustion happens when the engine reach at 8000 RPM because it produces the lowest amount of CO which is 4.3 (%). From the result it shown the combustion rate in the combustion chamber is different at variable RPM. So, it means that the flame propagation happen in the combustion chamber and the exhaust temperature is different when the engine goes at others RPM. The exhaust temperature also effects the amount of CO produced.

4.4.3 Conical Design.

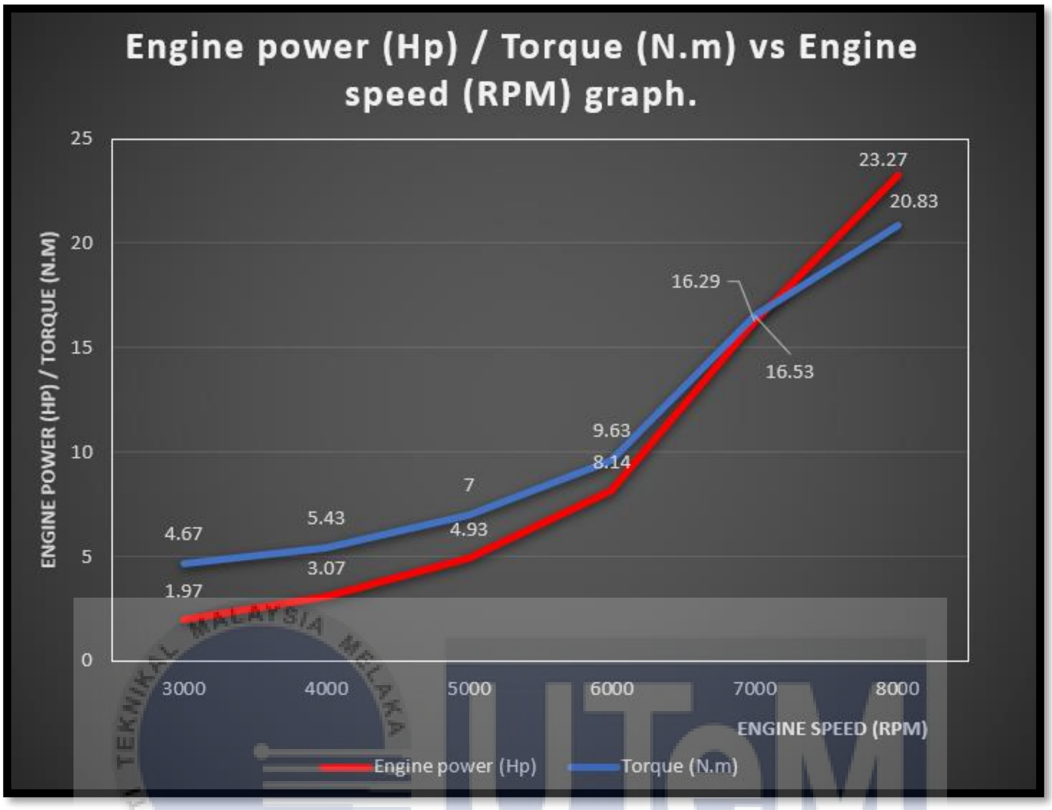


Figure 4.5 Conical engine power and torque graph.

This graph shown the engine power (Hp) and torque (N.m) of conical head cylinder design. The horsepower increasing in steady state from 3000 RPM to 6000 RPM which 1.97 Hp to 8.14 Hp and when it reaches at 6000 RPM the horsepower increases in drastic condition to 8000 RPM which is increasing from 8.14 Hp to 23.27 Hp. The maximum horsepower is 23.27 Hp at 8000 RPM. Then, the torque for this head cylinder design is increase steadily from 3000 RPM to 6000 RPM which is 4.67 N.m to 9.63 N.m. The torque increasing very drastic from 6000 RPM to 8000 RPM which is 9.63 N.m to 20.83 N.m. The maximum torque is 20.83 N.m at 8000 RPM. Then, the flame propagation caused by burning in the combustion chamber make the horsepower and torque increase massively from 6000 RPM to 8000 RPM. This means at that RPM flame propagation is very fast and allowing the engine to create a lot of power in a short amount of time.

