EVALUATION OF RON FUELS PERFORMANCE IN MALAYSIAN MARKET

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled “Evaluation of RON Fuels Performance in Malaysian Market” is the result of my own work except as cited in the references

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Date	: 24/5/2017

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive).

Signature :. ....

Name of Supervisor : Associate Professor Dr. Noreffendy Bin Tamaldin

Date : ....

DEDICATION

I dedicate this thesis to my beloved family, a respected supervisor, lecturers, assistant engineers and my friends. Thanks for everything.

ABSTRACT

Nowadays people still does not fully understand about to choose the fuel to fill in their car where the questions arise what are the best fuel grade or type of fuel brands because nowadays, many of fuel brands and grades appeared in our market. The goal of this research to analyse the fuel properties, performance of engine and emission level. In this research, fuels that have been used were PETRONAS as a baseline and were compared to SHELL and PETRON fuels. For fuel properties, the test are divided by two experiment such as bomb calorimeter test and hydrometer test. Engine performance test was performed by using engine dynamometer while emission level test was conducted by using portable gas exhaust analyzer. Next, the result of the experiments will indicate the graph of comparison of fuel properties, engine performance and emission level. For fuel properties test were determine the density of fuel and energy content as a heat of combustion of fuel. Besides, the engine performance test were collected data of power, torque and brake specific fuel consumption to be analysed. This emission test were running at the same time with engine performance test. So, the composition that tested and analysed for this research are carbon monoxide, carbon dioxide and hydrocarbon. After all the experiment were completely done, the result were collected and ready to be analysed. The result indicate the better performance produced between RON 95 and RON 97 fuels is RON 97. While, the comparison of RON 95 between fuels brands show PETRONAS 95 produced highest performance in term of highest value of power and torque. For RON 97, PETRONAS 97 produced the best performance between SHELL 97 and PETRON 97 also in term of power and torque produced. Further study can be carry out in detail to achieve the better result of engine performance and emission level.

.

ABSTRAK

Pada masa kini orang ramai masih tidak memahami sepenuhnya untuk memilih bahan api untuk mengisi ke dalam kereta mereka, di mana timbul persoalan apakah gred bahan api terbaik atau jenis jenama bahan api yang terbaik kerana pada masa kini, banyak jenama bahan api dan gred muncul dalam pasaran kita. Matlamat kajian ini untuk menganalisis sifat-sifat bahan api, prestasi enjin dan tahap pelepasan gas ekzos. Dalam kajian ini, bahan api yang telah digunakan adalah PETRONAS sebagai garis panduan dan dibandingkan dengan bahan api SHELL dan PETRON. Bagi sifat-sifat bahan api, ujian dibahagikan kepaada dua bentuk seperti ujian kalorimeter bom dan ujian hidrometer. Bagi ujian prestasi enjin pula dijalankan menggunakan enjin dinamometer manakala ujian tahap pelepasan gas ekzos telah dijalankan dengan menggunakan alat mudah alih penganalisa gas ekzos. Seterusnya, hasil daripada eksperimen akan menunjukkan graf perbandingan antara sifat-sifat bahan api, prestasi enjin dan tahap pelepasan gas ekzos. Untuk ujian sifat-sifat bahan api adalah menentukan ketumpatan bahan api dan kandungan tenaga sebagai haba pembakaran bahan api. Di samping itu, ujian prestasi enjin mengumpulkan data kuasa, tork dan brek penggunaan bahan api tertentu untuk dianalisis. Ujian tahap pelepasan gas ekzos telah berjalan pada masa yang sama dengan ujian prestasi enjin. Jadi, komposisi yang diuji dan dianalisis dalam kajian ini adalah karbon monoksida, karbon dioksida dan hidrokarbon. Selepas semua kajian ini telah sempurna dilakukan, hasilnya telah dikumpulkan dan bersedia untuk dianalisis. Berdasarkan kajian, prestasi terbaik yang dihasilkan oleh bahan api RON 95 dan RON 97 menunjukkan RON 97 adalah bahan api yang terbaik dari segi prestasi enjin. Manakala, bagi perbandingan antara bahan api RON 95 jenama PETRONAS 95 menghasilkan prestasi yang terbaik dari segi nilai kuasa dan tork. Bagi bahan api RON 97 pula, PETRONAS 97 mempamerkan prestasi yang terbaik berbanding SHELL 97 dan PETRON 97 dari segi kuasa dan tork yang dihasilkan. Kajian lanjut boleh dijalankan secara terperinci untuk mencapai hasil yang lebih baik dari segi prestasi enjin dan tahap pelepasan gas ekzos.

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LIST OF ABBREVIATION

RON	Research Octane Number
RPM	Revolution Per Minutes
C.R	Compression Ratio
AKI	Anti Knock Index
CO	Carbon Monoxide
CO_2	Carbon Dioxide
HC	Hydrocarbon
FTIR	Fourier Transform Infrared Spectrophotometer
FKM	Fakulti Kejuruteraan Mekanikal

CHAPTER 1

INTRODUCTION

1.1 Background of the study

The Research Octane Number (RON) is a number that is being assigned to various grades of fuel to present its capacity to oppose auto-ignition or known as knocking. RON is dictated by running the fuel in a test engine with a variable compression ratio under controlled condition, and the outcome is contrast with mixture of iso-octane and n-heptane. As such, it is a rating used to quantify an fuel knocking resistance in spark-ignition engines. The lower of RON the less easier it turn for fuels to ignite in engine. (Tamaldin N., 2012).

Below are the several kind of petrol fuel:

a) Unleaded Petrol (ULP)
Unleaded Petrol or ULP has a Research Octane Number (RON) of between 91 and 93. Vehicles that use ULP operates with a catalytic converter because of the emitted gasses from exhaust are too high.

b) Premium Unleaded Petrol (PULP)
This premium petrol is a special blend of petrol with a higher octane rating which can produce higher engine power. So it gives more performance to the vehicle as well as knock-free performance and assisting the vehicle to run at its optimum. PULP has a Research Octane Number (RON) of 95 or 96.

c) Ultra Premium Unleaded Petrol (UPLUP)

Ultra means ultimate or it is a fuel have high octane unleaded fuel that maximizes engine performance. The fuel burns cleanly as well as producing less pollution. UPULP which has a RON of 98 commonly recommended for imported high performance vehicles.

Nowadays, in our market, there are two types of fuel RON which are usually used by the Malaysian namely RON 95 and RON 97. A couple of years ago, government had introduced RON 95 fuel in our country because of the global fuel price increase sharply within short period of time. RON 97 fuel still remains in our market with a higher price than RON 95. The government will follow the development in the market prices of product cost for each time and currency exchange rate to determine the retail prices of petrol for the consecutive months.

People prefer the RON 95 fuels to be filled in their vehicles due to lowest price but questions arise about the performance of engine and fuel consumptions. There are so many rumours and speculative argument all over Malaysia about the exact short term, medium term and long term impact of using this lower RON grade fuel to the vehicle. Air pollution is one of the most dangerous environmental problems all over the globe. Continuously increasing use of fuel by the vehicles will give the poisoned emission to the surrounding. So, nowadays peoples are searching to use low emission product of fuel but have high performance. Manufacturers compete to produce new technology of fuel that gives the low emission.

This project was initiated to provide some insight of the engine performance in term of Power, Torque, Fuel consumption and emission produced by using different RON grade fuel using engine dynamometer and other equipment. The engine performance of vehicles will be analysed the graph of performance after fuel test using an engine dynamometer. Emission test will conduct using portable combustion analyzer, and the data will be analysed to decide which type of fuel RON and brands gives higher performance and less emission level.

1.2 Problem Statement

The general public nowadays still does not fully understand about to choice of fuel in their car between RON 95 and RON 97, which one will better deliver engine performance and also fuel consumption. There have been claims that RON 97 fuels performs than RON 95 fuels, and also helps clean engine components better. Some also said that the emission gasses output from a vehicle also affected by using different types of RON fuel grades. Therefore, the problem statements for this project are:

I. The actual content and detail composition of the RON 95 and RON 97 fuels between one manufacturer and another which is trade secret.
II. The effect of different of RON fuel grades and different brands to the vehicle remain unknown to the public.
III. The vehicle performance (power, torque, brake specific fuel consumption) resulting from this RON grades and fuel brands also not fully understood.
IV. Emission level produced from different RON grade and fuel brands also varies.

1.3 Objectives

Below are the objectives for this project:

I. To study the various of RON fuel properties in Malaysian market.

II. To compare the performance of engine with different types of RON fuel grades and brands (power, torque, brake specific fuel consumption).

III. To compare the emission level from vehicle by using different types of RON fuel grades and brands.

1.4 Project Scope and Limitations

The scopes of this project are:

I. The properties of petrol fuel that have been chosen to study are density and energy content.

II. The analysis of the performance of engine from the graph of performance (power, torque and brake specific fuel consumption) by using engine dynamometer.

III. The analysis of the amount of emission gasses produced by different type of RON fuel grades and brands using portable gas exhaust analyzer.

IV. Using two types of RON which RON 95 & RON 97 from three types of fuel producer which are Petronas, Shell, and Petron.

CHAPTER 2

LITERATURE RIVIEW

2.1 Introduction

Summary of the sources related to the research include about the fuel for instance research octane number and other things about the gasoline. In this section, will show how the theory that related to this project such as research octane number, internal combustion engine and about emission. This section also will show the success result and methods of other research which related to this project.

2.2 Research Octane Number (RON)

The octane number of a fuel describes how well it will or will not self ignite. The numerical scale is set by testing fuels. The fuel at question is compared to other fuels that have set standards. One fuel that is used for the test is isooctane (2,2,4 trimethylpentane), which is given the octane number (ON) of 100. The higher the octane number of the fuel the less likely it will self-ignite. In SI engines self-ignition will occur when the fuel ignites before the use of the spark due to high temperatures. When self-ignition occurs in SI engines pressure pulses are generated. This high pressure causes damage to the engine. This activity of self-ignition is called knock. Engines with low compression ratios can use low octane fuels since the temperatures and pressures are lower. High compression engines must use high octane fuel to avoid self-ignition and knock. (Faizal, 2009)

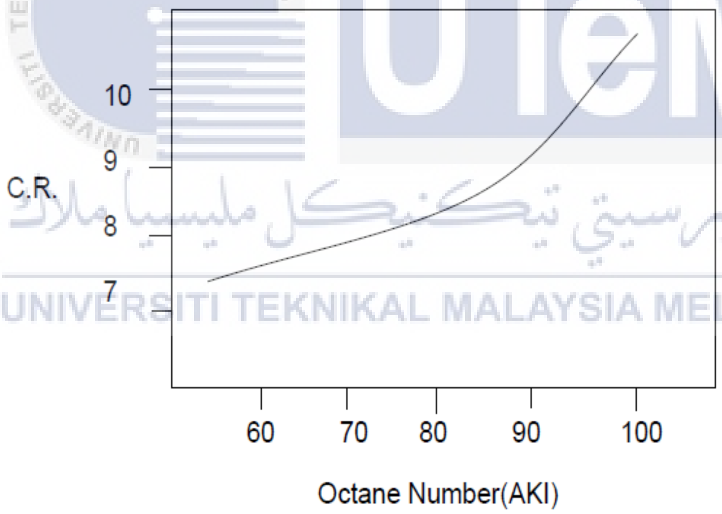


Figure 2.1: Graph of Compression ratio vs Octane number (Salaza , 1998)

Fuels that were used earlier had low octane numbers so therefore engines with low compression ratios were used. As technology advanced the engine design advanced. Engines were designed with higher compression ratios so higher pressures and temperatures were attained. Fuel had to be manufactured to have higher octane numbers. The structure of the fuel depicts the value of the octane number. For example hydrocarbon components that has long chains have low ON. On the other hand components with more side chains have higher ON. Also fuel components with ring molecules have high ON.

The combustion process involves the chemical reaction of hydrocarbon fuel with oxygen to produce water vapor and CO_2. The maximum amount of chemical energy from the hydrocarbon fuel is when it reacts with stoichiometric oxygen. The meaning of stoichiometric oxygen is defined as the amount of oxygen that is needed to convert all of the carbon in the fuel to CO_2 and all of the hydrogen to H_2O. The simplest chemical reaction using the simplest hydrocarbon with stoichiometric oxygen is:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

For this reaction to be complete it would take two moles of oxygen to react with one mole of methane to produce one mole of carbon dioxide and two moles of water vapor. The hydrocarbon fuel used in engines is not a simple fuel like methane but rather consists of isooctane and various additives. The chemical reaction involving isooctane and oxygen is:

$$C_8H_{18} + 12{:}5O_2 \longrightarrow 8CO_2 + 9H_2O$$

The above two chemical reactions involve the reaction of a hydrocarbon with oxygen. Since it would be extremely expensive to use pure oxygen the atmosphere is used as a rich source of oxygen. The hydrocarbon reacts with air which is composed of many substances. Nitrogen and oxygen are the two most found substances in air with a nitrogen composition of 78%, by mole, and oxygen composition of 21%. The stoichiometric combustion of isooctane with air is then:

$$C_8H_{18} + 12{:}5O_2 + 12{:}5(3{:}76)N_2 \longrightarrow 8CO_2 + 9H_2O + 12{:}5(3{:}76)N_2$$

Combustion can occur with an either lean or rich mixture. If the mixture is for example 150% of stoichiometric then there will be an excess amount of air and the products will involve excess oxygen. (Salaza, 1998)

2.3 Internal Combustion Engine (ICE)

Internal combustion engines are seen every day in automobiles, trucks, and buses. The name internal combustion refers also to gas turbines except that the name is usually applied to reciprocating internal combustion (IC) engines like the ones found in everyday automobiles. There are basically two types of IC ignition engines, those which need a spark plug, and those that rely on compression of a fluid. Spark ignition engines take a mixture of fuel and air, compress it, and ignite it using a spark plug. (Ramachandra, 2016)

The piston cylinder engine is basically a crank-slider mechanism, where the slider is the piston in this case. The piston is moved up and down by the rotary motion of the two arms or links. The crankshaft rotates which makes the two links rotate. The piston is encapsulated within a combustion chamber. The bore is the diameter of the chamber. The valves on top represent induction and exhaust valves necessary for the intake of an air-fuel mixture and exhaust of chamber residuals. In a spark ignition engine a spark plug is required to transfer an electrical discharge to ignite the mixture.

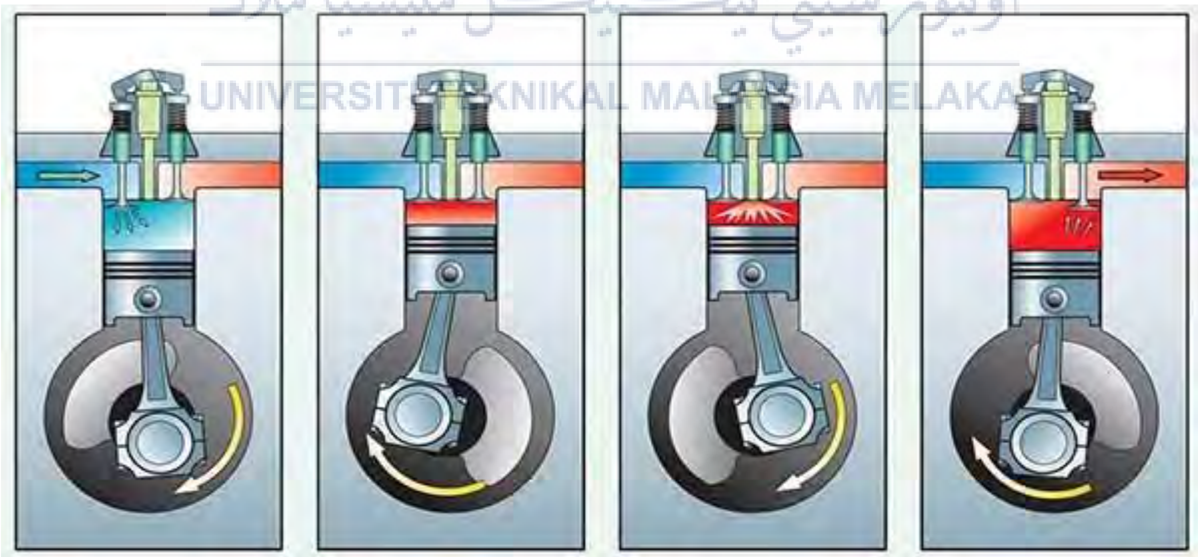


Figure 2.2: Four stroke engine cycle (John, 2016)

2.3.1 First Stroke: Induction Stroke or Intake Stroke

This process starts with the carburettor or the electronic fuel injection system flowing air into the intake manifold. While the air is passing through the carburettor or electronic fuel injection system, gasoline is added into the air creating a fuel mixture. As the fuel mixture passes through the intake manifold, it is separated from one collective port to individual ports for each of the cylinders. The fuel mixture then progresses into the cylinder heads where an intake valve opens to allow the incoming mixture to flow to the cylinder chamber, while the cylinder head's exhaust valve is closed so the mixture cannot escape from the chamber. During this stroke, the piston starts at the top of the cylinder moving backwards towards the bottom of the cylinder creating a vacuum which creates a vacuum pulling in the fuel mixture.

2.3.2 Second Stroke: Compression Stroke

During this cycle, both the intake and exhaust valves are closed, and the piston moves from the bottom of the cylinder chamber to the top, thereby compressing the fuel mixture. The stroke ends when a spark is ignited to initiate the combustion of the fuel mixture.

2.3.3 Third Stroke: Expansion Stroke

During the expansion stroke, the two valves in the cylinder head remain closed thereby containing the expansion of the ignited fuel mixture inside the cylinder chamber. The expanded gas propels the piston from the top to the bottom of the cylinder, providing the torque to drive the connecting mechanism.

2.3.4 Fourth Stroke: Exhaust Stroke

During this stroke, the combusted fuel mixture is forced from the cylinder chamber through the now open exhaust valve by the piston moving from the bottom to the top of the cylinder chamber. The exhaust gas flows into the cylinder head where it continues until it is discharged from the engine through an exhaust manifold pipe.

The four cycle process is assisted by several components. As the pistons reciprocate, they drive or are driven through connecting rods through the crank shaft, which in turn either drives or is drive by the flywheel. It is through the momentum generated in the revolving flywheel that the pistons are propelled in the first, second, and forth strokes of the Otto cycle and through the moment of inertia, which allows for smooth operation. Lastly, the camshaft, driven by a linkage connected to the crankshaft, opens and closes the intake and exhaust valves. Further additions to the engine, such as fuel additives and forced induction systems can provide further power gains from the engine, thereby improving on Nikolaus August Otto's innovations. (Balich et al. , 2004)

2.4 Engine Parameter

In this research, the engine parameters have been determined were brake power, brake torque and brake specific fuel consumption. These three parameters were determined by using engine performance test which is engine dynamometer. The tests were conducted by using different type of fuel.

2.4.1 Brake Power

The mechanical brake power of the engine is the product of the torque on the crankshaft and the rotational speed of the crankshaft.

$$N_b = T\omega$$

$$N_b = 2\pi T n$$

Where

N_b = Brake power (Watt)

T = Torque (Nm)

ω = Engine speed (rad/sec)

n = Engine speed (rev/sec)

1kW = 1.36 HP

2.4.2 Engine Torque

Engine torque is the twisting or turning effort that the engine applies through the crankshaft. Engine torque can be found from the following relation:

$$T_c = \frac{N_{bc}}{2\pi n}$$

Where

T_c = Engine torque (Nm)

N_{bc} = Engine brake power (Watt)

n = Engine speed (rev/sec)

2.4.3 Brake Specific Fuel Consumption (BSFC)

The brake specific fuel consumption is a measure of efficiency which indicates the amount of fuel that an engine consumes for the work it produces and is calculated using the below relation.

$$g_b = \frac{G_f}{N_{bc}}$$

Where

g_b = Brake specific fuel consumption (g/kW)

G_f = Rate of fuel consumption (g/hr)

N_{bc} = Corrected engine brake horsepower (HP)

2.5 Engine dynamometer

There is a wide variety of requirements for the test of a vehicle's combustion engine ranging from emissions and fuel economy, durability, noise and vibration optimization in addition to the high performance and responsiveness for acceleration/deceleration. Some of these targets often work against each other a large number of engine control parameters need to be set to ensure that the engine performance is optimal in consideration of the overall balance between each performance target. Therefore, the development of vehicle cannot be realized without engine testing.

A dynamometer, or dyno for short, is a device for measuring force moment of force (torque), or power. For example, the power produced by an engine, motor or other rotating prime mover can be calculated by simultaneously measuring torque and rotational speed (rpm). A dynamometer can also be used to determine the torque and power required to operate a driven machine such as a pump. In that case, motoring or driving dynamometer is used. A dynamometer that is designed to be driven is called an absorption or passive dynamometer. A dynamometer that can either drive or absorb is called a universal or active dynamometer.

Engine power is calculated from the product of rotating speed and the braking or driving torque seen by the dynamometer. For the measurement of the engine's mechanical parasitic losses or for the simulation of road load dynamics, dynamometers should not only be able to absorb the engine's power output but also to drive the engine. (Tominaga , 2010)

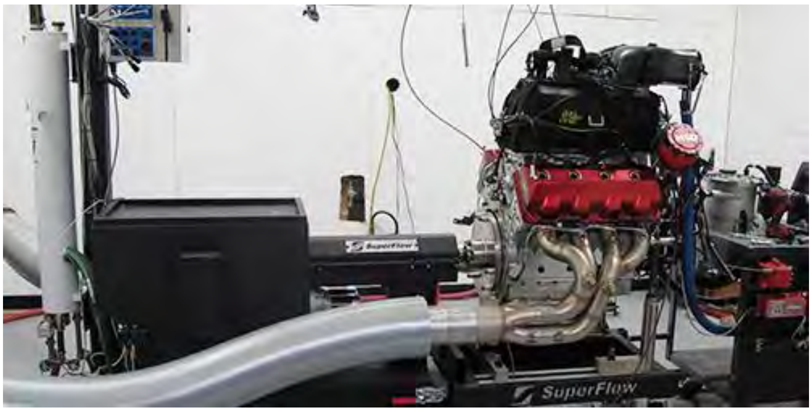
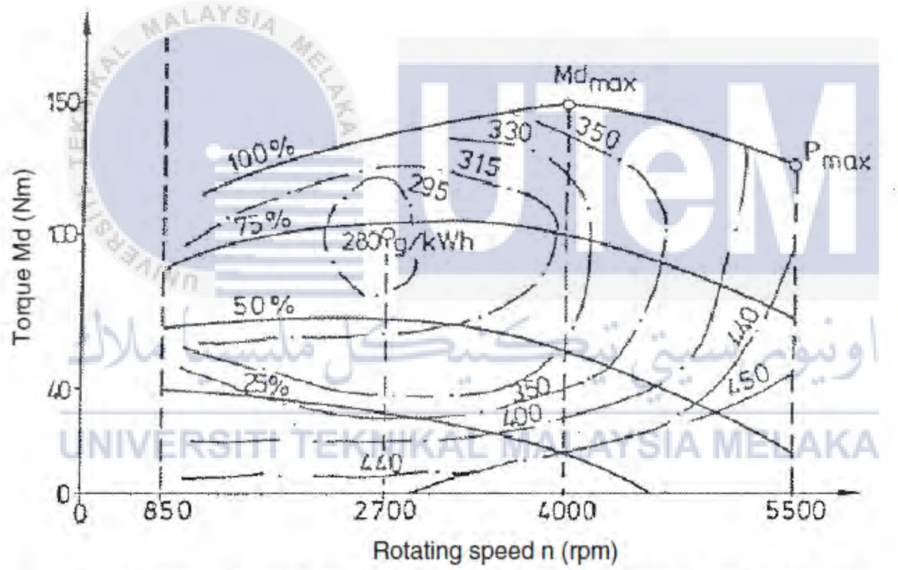


Figure 2.3: Example of Engine dynamometer.(Sterling Performance , 2016)

The process of engine development requires data acquired at many measuring points in various conditions to establish the engine's characteristics. Sufficient time should be given to each test condition in order that the measurement is made when the engine has reached a thermally stable state; this leads to an extensive period only for data collection. This has driven the development and improvement of automation systems that control test conditions and record key data. Normally automation system can measure, collect and record emission gas component concentrations, fuel economy, temperature, pressure and other measurement items. It also allows operation in prescribed modes required by emission gas measurement legislation and fuel economy measurement.



Performance Range : Position of equivalent throttle position related to the curve of "speed versus torque" and specific fuel consumption - shown as long and short dash line

g/kWh : Fuel consumption rate (Fuel consumption weight/hr with 1kW)

Md max = Maximum torque, Pmax = Maximum power output

Figure 2.4: Engine torque characteristic curve. (Tominaga , 2010)

2.5.1 Principle of Dynamometer operation

Engine dynamometer which the engine has to be removed from the car and directly connected to the testing mechanism. The testing mechanism then uses either hydraulic fluid or water to create resistance to the engine's spinning force. This resistance is continued until the engine's maximum turning force is measured at every RPM, giving the tester an accurate reading of the engine's torque. A computer or the tester can then use the same equations to derive a horsepower number for the engine.

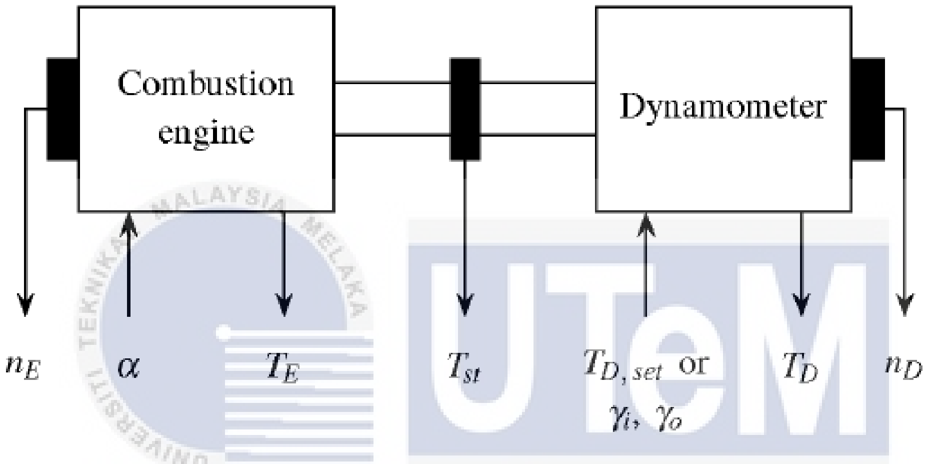


Figure 2.5: Setup of the Engine dynamometer. (Passenbrunner T. E., 2011)

A dynamometer consists of an absorption unit and usually includes a means for measuring engine parameters for instance torque and rotational speed. An absorption unit consists of some type of rotor in housing. The rotor is coupled to the engine and it is free to rotate at whatever speed is required for the test. Some means is provided to develop a braking torque between dynamometer's rotor and housing. The means for developing torque can be frictional, hydraulic, electromagnetic and others according to the type of absorption unit.

2.6 Emission

The combustion of gasoline and diesel fuel in vehicle engines produces emissions of several potentially harmful substances. These emissions are not solely the result of the combustion process, nor do they come only from the tailpipe of the vehicle; rather, they result from a combination of the engine design and the fuel characteristics. Also apparent is that evaporative emissions from refuelling, spills onto heated engine parts, and so on can equal emissions from the tailpipe. The primary emissions from motor vehicles come in two predominant forms which are major gaseous and particulate air pollutants, which can be found in relatively high amounts in the atmosphere, and called air toxics, which usually are found in lower amounts in the atmosphere but can have important health implications. The gaseous and particulate pollutants to which motor vehicles contribute include carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbons (HC).

2.6.1 Carbon monoxide (CO)

Carbon monoxide (CO) is most concentrated with fuel-rich mixtures, as there will be incomplete combustion, With lean mixtures, CO is always present owing to dissociation, hut the concentration reduces with reducing combustion temperatures, Hydrocarbon (HC) emissions arc reduced by excess air (fuel-lean mixtures) until the reduced flammability of the mixtures causes a net increase in HC emissions. These emissions originate from the flame quench layer where the flame is extinguished by cold boundaries regions like piston ring grooves can be particularly important. The outer edge of the quench can also contribute to the CO and aldehyde emissions. (W. Ballich, 2004)

2.6.2 Carbon dioxide (CO_2)

Carbon dioxide is a product of perfect combustion in the gasoline engine. The effect of the carbon dioxide to the environment is give the greenhouse effect to the earth and increase the global warming. The more carbon dioxide produce the higher the temperature of the environment. The largest human source of carbon dioxide emissions is from the combustion of fossil fuels. This produces 87% of human carbon dioxide emissions. Burning these fuels releases energy which is most commonly turned into heat, electricity or power for transportation. Some examples of where they are used are in power plants, cars, planes and industrial facilities. In 2011, fossil fuel use created 33.2 billion tonnes of carbon dioxide emissions worldwide. (Le Quere, 2012)

2.6.3 Hydrocarbons

Many hydrocarbons have been classified as carcinogens, which is why their emissions are regulated and closely monitored in new engine designs. To claim hydrocarbons as a complete by-product of the combustion reaction is mildly misleading. Hydrocarbons themselves can be better defined as unburned fuel. If some portion of the gasoline does not combust when the spark ignites the fuel in the cylinder, it passes out through the exhaust unburned. In the combustion process, passing hydrocarbons through the exhaust can result from several actions. If the ignition is improperly timed and is ignited before or after the desired angle from top dead center, the reaction will not occur stoichiometrically. Also, non-stoichiometric fuel mixture or a defective catalytic converter can result in high hydrocarbon content. (Moore, 2013)