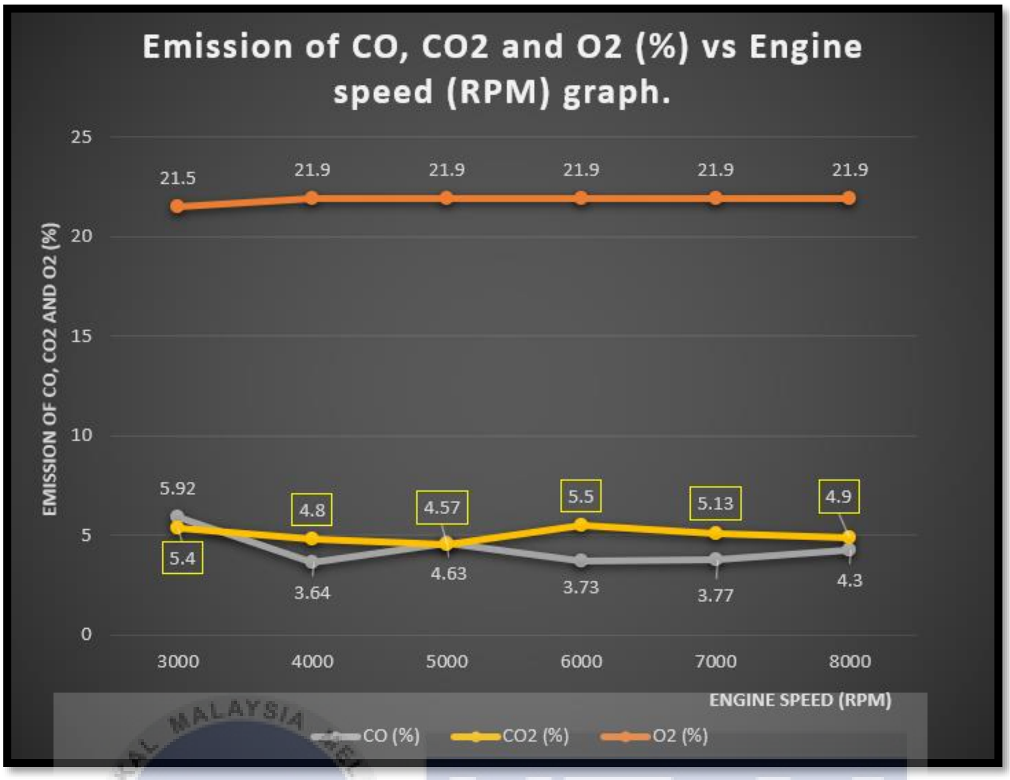


Figure 4.6 Conical emission graph.

This graph shown the emission of conical head cylinder design. The percentage of CO decrease from 3000 RPM to 4000 RPM which is 5.92 (%) to 3.64 (%) and increase to 4.63 (%) at 5000 RPM. Then, its decrease again to 3.73 (%) at 6000 RPM and slightly increase to 3.77 (%) at 7000 RPM before its goes increase to 4.3 (%) at 8000 RPM. The percentage of CO_2 just slightly drop from 5.4 (%) to 4.63 (%) at 3000 RPM to 5000 RPM and increase to 5.5 (%) at 6000 RPM before its slightly decrease again to 4.9 (%) at 8000 RPM. Meanwhile the amount of O_2 is increase from 21.5 (%) to 21.9 (%) at the beginning 3000 RPM to 4000 RPM and it goes constant at 21.9 (%) until 8000 RPM. The amount of CO is the highest at 3000 RPM. This mean the combustion at that RPM is very poor combustion compared at other RPM. The greatest combustion happens when the engine at 4000 RPM because it produces the lowest amount of CO which is 3.64 (%). From the result it shown the combustion rate in the combustion chamber is different at variable RPM. So, it means the flame propagation happen in the combustion chamber also different.