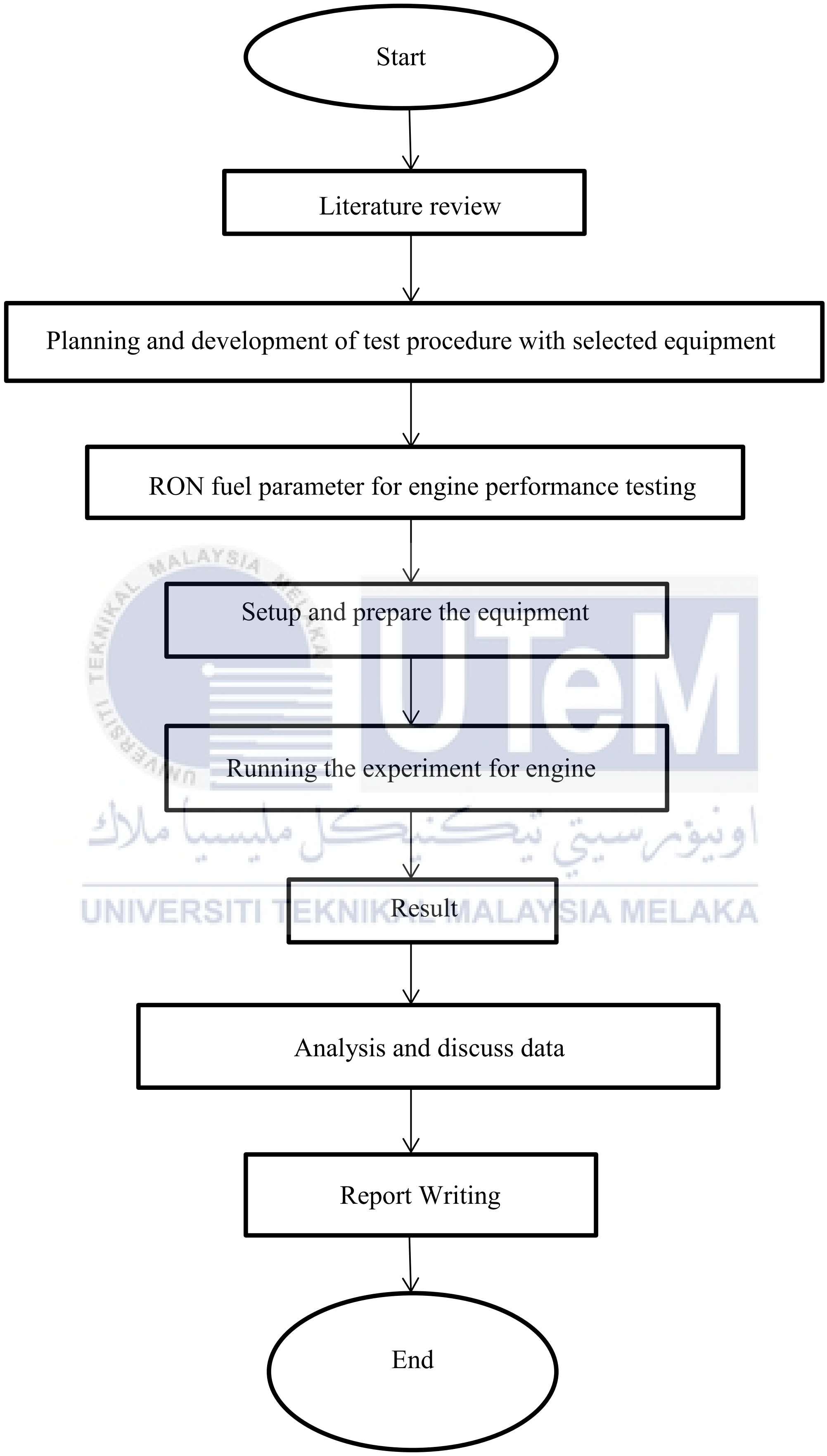
CHAPTER 3

METHODOLOGY

3.1 Introduction

This section describes the rational for the application of specific procedures or techniques used to identify, select, and analyse information applied to understanding the research, thereby allowing conducting the experiment and getting the exact results. The method must be appropriate to fulfilling the overall aims of the study. For example, in this section will be discuss how the experiments will carry out and why the methods can be chosen.

3.2 Flowchart of PSM



3.3 Experimental research

In this research, the experimental research is divided by three parts of experiments. For the first part, we will carry out the testing of the properties of the RON fuel. Secondly, we will conduct the engine performance testing using the engine dynamometer to collect the several data. Lastly, we will perform the engine emission testing using the emission analyser to get the percentage of the compound in the exhaust emission.

3.3.1 RON fuel properties testing

This experiment will be conduct using of two types of the RON fuel grades that available in Malaysia market which are RON 97 and RON 95. For these two types of the RON fuel grades, the three fuel brands are chosen to use as a samples of the experiments. The three types of fuel brands are PETRONAS, SHELL and PETRON. In this part, two types of experiment will be carry out using two equipment, for instance Bomb Calorimeter and Hydrometer.

3.3.1.1Bomb Calorimeter

Calorimetry is the science of measuring quantities of heat, as distinct from .In this experiment we are concerned only with oxygen bomb calorimeters, which are the standard instruments for measuring calorific values of liquid combustible samples. The calorific value (heat of combustion) of a sample may be broadly defined as the number of heat units liberated by a unit mass of a sample when burned with oxygen in an enclosure of constant volume. In this reaction the sample and the oxygen are initially at the same temperature and the products of combustion are cooled to within a few degrees of the initial temperature also the water vapor formed by the combustion is condensed to the liquid state. A more exact definition would specify the temperature at which the reaction begins and ends.

However, the change in the heat of combustion with possible variations in the initial temperature is so small that this specification is not necessary. Also, the initial and final temperatures are not the same differing by the amount of temperature rise in the calorimeter but the effect of this difference is small and usually it is neglected. Thus the term calorific value (or heat of combustion) as measured in a bomb calorimeter denotes the heat liberated by the combustion of all carbon and hydrogen with oxygen to form carbon dioxide and water, including the heat liberated by the oxidation of other elements such as sulphur which may be present in the sample.

Figure 3.1: Example of the Bomb calorimeter in FKM's Lab

3.3.1.1.1 Working principles of the Bomb Calorimeter:

Heats of combustion as determined in an oxygen bomb calorimeter are measured by a substitution procedure in which the heat obtained from the sample is compared with the heat obtained from combustion of a similar amount of RON fuel whose calorific value is known. These measurements are obtained by burning a representative sample in a high pressure oxygen atmosphere within a metal pressure vessel or bomb. The energy released by this combustion is absorbed within the calorimeter and the resulting temperature change within the absorbing medium is noted. The heat of combustion of the sample is then calculated by multiplying the temperature rise in the calorimeter by a previously determined energy equivalent or heat capacity determined from previous tests with a standardizing material.

3.3.1.1.2 Equipment of Bomb calorimeter:

1. Basic device C 200
2. Decomposition vessel C 5010
3. Ignition adaptor
4. Attachment set
5. Table power supply
6. Plug
7. Operating instructions
8. Water emptying hose (length: 1 m)
9. Oxygen station C 248
10. Measuring cup (2 L)

Figure 3.2: Equipment of the Bomb calorimeter.

3.3.1.1.3 Procedure of Bomb calorimeter:

Figure 3.3: Water bath has a digital or analogue interface to allow user set the temperatures.

PART A: Preparation of water bath.

1. The distilled water was filled into the water bath container until the container full.
2. The temperature was set up below the 25 ºC and start the water bath until the temperature of the distilled water dropped.
3. When the temperature of the distilled water is below 25 ºC, the distilled water was transferred to the calorimeter container using measuring cup.

Figure 3.4: Digital analytical balance to measure the sample weight

PART B: Preparation of the fuel as a sample.

1. The crucible was ensured that has no dirt and cleaned before filled up the fuel.
2. The fuel was filled into the crucible and measures the weight of the fuel using digital analytical balance.
3. The crucible which filled with fuel was carrying out and the crucible was put into the decomposition vessel.

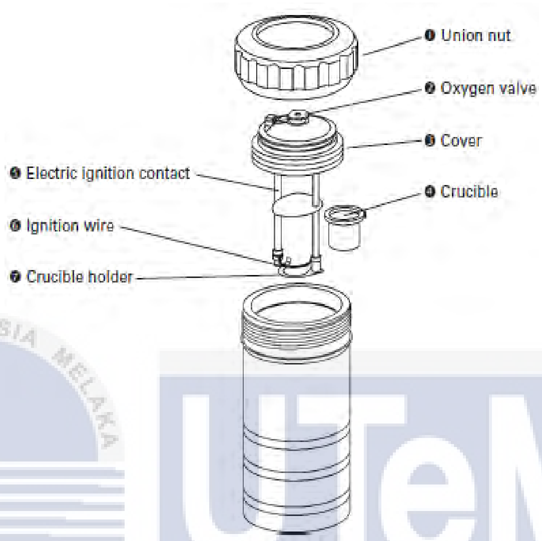


Figure 3.5: Parts of the decomposition vessel

PART C: Preparation of the decomposition vessel

1. The cover of the decomposition vessel was removed.
2. The ignition wire was attached to the electric ignition contact.
3. A cotton thread was attached to the centre of the ignition wire using a loop.
4. The crucible which filled with fuel was inserted into the crucible holder.
5. The cotton thread was aligned using tweezers so that it hangs inside the crucible and was immersed in the fuel. This will ensure that the burning thread ignites the sample during the ignition process.
6. The cover of the decomposition vessel was placed on to the lower section and the cover was pushed down until it presses against the stop piece in the lower section. Then, the union nut placed onto the lower section and the cover tightens by hand.
7. The decomposition vessel was filled up with oxygen gas using oxygen station.
8. When the oxygen gas was filled into vessel, the ignition adaptor was slide onto the vessel.

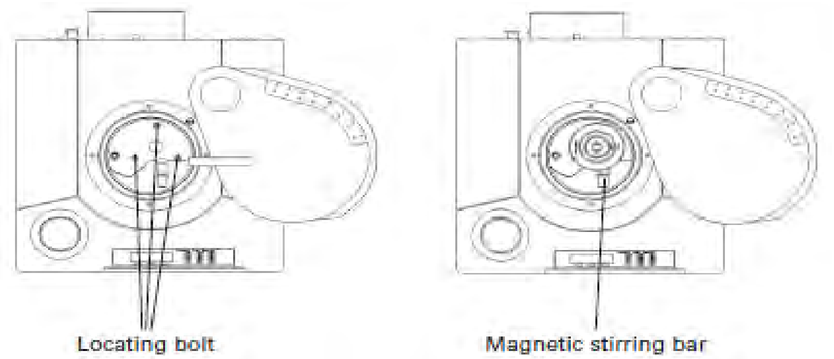


Figure 3.6: Top view of the calorimeter when the cover is opened

PART D: Set up the experiments

1. The calorimeter cover is opened by hand by lifting the cover by the gripping groove and raising it until it automatically swivels to the right and lock in position.
2. The decomposition vessel is placed into the inner vessel of calorimeter. The decomposition vessel must be placed between the three locating bolts.
3. Pour the 2 L distilled water into the tank using the measuring cup.
4. When the calorimeter is in waiting mode, the prepare measurement was selected at the menu screen.
5. The weight of the sample is entered in the marked “Einwaage” (weighted sample) field with an accuracy of 0.0001 g using the keyboard.
6. The cover was closed by moving it to the left out of the locking position until it slides down by itself. The decomposition vessel comes into contact with the lighters via the ignition adaptor.
7. The inner vessel was filled with water. The measurement process will begin as soon as it is full.
8. The measurement process is fully automatic for automatic measuring procedures. The result was appeared once the measuring process is complete. The result was recorded.
9. After the result was recorded, the cover of the calorimeter was opened to automatically empty the inner vessel. The decomposition vessel and the ignition adaptor were removed. The tension in the decomposition vessel was release using venting button under a fume hood or venting station.
10. The decomposition vessel was opened and the crucible was checked for signs of incomplete combustion. The test was repeated with other sample.

3.3.1.2 Hydrometer

A hydrometer is an instrument whose function is based on Archimedes principle. This principle states that the hydrometer immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid. The hydrometer measures the weight of the liquid displaced by the volume of the hydrometer.

Hydrometers have been used for hundreds of years to measure the specific gravity or relative density of liquids. They are commonly used for measuring petroleum liquids, for the measurement of saltwater, and for measuring the density of sugar solutions. The specific gravity of a liquid is obtained by floating a hydrometer in the sample of interest and reading the meniscus on the graduated scale. Since the specific gravity of water equals 1.000, liquids lighter than water have a specific gravity below 1.000, and liquids heavier than water have a specific gravity greater than 1.000.

Figure 3.7: Hydrometer in FKM's laboratory

Hydrometers are usually calibrated to be read at one temperature. Density is often 20ºC. If the temperature of the liquid is much different from the hydrometers calibrated temperature, a correction may need to be made. There are two types of temperature corrections. The first is a correction for the hydrometer. A hydrometer will expand in size when hot and will contract when cold. This obviously changes the volume of the hydrometer. If it expands, it floats higher in the liquid and gives an incorrect reading. A minus correction needs to be applied to allow for the change.

This correction is minimal on some hydrometers and quite large on others. It depends on the accuracy of the hydrometer, and what the hydrometer reads. The more accurate the hydrometer, the more important the correction. Density hydrometers may vary by 5 degrees with only a small correction required, whereas a hydrometer will need to be corrected for small changes in temperature. This is true of most hydrometers that read percentage.

3.3.1.2.1 Procedure of hydrometer.

1. The sample is poured into a hydrometer cylinder or appropriate test jar.
2. The sample is ensured that being mixed well.
3. The temperature of the sample is ensured that should be near of the surrounding atmosphere to prevent changes during reading of the scale.
4. The stem of the hydrometer is hold and lowered into the sample to a level close to where it naturally floats and it released.
5. The liquid is make sure at rest and free of bubbles.
6. The scale is read at the meniscus.
7. The result is recorded.

3.3.2 Engine performance test

Engine performance test is define where the engine is testing to identify its performance according to its parameter such as brake specific fuel consumption (bsfc), torque, speed and power. This test also to determine how the fuel is effect to the engine performance and to compare the performance of the fuel. Engine performance test is carried out using the engine dynamometer in our laboratory. The test is performed using several grades of fuel and a few types of fuel brands. The test is conducted to determine which the grade is good and the brand of fuel give highest performance of engine.

3.3.2.1 Engine dynamometer

The use of a dynamometer (dyno) provides a means for testing an electric motor, or engine, in various desired and controlled conditions. Dynos produce measurements of a motor's mechanical force, speed, or power. It is important to have a method to accurately measure the performance of the motors and ensure they operate as desired. This research focuses on the use of dynos to test the engine with different fuel grades brands. The result will show the performance of the engine according to the different fuel grades and brands. Special software is also required to properly run dyno testing. This software allows the user to have complete control over the engine or vehicle parameters via computer. These controls include speed, torque, and horsepower. Dyno software also allows the user to run drive cycle simulations.

Figure 3.8: Dynomite Engine dynamometer.

3.3.2.1.1 Working principles of Engine dynamometer

A typical dynamometer used in automotive industry is the engine dynamometer where it is connected to the crankshaft of the engine. The dynamometer applies the resistance as a load to the engine. The load can be applied by using a variety of brakes for example electric brake, water brake and friction brake. In the system, the dynamometer is seated in bearings, allowing it to rotate. This rotation is prevented by a torque arm with an attached force measuring scale.

As the dynamometer loads the engine, the torque arm experiences a force. This force multiplied by the distance from its center of rotation equals the torque of the engine. With the known torque and angular velocity, the power of the system can be calculated from the product of these two values. The purpose of the engine dynamometer is to examine the engine's performance. There are generally two types of dynamometers.

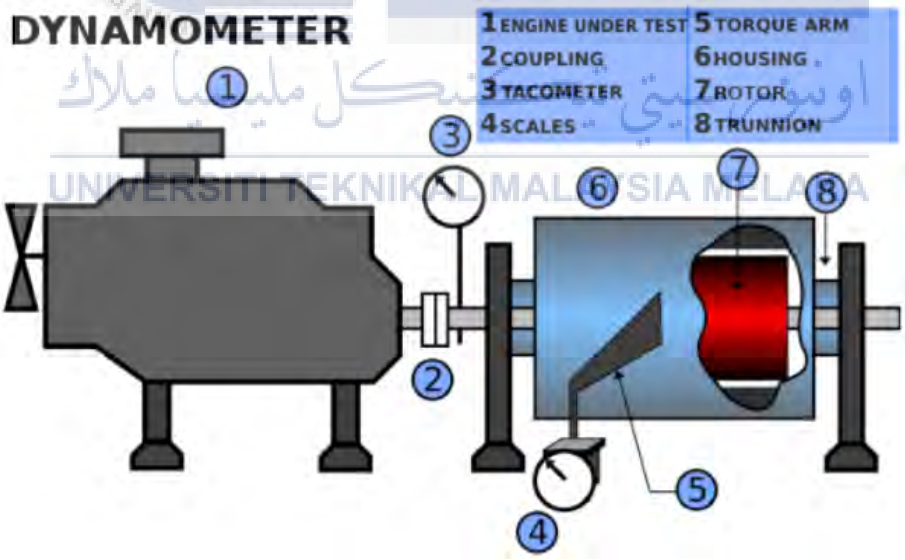


Figure 3.9: Common used dynamometer's schematic (N. Singh, 2016)

3.3.2.1.2 Specification of the test engine:

Table 3.1: Test engine specification.

Brand	**Mitsubishi**
Descriptions	4G92-DOHC
Number of cylinders	4
Total displacement dm^3	1597
Cylinder bore mm	81.0
Piston stroke mm	77.4
Compression ration	11.1
Maximum output	108 kW (147 PS; 145 bhp) @ 7000 rpm
Maximum torque	149 N·m (110 ft·lbf) @ 4500 rpm
Fuel	Petrol

3.3.2.1.3 Procedure of the Engine dynamometer:

1. Dynamometer is checked for calibration and serviceability and prepared for operation
2. The engine is prepared to make sure the engine is in good condition to before start the experiment.
3. All cables are connected to the Data Acquisition System port.
4. The cooling fan is put in front of the engine to prevent it from overheating.
5. The tank is cleared from another fuel.
6. The tank is filled with RON fuel (95 or 97) and different brands.
7. The engine is started and the process of idling starts.
8. After 20 seconds, the test was started and the make sure the throttle is full.
9. The test are performed from 2000 RPM until 6000 RPM.
10. The output data is observed and printed out as same in the software.
11. After the first fuel grade is tested, then the test is repeated with other fuel grade and brands.
12. The data and result is recorded and save in file.
13. Graph of horsepower and torque against engine RPM and fuel ratio against engine RPM are analysed from computer.

3.3.3 Emission test

Emission test is a process where the emission of the engine is tested by the gas analyser to identify the compound in the exhaust gas and to allow the comparable measurement of exhaust emission during engine is operated. For this test, it is conducted by using gas analyser to test the exhaust emission. Each analysing range that may be used during a test mode must have the zero and span responses recorded prior to the start of the test. Only the range used to measure the emissions during the test is required to have its zero and span recorded after the completion of the test. The compound of the exhaust gas is more focused on Hydrocarbon (HC), Carbon Monoxide (CO) and Carbon Dioxide (CO_2). The test engine used is Mitsubishi 4G92 1.6L.

3.3.3.1 Gas analyzer

Gas analyzer is an instrument which is capable of analysing the species of chemical gases is present in the sample. Not only it identifies the species but it also has capability to give measurement value of the quantity which it displays either in numerical form or shows it graphically.

3.3.3.1.1 Gas analyser specification:

Table 3.2: Gas analyser specification.

Type	EMS 5200 Portable Exhaust gas Analyser
Power	10 -16 VDC (110/220 VAC 50/60 Hz optional)
Ranges	1) HC: 0-20,000 ppm High Range 2) CO: 0 - 10% 3) CO2: 0 - 20% 4) O2: 0 - 25% 5) NO: 0 - 5000 ppm (Nitric Oxide)
Preheat times	Less than 5 minutes
Weight	4.5 Kg

Figure 3.10: Exhaust gas analyzer.

3.3.3.1.1 Procedure of Gas analyser:

1. The engine is started to ensure the engine is heated in at least 15 minutes before an emission test.
2. The analyser is switched on and waiting for preheating process.
3. After 15 minutes, the sampling probe is entered into the car exhaust pipe for auto calibration.
4. Then, a method of the measurement for simple driving condition is choose.
5. The button measurement is pressed and the test name is entered.
6. A measurement is recorded while engine running at the dynamometer or in idle condition until the red limit of revolution per minute (rpm).
7. The data is observed and save manually by pressing arrow.
8. The data recorded is print out using printed built in the analyser.
9. Step 1 until 9 is repeated by using different fuel grade (95 & 97) and fuel brand (PETRONAS, SHELL and PETRON).
10. The result of the different fuel grade and brands are compared and discussed.

CHAPTER IV

RESULT AND DISCUSSION

4.0 INTRODUCTION

In this chapter will be covered the result obtain from the experiment which are fuels properties tests, engine performance test and emission test. These kind of experiments are carried out by using different type of RON fuels and manufacturer. All the result will be shown and have an elaboration related to the result.

4.1 FUEL PROPERTIES TEST

In this section, fuel properties test have two kind of experiment to find the density of fuel and heat of combustion of the fuel or energy content of fuel. These two experiment were carried out by using different grades of RON fuel which are RON 95 and 97 from different type of fuel brands such as PETRONAS, SHELL and PETRON. First experiment is to find the heat of combustion of RON fuel. This experiment were carried out by using Bomb Calorimeter. This experiment are conducted in the Chemistry Laboratory of Faculty of Mechanical in UTeM. The experiment of Bomb Calorimeter are conducted for three times per sample to get the average and accurate result.

Second experiment in fuel properties tests is to determine the density of the RON fuel. This experiment are conducted by using the hydrometer. The hydrometer test will function based on Archimedes principle. The hydrometer measures the weight of the liquid displaced by the volume of the hydrometer. In this experiment are carried out by using RON fuel, so to determine the density of RON fuel, the temperature of RON fuel must be at 15°C. This experiment also were conducted for three time to get the average result. Below are the result obtained from the experiments.

4.1.1 Energy Content of RON fuels.

The result of energy content of RON fuel tested are shown in the Table 4.1 below. The data were be repeated three times to get the accurate value. But due the problem of the equipment and machine a few reading cannot be repeated three times. The comparison of the energy content value from RON 95 fuels and RON 97 fuels are shown in the figure 4.1 and 4.2. The comparison are covered between fuel brands.

Table 4.1: Result of the energy content experiment by using Bomb Calorimeter.

No	Fuel Brands	Energy Content (MJ/Kg)							
		RON 95				RON 97			
		1st	2nd	3rd	Average	1st	2nd	3rd	Average
1	PETRONAS	38.290	37.551	38.720	**38.187**	40.540	39.490	-	**40.015**
2	SHELL	40.789	-	-	**40.789**	41.137	-	-	**41.137**
3	PETRON	35.857	34.116	35.344	**35.106**	40.784	-	-	**40.784**

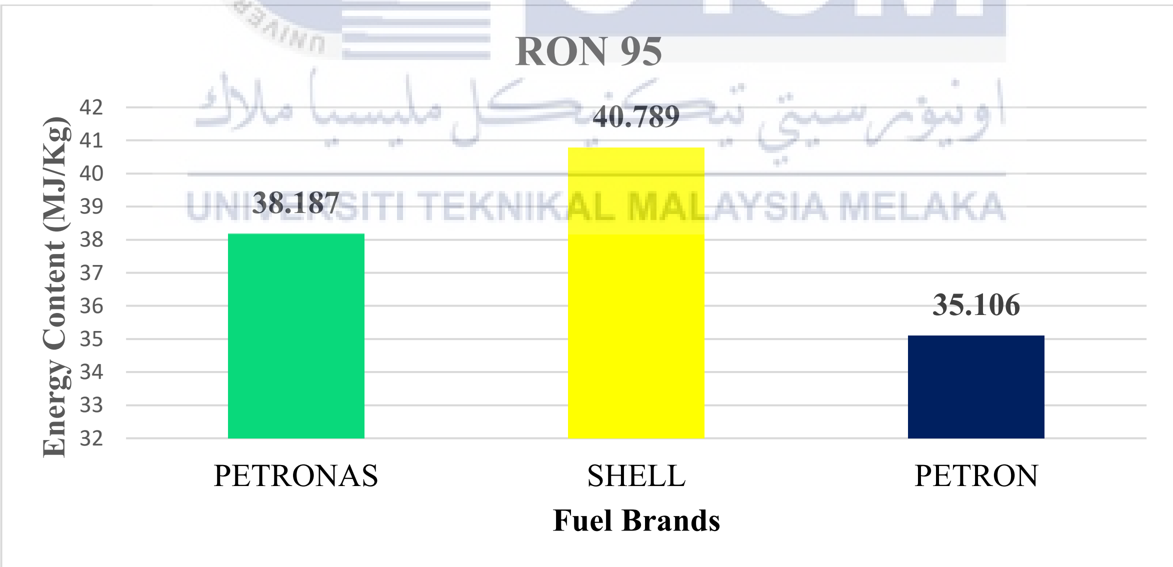


Figure 4.1: The graph of energy content show the comparison of the RON 95 fuel with different brands.

From the graph of energy content that show the comparison of the RON 95 fuel with different type of fuel brands, the highest value of the energy content for RON 95 is SHELL 95 which is 40.789 MJ/Kg followed by the PETRONAS 95 and PETRON 95 which are 38.187 MJ/Kg and 35.106 MJ/Kg respectively. SHELL 95 was proven as the highest value of energy content by experiment of Bomb Calorimeter as shown in Figure. The highest the value of energy content will give highest value of heat combustion which give more energy when combustion especially in internal combustion engine. The lowest value of the energy content is PETRON 95 and it seems the PETRON 95 fuel give the lowest energy when it burn in the combustion engine.

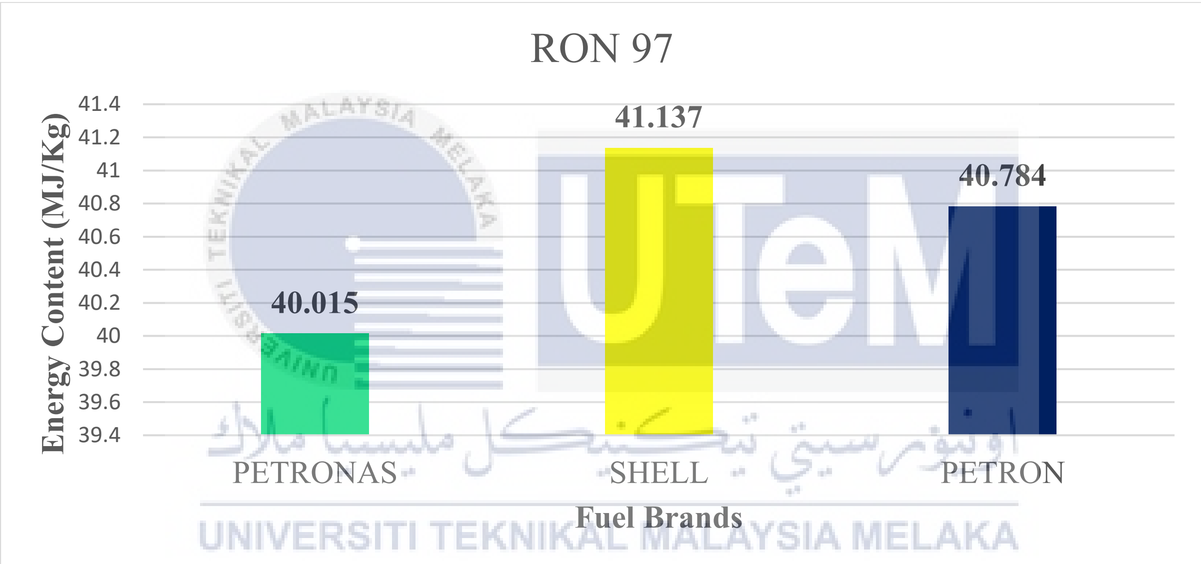


Figure 4.2: The graph show the comparison of energy content of RON 97 with different types of fuel brands

Refer to figure 4.2 above, the graph show the comparison of energy content of RON 97 with different types of fuel brands. The graph show the highest value of energy content on RON 97 is SHELL 97 fuel which is 41.137 followed by PETRON 97 fuel and PETRONAS 97 fuel which are 40.784 and 40.015 respectively. SHELL fuel once again become the highest value of energy content when the SHELL 95 become the highest value of energy content before. SHELL 97 fuel give the highest value of heat when the combustion occurred compared to the PETRON 97 and PETRONAS 97 fuels. For the RON 97 fuel, the lowest value of the energy content is PETRONAS 97 fuel. It means that, PETRONAS 97 fuel was give lowest energy of when it burned in engine combustion.

4.1.2 Density of the RON fuel test.

The equipment that involved in experiment to determine the density of the RON fuel is hydrometer. This experiment were carried out in the FKM's Chemical Laboratory which also were repeated three times for each sample. The result of the density of the RON 95 fuels were tabulated in table while RON 97 fuels in table as shown below.

Table 4.2: The result of the density of RON 95 fuels.

No	**Fuel Brands**	**Fuel Grade**	**Density of fuel (Kg/m^3)**			
			1st	2nd	3rd	**Average**
1	PETRONAS	RON 95	750	750	750	**750**
2	SHELL		745	745	745	**745**
3	PETRON		745	745	745	**745**

Table 4.3: The result of the density of RON 97 fuels.

No	**Fuel Brands**	**Fuel Grade**	**Density of fuel (Kg/m^3)**			
			1st	2nd	3rd	**Average**
1	PETRONAS	RON 97	760	760	760	**760**
2	SHELL		770	770	770	**770**
3	PETRON		750	750	750	**750**

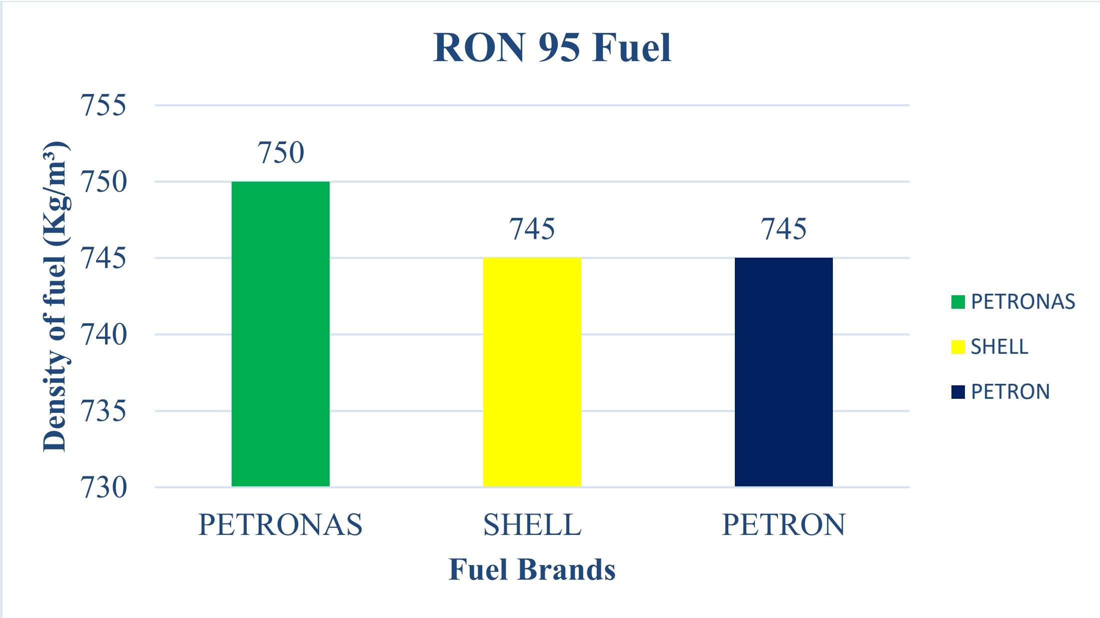


Figure 4.3: The graph show the comparison of the density of RON 95 fuel with different types of brands.