4.4.4 Comparison of Engine Power (Hp).

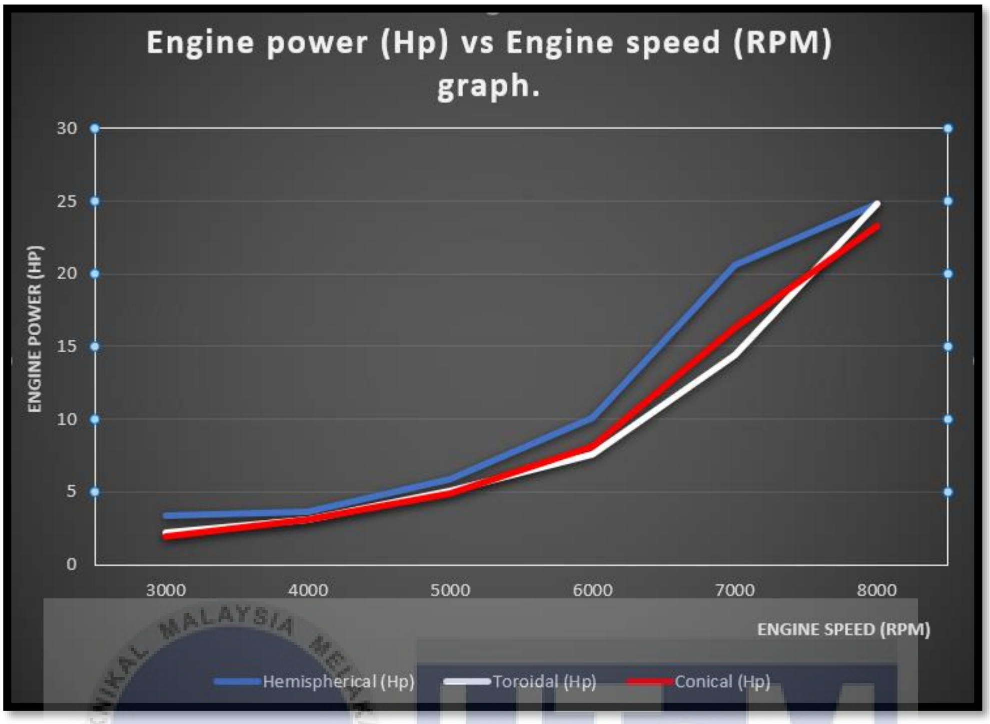


Figure 4.7 Comparison of engine power graph.

This graph shown the comparison of the engine power (Hp) between three different design of combustion chamber which are hemispherical, toroidal and conical. The highest power was achieved by hemispherical design which is 24.84 Hp and follow by toroidal and conical design which is 24.83 Hp and 23.27 Hp. At the low RPM (3000 - 6000) the hemispherical design is slightly highest than both of toroidal and conical and both of this design engine power is almost the same. When the engine reach 6000 RPM. Three of them start to increase drastically. However, the increasing rate of hemispherical design start to decrease when reach 7000 RPM meanwhile the toroidal design increase very drastic when at 7000 RPM. Then, the conical design increasing rate is slightly decrease when achieved 7000 RPM. The horsepower increase in drastic condition from 6000 RPM to 8000 RPM because of the flame propagation resulting from the combustion in the combustion chamber.