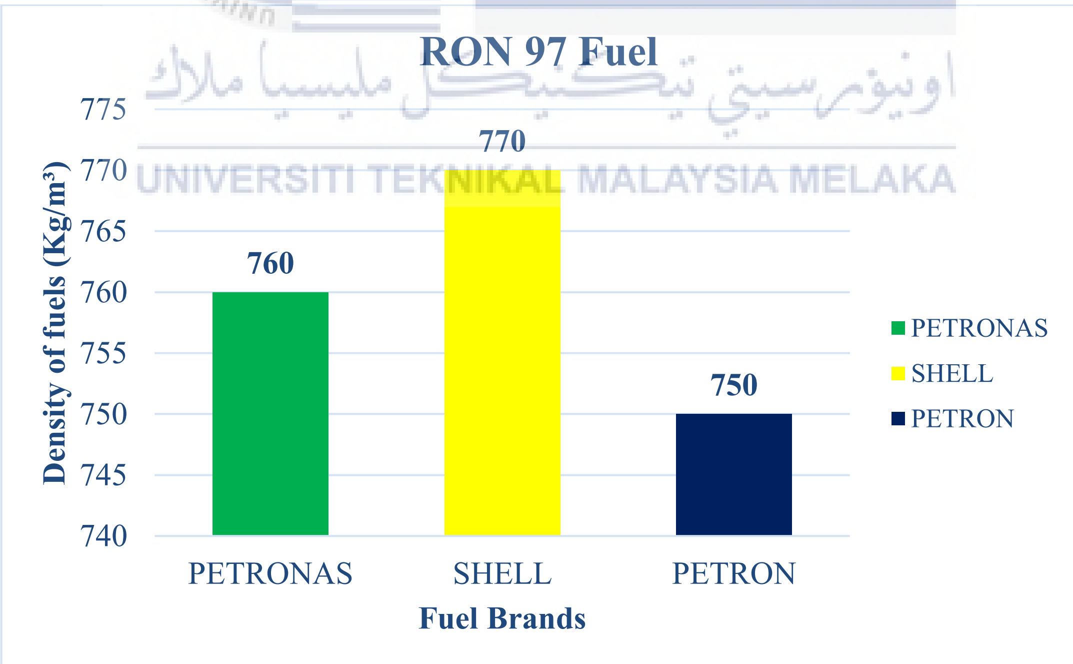


Figure 4.4: The graph show the comparison of the density of RON 97 fuel with different types of brands.

From the data given in table 4.2 and table 4.3, two graph of density of RON 95 and 97 fuels were constructed to show the comparison of density value of RON 95 and 97 fuels as shown in figure 4.3 and 4.4. The graphs are compared with different types of fuel brands. Refer to the figure it show the highest value of density of RON 95 is PETRONAS 95 fuel and followed by SHELL 95 and PETRON 95 fuels which are have same value of density. Based on figure that show the comparison of density of 97 fuels with different fuel brands, it seems that SHELL 97 is the highest value of density compared to the PETRONAS 97 which is second and the lowest value of density is PETRON 97.

4.2 ENGINE PERFORMANCE TEST.

Engine performance test is the most important experiment for this research. It is because this experiment is determine the performance of RON fuel from the performance of engine. This test are carried out by using engine dynamometer. Many types of engine dynamometer were used to determine the engine performance but in this research is focused on Alternating Current (AC) dynamometer.

The engine were tested with different types of fuel brands and different grades which are RON 95 and 97 from PETRONAS, SHELL and PETRON fuels. For this research, the baseline of fuel is PETRONAS fuel. Generally, the test is conducted to determine the output performance of engine and it represent with several perimeter such as power, air fuel ratio, torque and brake thermal efficiency. Special software is also required to properly run engine performance testing. This software allows the user to have complete control over the engine or vehicle parameters via computer.

In this research were used the four stroke engine and have four cylinder. The engine is 1.6 L Mitsubishi 4G92 engine. Before testing the engine, the condition of the engine must be checked and confirmed whether the condition is good or not to be tested. It is because the condition of the engine is the biggest factor that can affect the engine performance and thus affect the performance of fuel. The engine must be maintain and service properly to ensure the engine's condition is safe. The test were performed from 2000 RPM to 6000 RPM.

From the experiment, the data are collected in the computer and the graph were made up to show the performance of engine due to the performance of fuels. The graph of engine performance are represented the result of the experiment and the result will be compared with different type of brands and grades of RON fuel to determine which fuel give the highest performance to the engine. Below were the result collected from the engine performance test and some comparison were made up.

4.2.1 Result of the baseline fuel of RON 95 fuel which is PETRONAS

The result of the engine performance testing for PETRONAS 95 fuel is interpreted into the graph below in Figure 4.5 and 4.6. PETRONAS 95 is act as the baseline result to the rest.

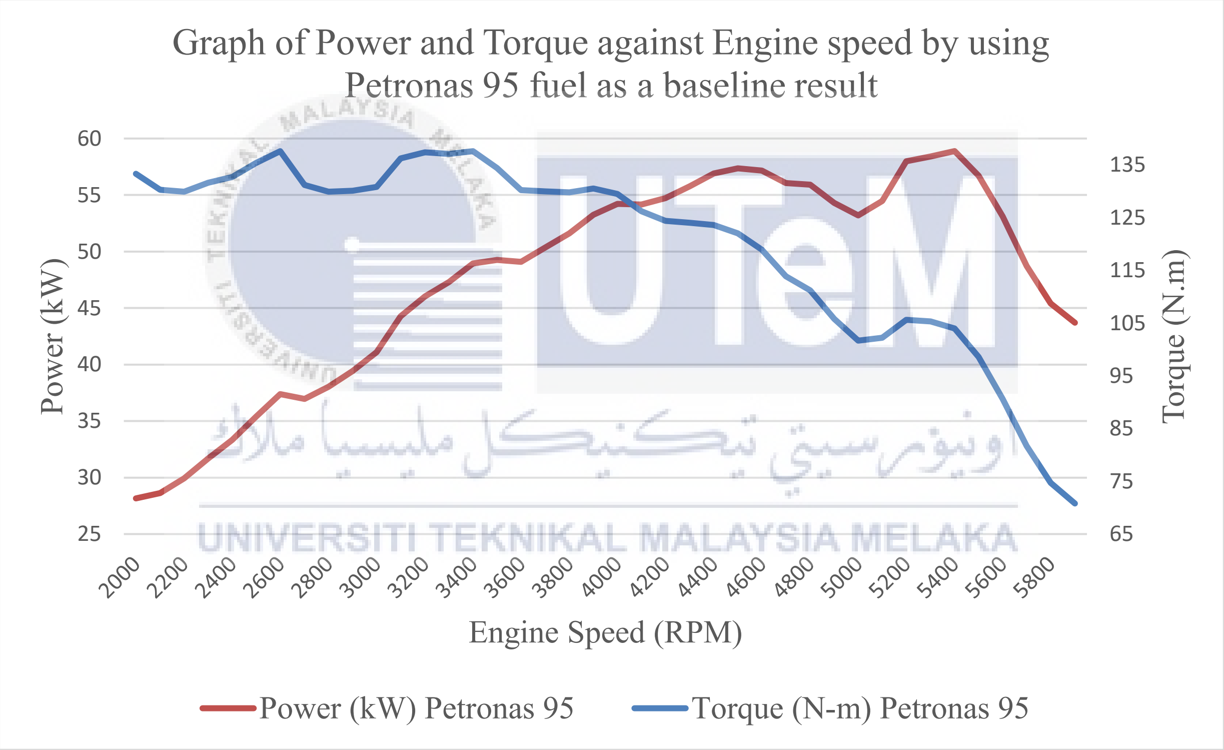


Figure 4.5: Graph of Power and Torque against Engine speed by using PETRONAS 95 fuel as a baseline result.

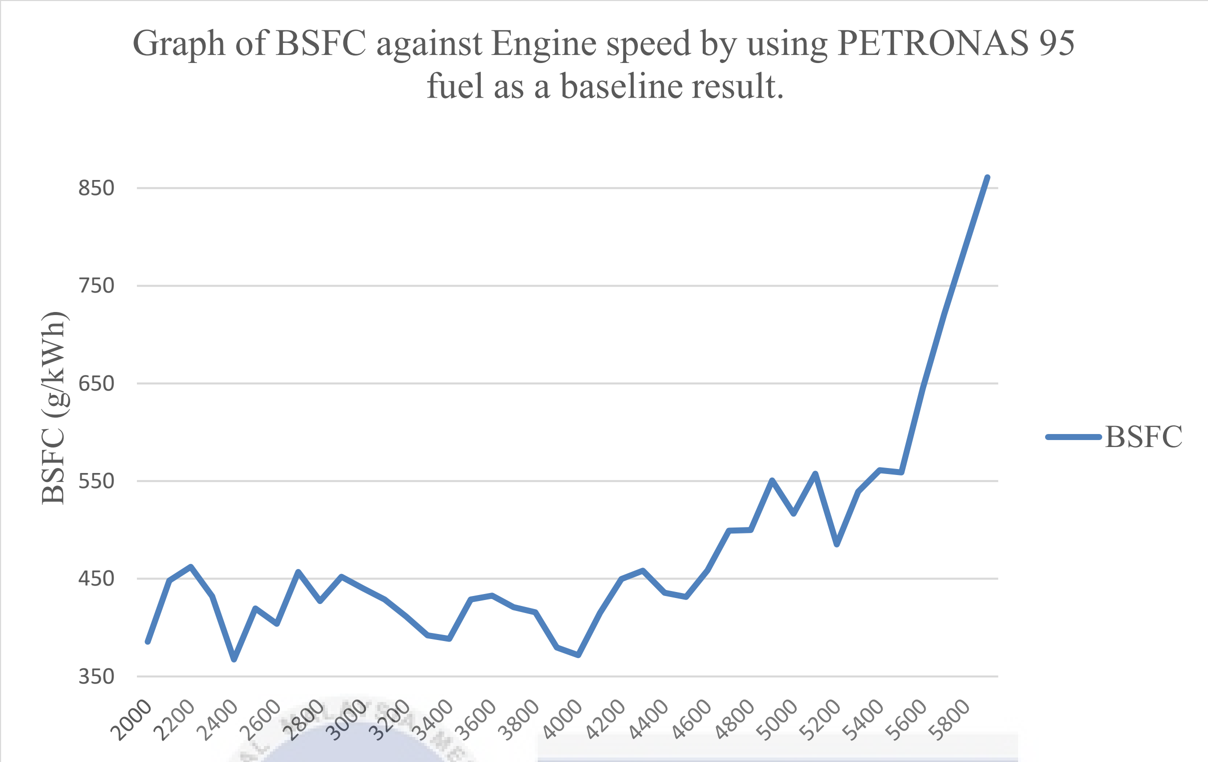


Figure 4.6: Graph of BSFC against Engine speed by using PETRONAS 95 fuel as a baseline result.

For the result of the baseline in figure 4.5, the highest of the power produced is 58.89 kW at 5400 rpm while the highest value of the torque produced is 137.6 Nm. Refer to the figure 4.6, the lowest of brake specific fuel consumption (BSFC) is 367.37 g/kWh. So, the result of PETRONAS 95 fuel become a baseline to compare with other fuel brands.

4.2.1.1 Comparison of the power by using RON 95 with different type of brands.

The result of the comparison of power by using RON 95 with different fuel brands are shown below in figure 4.7, 4.8, 4.9 and 4.10.

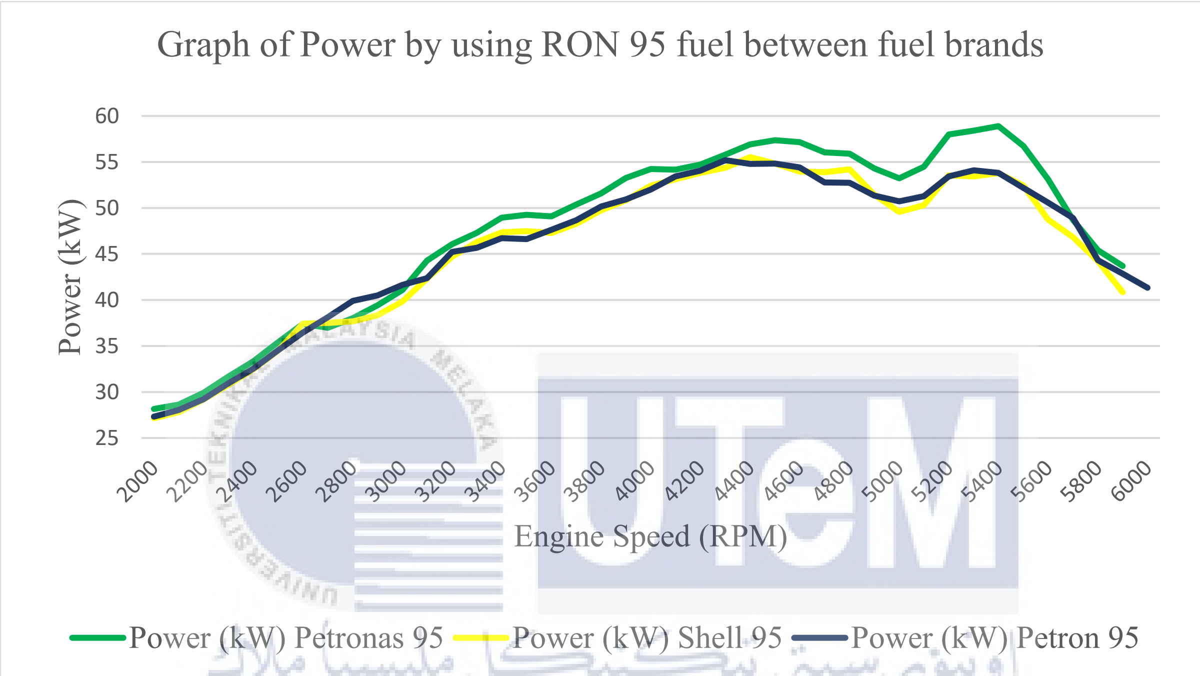


Figure 4.7: Graph of Power against Engine speed by using RON 95 fuel with different fuel brands.

By referring to the figure 4.7, graph of power against engine speed by using RON 95 fuel with different fuel brands show the fuel brand that reached the highest power is PETRONAS 95 which is 58.89 kW at 5400 RPM followed by the SHELL 95 and PETRON 95 which are 55.52 kW at 4400 RPM and 55.19 kW at 4300 RPM respectively. By comparing the data, there are three region can be separate to see the detail of the different between power that produced by the baseline fuel with other fuels.

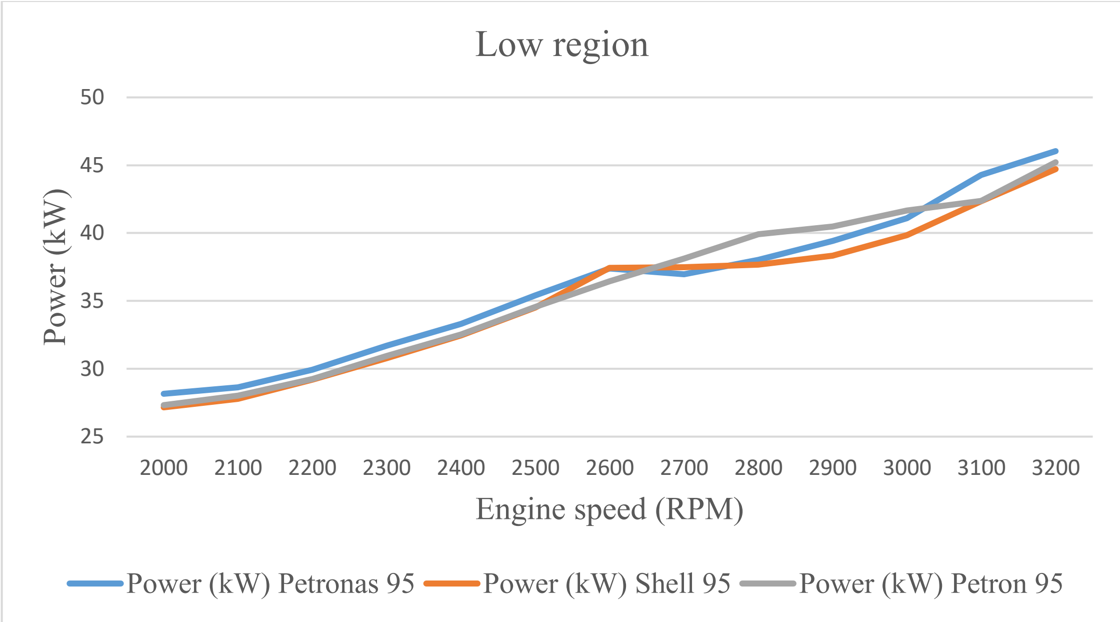


Figure 4.8: Low region for Graph of Power against Engine speed by using RON 95 fuel with different fuel brands.

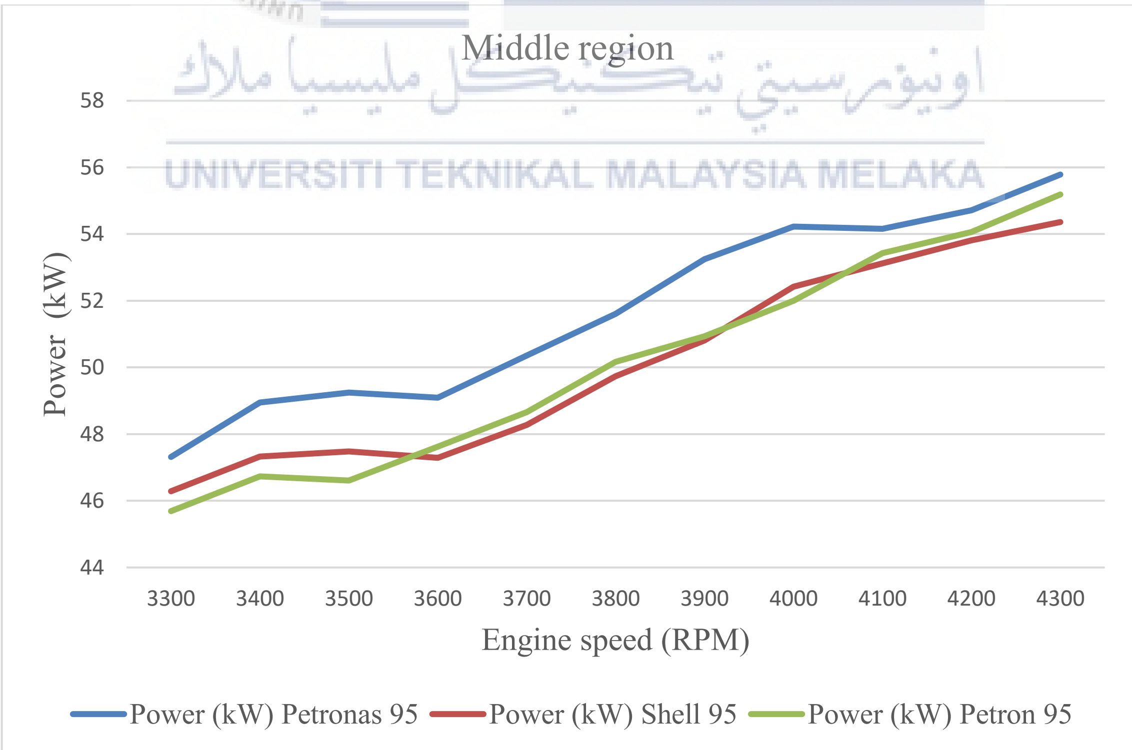


Figure 4.9: Middle region of graph of power against engine speed by using RON 95 fuel with different fuel brands.

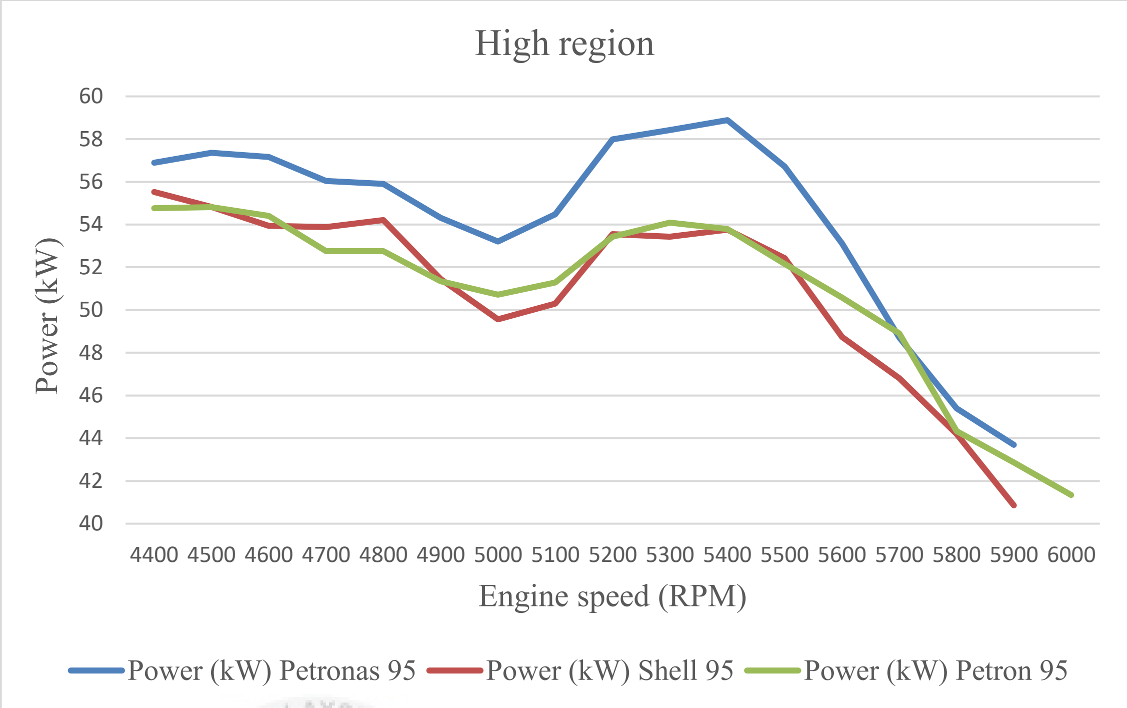


Figure 4.10: High region of graph of power against engine speed by using RON 95 fuel with different fuel brands.

For low region which have range from 2000 RPM to 3200 RPM, the bigger different of the power compare to the baseline is at 2800 RPM. PETRONAS 95 fuel reached power to 38.02 kW compare to the SHELL 95 where it reached lower than baseline fuel which is 37.67 kW. When SHELL 95 fuel were tested, the power at 2800 RPM was dropped to 0.358 kW is equal to 0.94 % compared to the baseline result. Besides, the power that PETRON 95 fuel can reached at 2800 RPM is 39.910 kW which is higher than baseline fuel. PETRON 95 fuel has increase power by 1.887 kW is equal to 4.96 % compared to the baseline fuel.

For middle region, the range is from 3300 RPM to 4300 RPM, the biggest different is at 3500 RPM. PETRONAS 95 as a baseline fuel has reached power to 49.25 kW at 3500 RPM. The power reached by SHELL 95 at same RPM is 47.48 kW while the power dropped by 1.767 kW is equal to 3.59 %. For PETRON 95 fuel also was dropped by 2.640 kW equal to 5.36 % which is 46.61 kW compared to baseline fuel result.

Next, for high region, the range is from 3400 RPM to 6000 RPM show the biggest different of power between fuel brands at 5400 RPM. The baseline result which is PETRON 95 has reached power to 58.89 kW while SHELL 95 fuel has reached to 53.77 kW where the power is dropped by 5.123 equal to 8.70 %. For PETRON 95 fuel, the power reached is lower than baseline by 5.093 kW equal to 8.65 % compared to the baseline fuel where the power reached to 53.79 kW.

4.2.1.2 Comparison of the torque by using RON 95 with different type of brands.

The result of the comparison of power by using RON 95 with different fuel brands are shown below in figure 4.11, 4.12, 4.13 and 4.14.

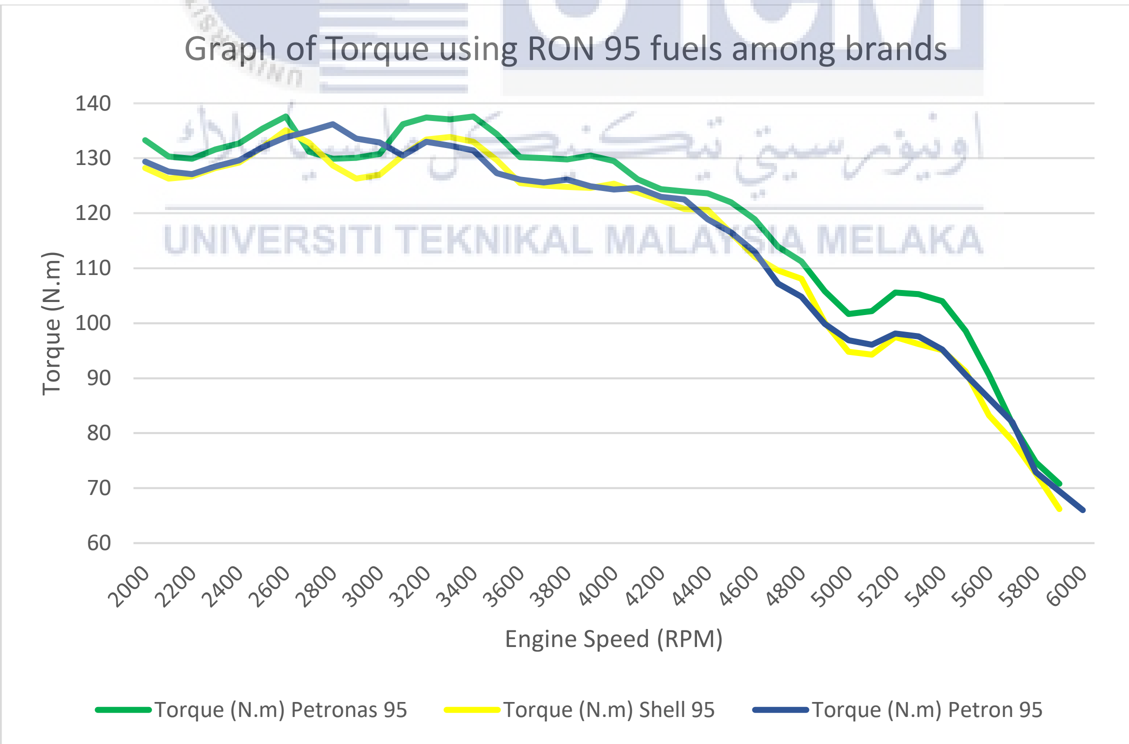


Figure 4.11: Graph of torque against engine speed by using RON 95 fuel with different fuel brands.

From the figure 4.11 above show the highest value of torque was produced by PETRONAS 95 fuel which is 137.6 Nm at 2600 RPM followed by PETRON 95 and SHELL 95 which are 136.2 Nm at 2800 RPM and 135.1 Nm at 2600 RPM respectively. To see the different between the torque produced by different fuel brands, the graph were divided to three region which are low region at range from 2000 RPM to 3100 RPM, mid region at range 3200 RPM to 4200 RPM and high region at range 4300 RPM to 6000 RPM.

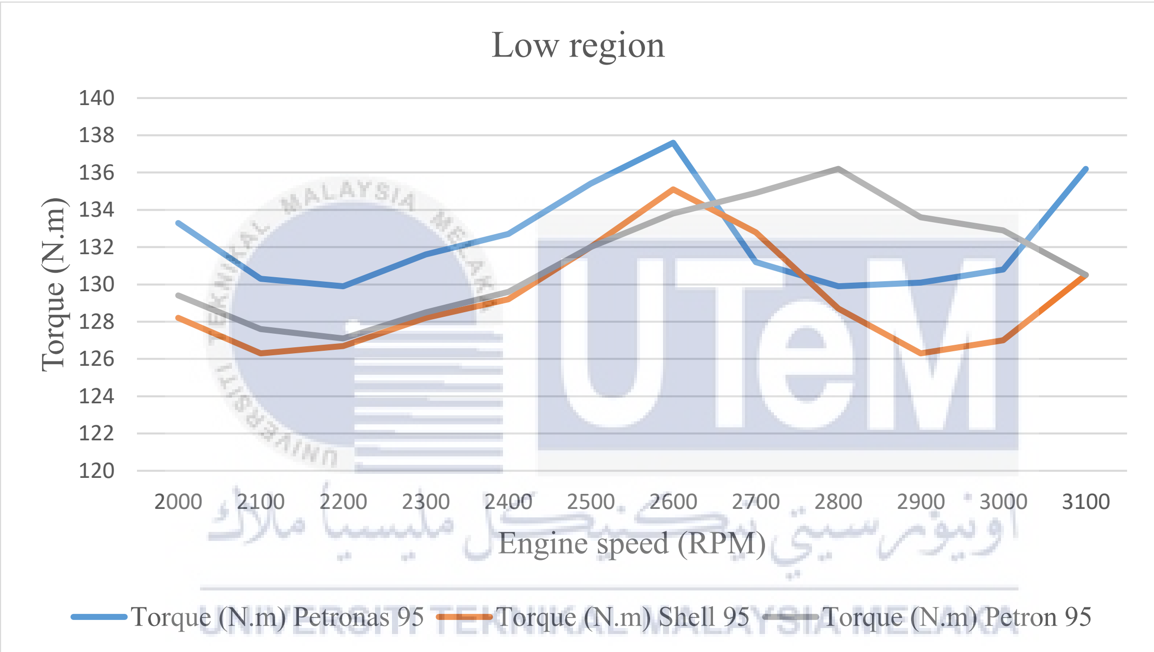


Figure 4.12: Low region of graph of torque against engine speed using RON 95 fuels with different fuel brands.

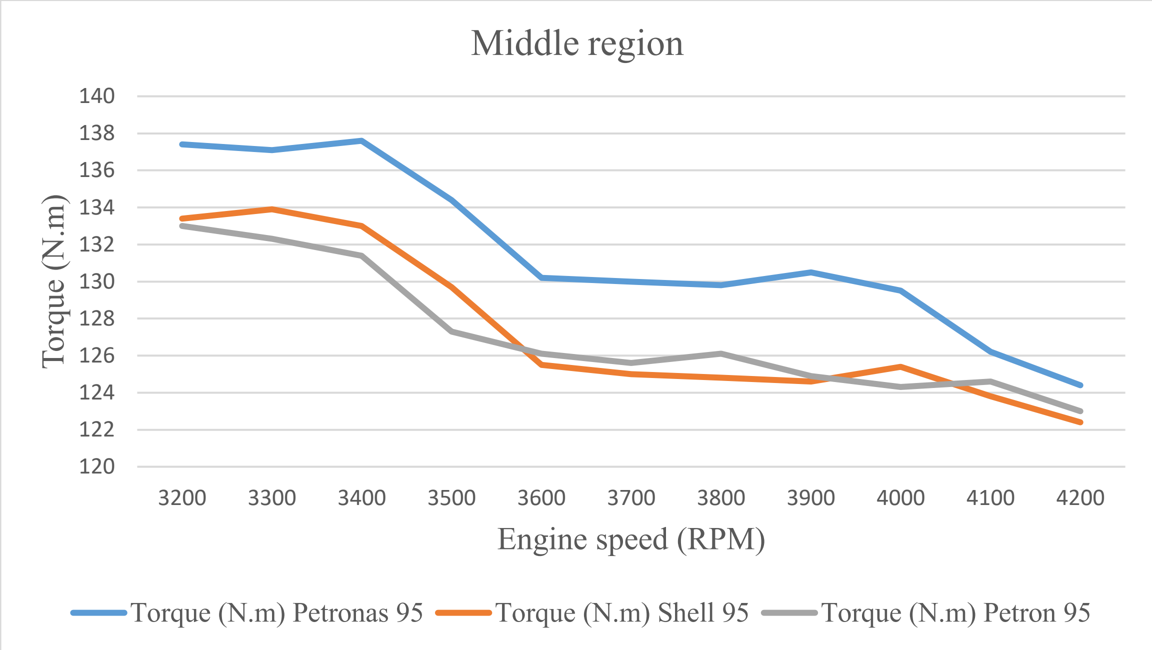


Figure 4.13: Mid region of graph of torque against engine speed using RON 95 fuels with different fuel brands.