4.4.5 Comparison of Torque (N.m).

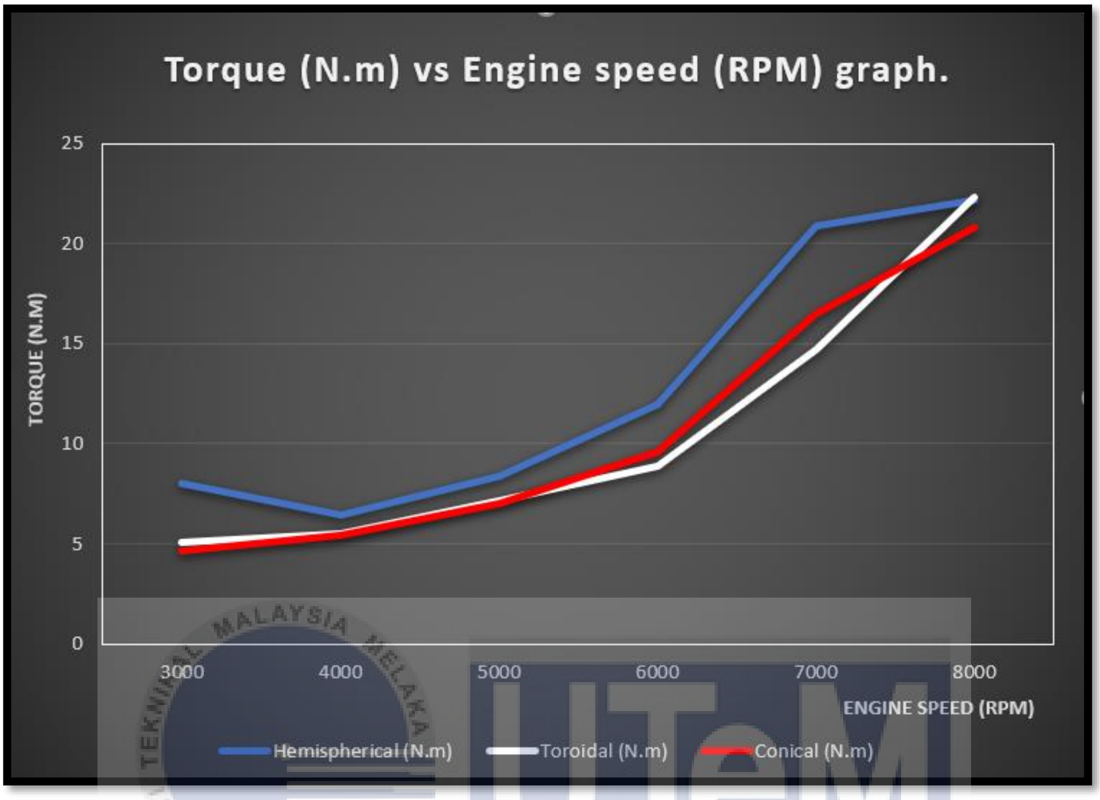


Figure 4.8 Comparison of torque graph.

This graph shown the comparison of torque between three different combustion chamber design which are hemispherical, toroidal and conical design. The highest torque was achieved by toroidal design which is 22.30 N.m and follow by hemispherical and conical design which is 22.17 N.m and 20.83 N.m. The hemispherical design is the highest torque almost at all RPM. But its torque is drop when at the early RPM which is 3000 to 4000 RPM and start to increase until 8000 RPM. At the low RPM (3000 - 6000) both of toroidal and conical is almost the same. When the engine reach 6000 RPM. Three of them start to increase drastically. However, the increasing rate of hemispherical design start to decrease when reach 7000 RPM meanwhile the toroidal design increase very drastic when at 7000 RPM. Then, the conical design increasing rate is slightly decrease when achieved 7000 RPM.

4.5 Discussion

In this chapter the result from the case studies was presented. The result is to demonstrate the power output and the emission from the engine by using three different combustion chamber which is hemispherical, toroidal and conical design. The engine that has been tested is manufactured from Yamaha which is Y125ZR motorcycle model that using two-stroke engine with 6-speed. The stock specification for this model can achieve 17.5 Hp at 8000 RPM and 18.1 N.m at 7500 RPM. For testing specification, the engine can achieve 25.77 Hp at 8000 RPM and 23.1 N.m at 8000 RPM which the highest value was achieved during the experiment. The highest horsepower was achieved by using hemispherical combustion chamber design while the highest torque was achieved by using conical combustion chamber design.