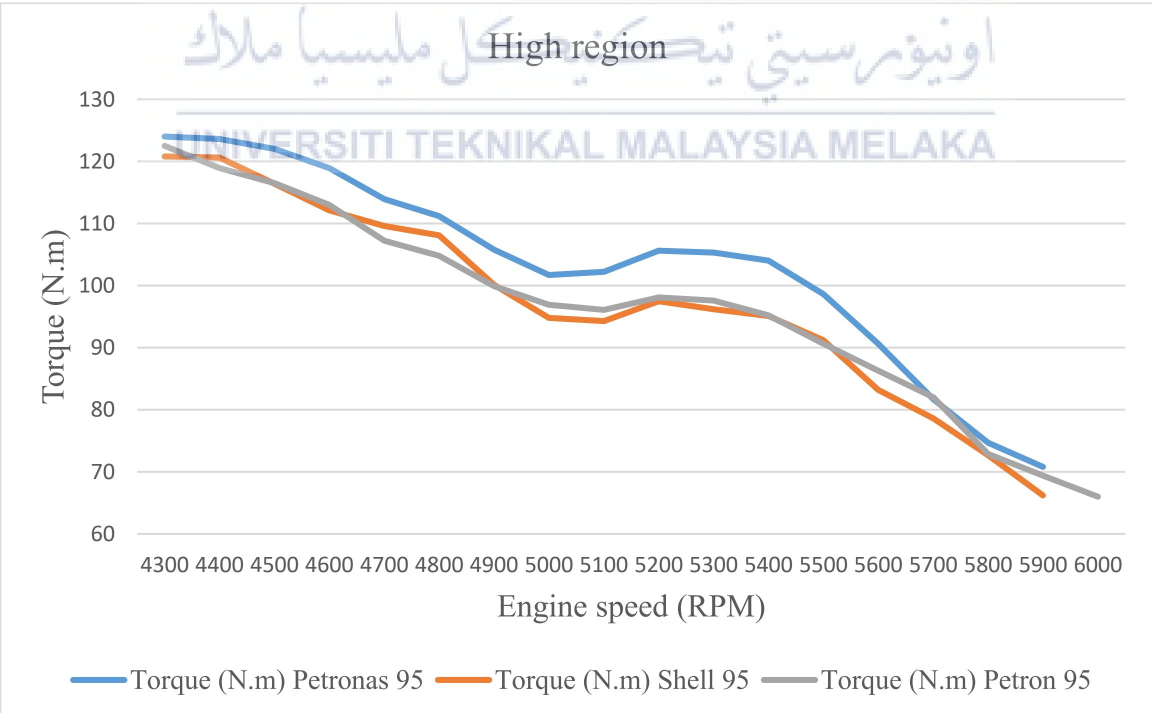


Figure 4.14: High region of graph of torque against engine speed using RON 95 fuels with different fuel brands.

For low region, the bigger different is at 2800 RPM. The baseline fuel which is PETRONAS 95 fuel was produced 129.9 Nm of torque while SHELL 95 fuel produced 128.7 Nm torque where it dropped to 0.924 % equal to 1.20 Nm.as shown below in figure 4.12 Besides, PETRON 95 fuel was produced 136.2 Nm torque where it is increased by 4.85 % equal to 6.30 Nm compared to baseline fuel.

For middle region, the obvious difference is at 3400 RPM as shown below in figure 4.13. PETRONAS 95 fuel produced highest torque in this region which is 137.6 Nm followed by SHELL 95 which is 133.0 Nm where it dropped by 3.34 % equal to 4.6 Nm. Then, it followed by PETRON 95 which the torque is 131.4 Nm has 4.5 % equal difference equal to 6.2 Nm compared to the baseline fuel.

For high region, the big difference is at 5400 RPM. The baseline fuel produced 104 Nm of torque higher than SHELL 95 which is 95.1 Nm. The difference between SHELL 95 and baseline fuel is 8.9 Nm equals to 8.56 %. PETRON 95 fuel also produced lower torque in this region which is 95.2 Nm where it is dropped by 8.46 % equals to 8.8 Nm as shown below in figure 4.14.

4.2.1.3 Comparison of the brake specific fuel consumption (BSFC) by using RON 95 with different type of brands.

The result of the comparison of Brake Specific Fuel Consumption (BSFC) by using RON 95 with different fuel brands are shown below in figure 4.15, 4.16, 4.17 and 4.18.

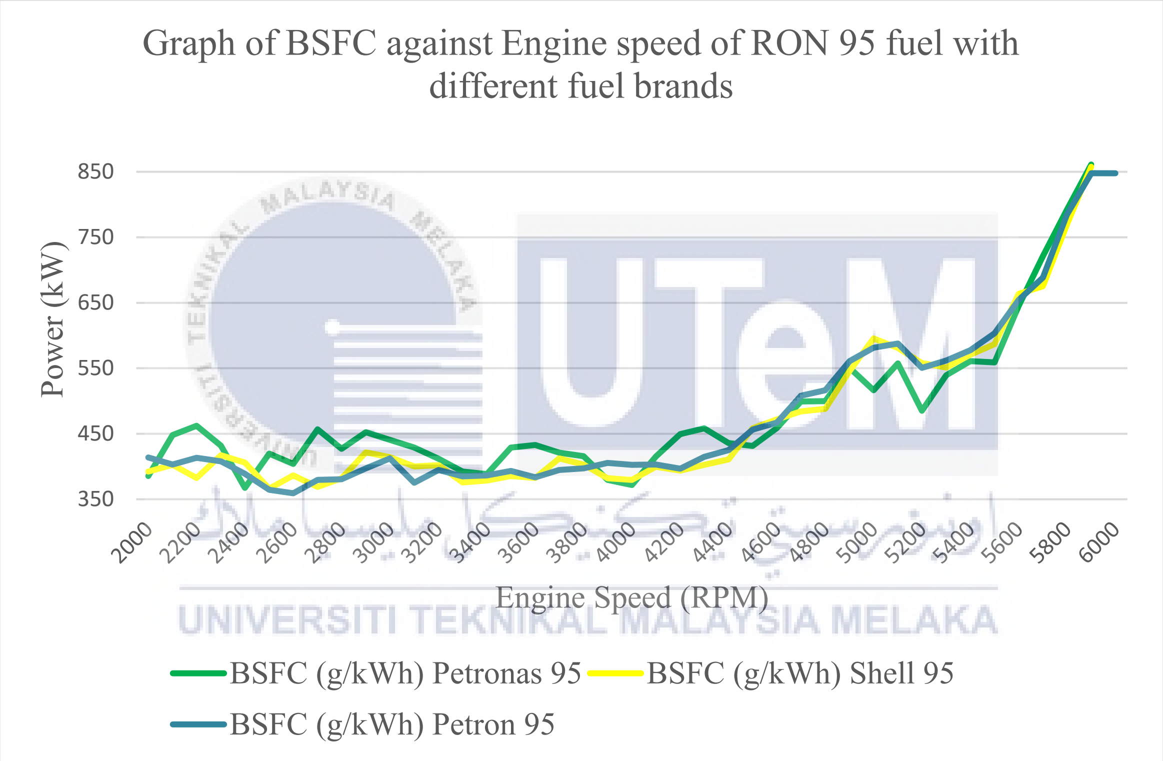


Figure 4.15: Graph of BSFC against engine speed of RON 95 fuel with different fuel brands

From the figure 4.15 above show the highest value of BSFC was produced by PETRONAS 95 fuel which is 861.056 g/kWh at 5900 RPM followed by PETRON 95 and SHELL 95 which are 857.63 g/kWh at 5900 RPM and 847.82 g/kWh at 5900 RPM respectively. To compare the difference between the BSFC produced by different fuel brands, the graph in figure 4.15 above were divided to three region which are low region at range from 2000 RPM to 3300 RPM, mid region at range 3400 RPM to 4500 RPM and high region at range 4600 RPM to 6000 RPM.

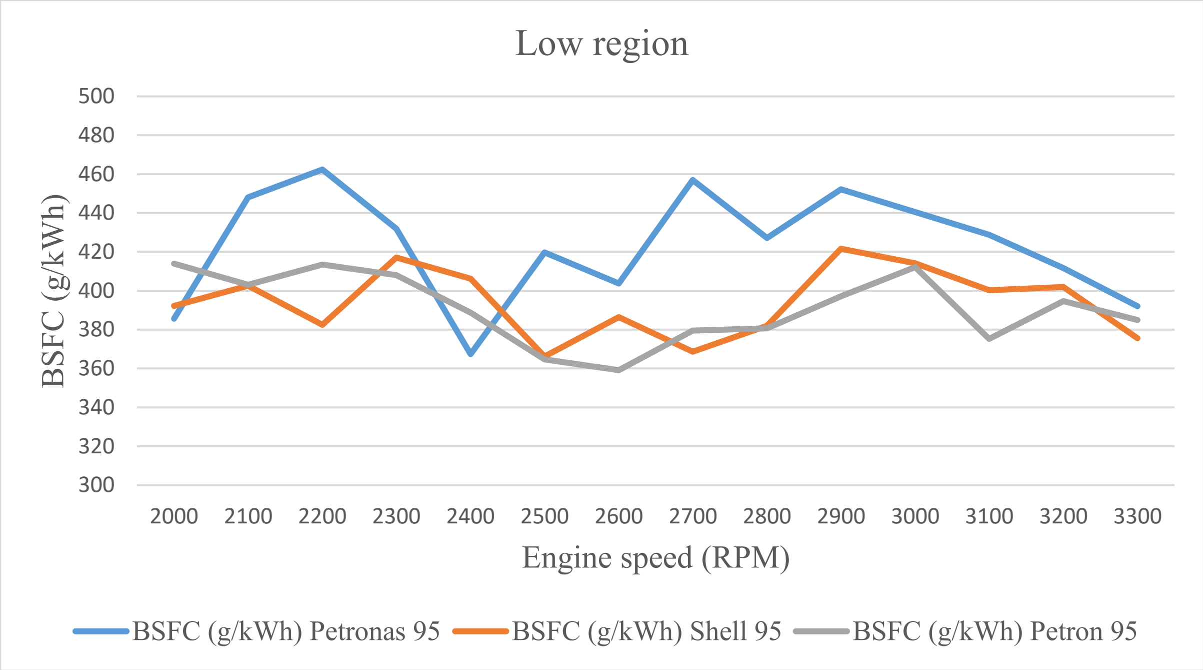


Figure 4.16: Low region of BSFC against engine speed of RON 95 fuel with different fuel brands.

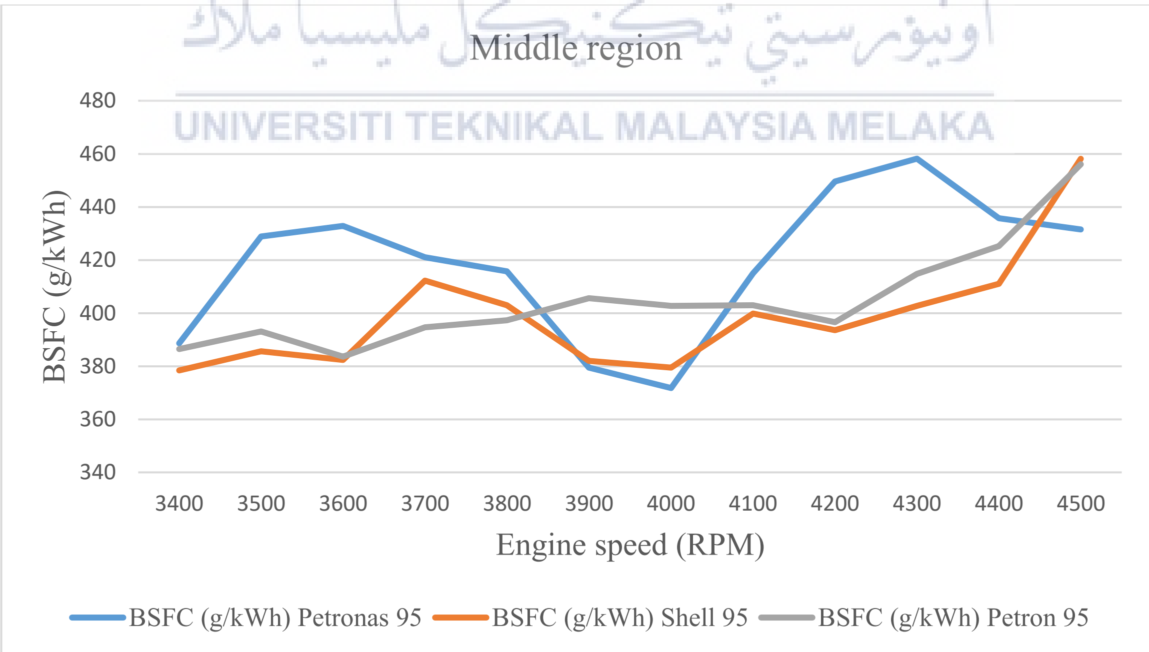


Figure 4.17: Middle region of BSFC against engine speed of RON 95 fuel with different fuel brands.

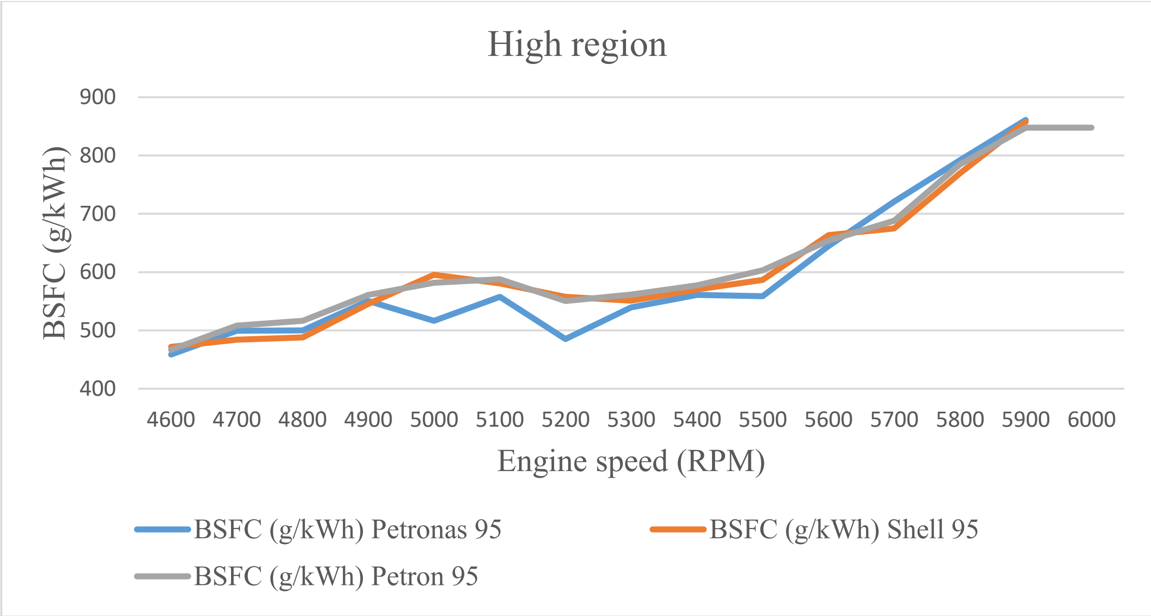


Figure 4.18: High region of BSFC against engine speed of RON 95 fuel with different fuel brands.