However, this large range value of the horsepower and torque produced is not only cause from the combustion chamber design, but this is also because of the testing specification is different with the stock specification. The compression ratio has been increased from 6.5:1 to 6.95:1 and the engine capacity also has been upgraded from 124.3cc to 144.54cc. So, this is why the power output is increase drastically. But this result still relates with the objective of this experiment which is to analyse different head combustion chamber to engine power, torque and emission. This is because during the testing parameter that can disturb the result such as the compression ratio has been fixed. The result obtained from three different combustion chamber is different which the maximum output for hemispherical design is 24.84 Hp and 22.17 N.m. For toroidal design, the maximum output is 24.83 Hp and 22.3 N.m while the conical design produced 23.27 Hp and 20.83 N.m for maximum. This result shown the different combustion chamber will produce different engine output. This is because of the flame propagation happen during the combustion stroke. Based on the results, it shown the flame propagation of every design at variable engine RPM was different. This means the combustion chamber design can affect the engine performances. In the rapid combustion period, turbulence is more widespread, and the flame spreads with turbulent flame speed. The greater turbulent flow speed helps increase the flame propagation speed during fast burning (Wu et al., 2016).

For engine emission, particulate matter (PM), hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), and other harmful emissions arising from the discharge of burnt and unburned lubricating lubricants are all substantial causes of pollution from motorcycles. The emission standard for CO is 4.5 (%) – 7 (%), 900-1000 ppm for HC and 40 (%) for PM (Travis, 1997). The emission in this experiment, for the hemispherical design produces the lowest amount CO which is 3.08 (%) compared to others design. It is the greatest combustion occur in the combustion chamber for the engine. The lowest amount of CO_2 produced by conical combustion design which is 4.33 (%) and the amount of O_2 of these three designs is almost the same. It just has a slightly different that maybe cause from the surrounding or external factors. From the result it also shown the combustion rate in the combustion chamber is different at variable RPM. So, it means that the flame propagation happen in the combustion chamber and the exhaust temperature is different when the engine goes at others RPM. The exhaust temperature also effects the amount of emission produced. This result was taken as the average from the multiple testing of the experiment and the average from 3000 RPM to 8000 RPM. It is to make more easier and more accurate to compare which design produce a better emission.

A single two-stroke engine produces a lot pollution equivalent 30 to 50 four-stroke automobile (David Kushner, 2008). This is because the fuel-air mixture in them gets contaminated with the engine's lubricating oils that burned together. The simultaneously of the exhaust stroke and intake stroke draws some of fuel expelled through the exhaust port. This also one of the main causes that two-stroke engine has more pollution. Many ways have been tried to minimize this pollution such by using the expansion chamber piping exhaust that can push the expelled fuel mixture to enter the combustion chamber before the exhaust port was closed. This is because the expansion chamber has the return wave that produce from the exhaust stroke. So, when the wave reaches the end of the baffle cone, the wave will return to push back the expelled mixture. This exhaust pipe design is to replace the old design which is the straight pipe exhaust system that has no return wave to push the expelled mixture back. So, the expelled mixture will go through out the exhaust and can cause the pollution.

However, this method needs a good calculation for the exhaust port duration and the length of the exhaust pipe to make sure the return wave will reach into the combustion chamber at the same time before the exhaust port was closed. If not, the expelled mixture cannot be fully push into the combustion chamber because of the exhaust port has been closed early before the return wave reach to the combustion chamber. However, two stroke engine cannot be prevent with the amount of the pollution because of the combustion rate and also the contaminated with the engine's lubricating oils that burned together with the fuel.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, this experimental has been done as the follows plan. The objective of this project also was achieved successfully and achieve the target which is to analyse the different combustion chamber used to the engine power, torque and emission. This analyse has been done by using a two-stroke motorcycle engine that using gasoline to runing the engine. The type of the gasoline that used during the experiment is RON 95 with Shell VSX lubricant (2T oil). In this experiment has approved that the different shape or design of the combustion chamber will produce different output from the engine. Its just not only different againts the maximum output but the shape also influence the engine output from the variable RPM.

As the example the hemispherical design has a good power from the low RPM and its start to drop when achieve high RPM meanwhile the others just start to increase at the high RPM. Overall, the research presented in this experiment has done succesfully to analyse and understanding the power delivers from the different design of the combustion shape.This project also presents even a little modification has been done to the engine it can give more side impact to the engine performance or output. From the analysis, the best design is hemispherical combustion chamber shape that produce consistant power at variable RPM and also the emission produce such as CO is the lowest compared to others. Its does not mean the others design is not good to use but its not suitable for daily use because of the emission. These designs can be use for the engine that made for high performance especially for racing use because its can deliver more power at the highest RPM. Even the emission is high but it is still follow the standard range which is 4.5 (%) to 7 (%).

5.2 Recommendation

For future improvements, the result can be obtained with the most accurate data by enhanced as the follows:

i. Use the CNC to machine the cylinder head to get the accurate shape and volume of the combustion chamber.
ii. Make the caliberation of the vernier caliper to make sure the value is accurate and use the proffesional standard caliper brand.
iii. Take the temperature during the engine operates because the surrounding temperature also can influence the result.
iv. Take the temperature of the engine with the different combustion chamber after it was testing to study either these modification affect the temperature of the engine that can disturb the engine performance.
v. Use stock engine specification to make sure the different result obtained is only from the combustion chamber design and not influence by any or others factors.

5.3 Project Potential

Based on the research, the study finding can be applied on the organization that make the engine for daily and racing use based on the combustion design. This will help the teams to develop and improve their engine to be more efficient and gain more power even a little change. Sometimes, this simple thing was not emphasized from certain reseachers that research and development for their engine. Although its just a bit of improvement maybe it can give the engine at the highest performance and delivers a good power output. Then, for the two-stroke engine that has been used the conical design can change the combustion chamber to the hemispherical design that can give a good engine power at variable RPM and produce the lower emission to the surrounding especially for daily use engine.

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APPENDICES

APPENDIX A Project gantt chart.

Project Gantt Chart				**PSM 1: Year 3 semester 2 (2020/2021)**													
Bill.	Task	%Progress	Assigned to	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**
1	Chapter 1 (Introduction)																
2	Research background study, objective, and problem statement.	**100**	**Student**														
3	Scope of research brainstorming.	**100**	**Student**														
4	Chapter 2 (literature review)																
5	Introduction of two-stroke engine concept.	**100**	**Student**														
6	Engine component and combustion chamber design research.	**100**	**Student**									Mid Term Break					
7	The study of combustion chamber design performance and emission.	**100**	**Student**														
8	Chapter 3 (methodology)																
9	Introduction, flow chart and Gantt chart.	**100**	**Student**														
10	Experiment layout and equipment.	**100**	**Student**														
11	Result analysis and expectation.	**100**	**Student**														
12	PSM 1 Full report submission.	**100**	**Student**														

Project Gantt Chart				**PSM 2: Year 4 semester 1 (2021/2022)**													
Bill.	Task	%Progress	Assigned to	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**
1	Chapter 3 (methodology)											Mid Term Break					
2	Cylinder head machining	**100**	**Student**														
3	Dyno testing	**100**	**Student**														
4	Chapter 4 (result & discussion)	**100**	**Student**														
5	Introduction	**100**	**Student**														
6	Testing result analysis	**100**	**Student**														
7	Graph analysis	**100**	**Student**														
8	Discussion	**100**	**Student**														
9	Chapter 5 (conclusion & recommendation)	**100**	**Student**														
10	Conclusion	**100**	**Student**														
11	Recommendation & Project potential	**100**	**Student**														
12	PSM 2 Full report submission.	**100**	**Student**														

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by iqmal suhaimi

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