Refer the low region in figure 4.16 above, the biggest difference of the BSFC between RON 95 fuel brands is at 2700 RPM. PETRONAS 95 fuel as a baseline reached 456.93 g/kWh of BSFC compared to SHELL 95 fuel only reached 368.67 g/kWh. The reading of BSFC of SHELL 95 fuel was dropped by 88.26 g/kWh equals to 19.31% compared to baseline fuel. The result of BSFC of PETRON 95 fuel is 379.59 g/kWh also show the decreasing of BSFC value which is decreased by 77.34 g/kWh equals to 16.93 % compared to baseline result.

For middle region of BSFC against engine speed of RON 95 fuel with different fuel brands, the bigger difference that show in figure 4.17 above is at 4300 RPM. The result of BSFC of PETRONAS 95 as a baseline is 458.181 g/kWh while SHELL 95 is 402.675 g/kWh. The result of SHELL 95 is decreased by 12.11 % equals to 55.51 g/kWh. The result of PETRON 95 is also decreased compared to baseline by 9.48 % equals to 43.43 g/kWh where the result is 414.755 g/kWh.

For high region as shown in figure 4.18 above, there is biggest difference in this region at 5000 RPM. The reading of BSFC of PETRONAS 95 is 516.486 g/kWh while SHELL 95 is 595.561 g/kWh and PETRON 95 is 581.596 g/kWh. The result of SHELL 95 is higher than baseline result where it increased by 15.31 % equals to 79.08 g/kWh while the result of PETRON 95 also higher than baseline where it is increased by 12.61 % equals to 65.11 g/kWh.

4.2.2 Result of the baseline fuel of RON 97 fuel which is PETRONAS 97.

The result of the engine performance testing for PETRONAS 97 fuel is interpreted into the graph below in Figure 4.19 and 4.20. PETRONAS 97 is act as the baseline result compare to the other fuel brands.

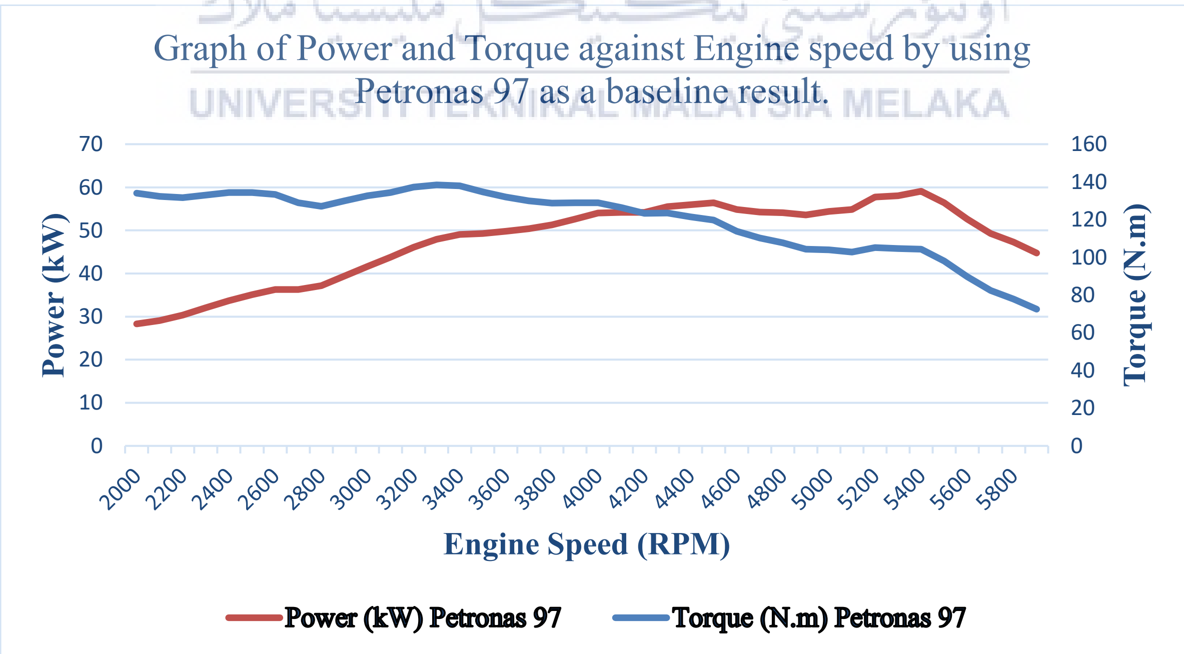


Figure 4.19: Graph of Power and Torque against Engine speed by using Petronas 97 as a baseline result.

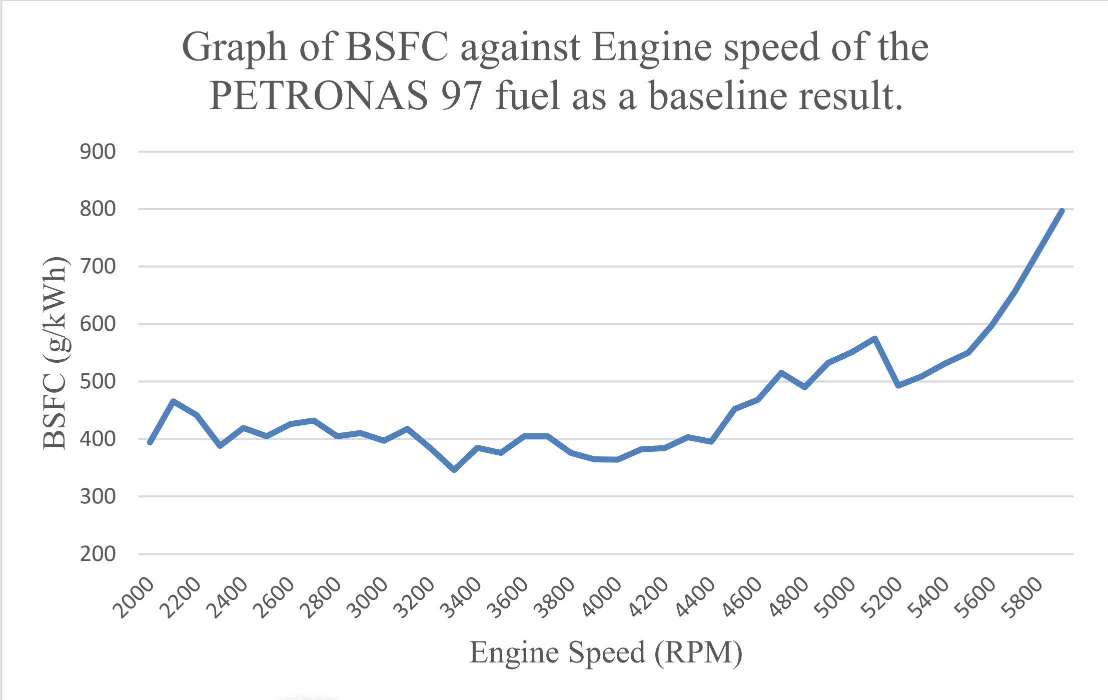


Figure 4.20: Graph of BSFC against engine speed of the PETRONAS 97 fuel as a baseline result.

Refer to figure 4.19 above, the graph show the highest of the power produced by using PETRONAS 97 fuel is 59.08 kW at 5400 RPM while the highest torque produced from PETRONAS 97 is 138.4 Nm at 3300 RPM. For the figure 4.20 above, the lowest value of brake specific fuel consumption (BSFC) is 346.18 g/kWh at 3300 RPM while the highest value of brake specific fuel consumption is 796.71 g/kWh at 5900 RPM.

4.2.2.1 The comparison of power by using RON 97 with different fuel brands.

The result of the comparison of power by using RON 97 with different fuel brands are shown below in figure 4.21, 4.22, 4.23 and 4.24.

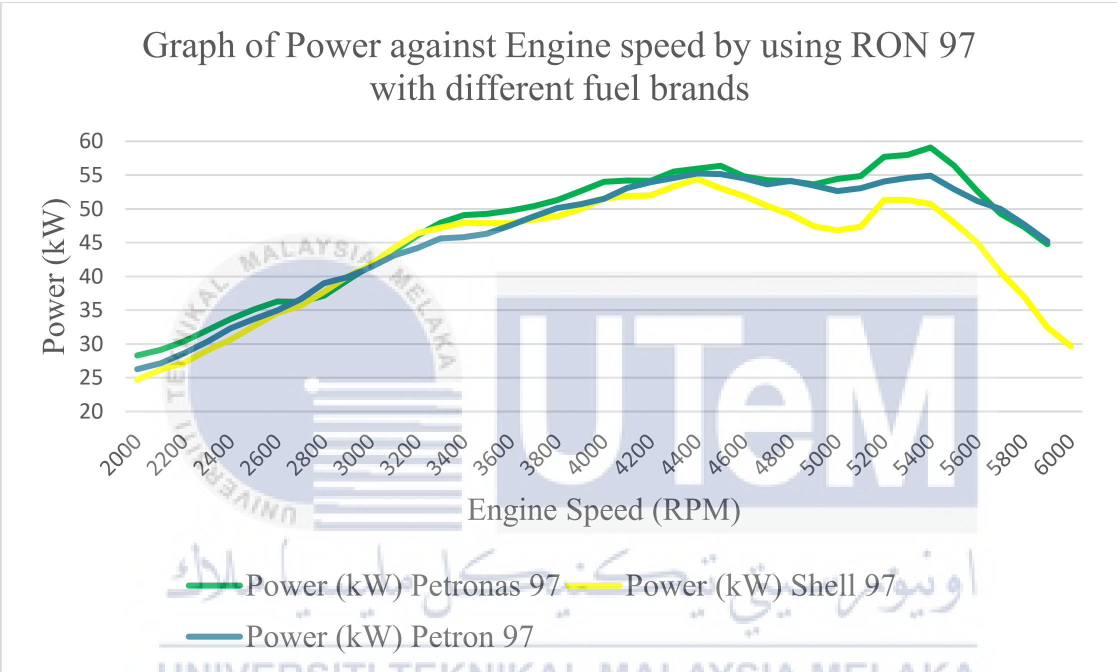


Figure 4.21: Graph of power against engine speed by using RON 97 with different fuel brands.

Based on the figure 4.21 above, the fuel produced the highest power is PETRONAS 97 which is 59.08 kW at 5400 RPM followed by PETRON 97 and SHELL 97 which are 55.24 kW at 4400 RPM and 54.44 kW at 4400 RPM respectively. PETRON 97 and SHELL 97 were produced highest power at the same engine speed. By comparing the data in the graph in figure 4.21 above, there are several differences of power between type of fuel brands. So, the graph was divided into three region to show the detail of the differences. The region have their own range, for example low region at range 2000 RPM to 3000 RPM, mid region at range 3100 RPM to 4800 RPM and low region at range 4900 RPM to 6000 RPM.

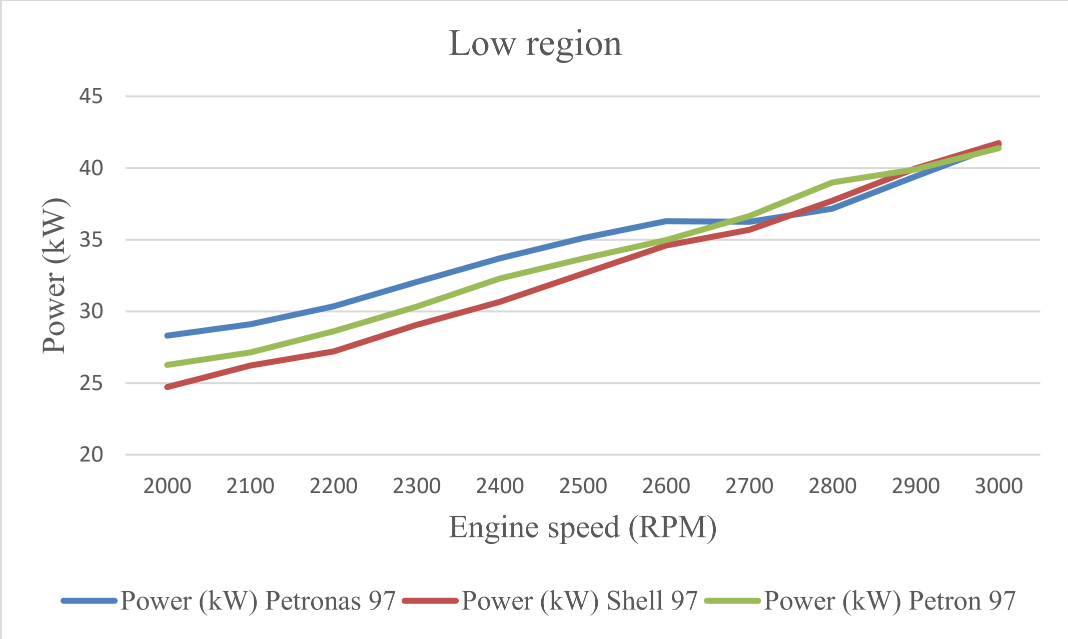


Figure 4.22: Low region of graph of power against Engine speed by using RON 97 with different fuel brands.

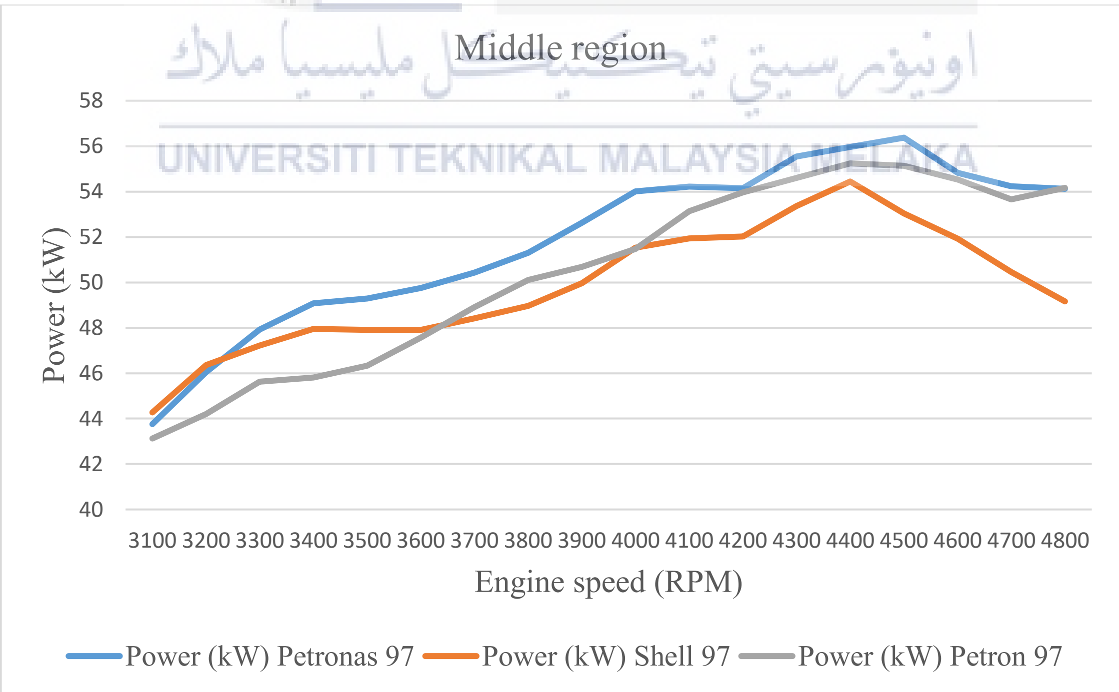


Figure 4.23: Middle region of graph of power against engine speed by using RON 97 with different fuel brands.

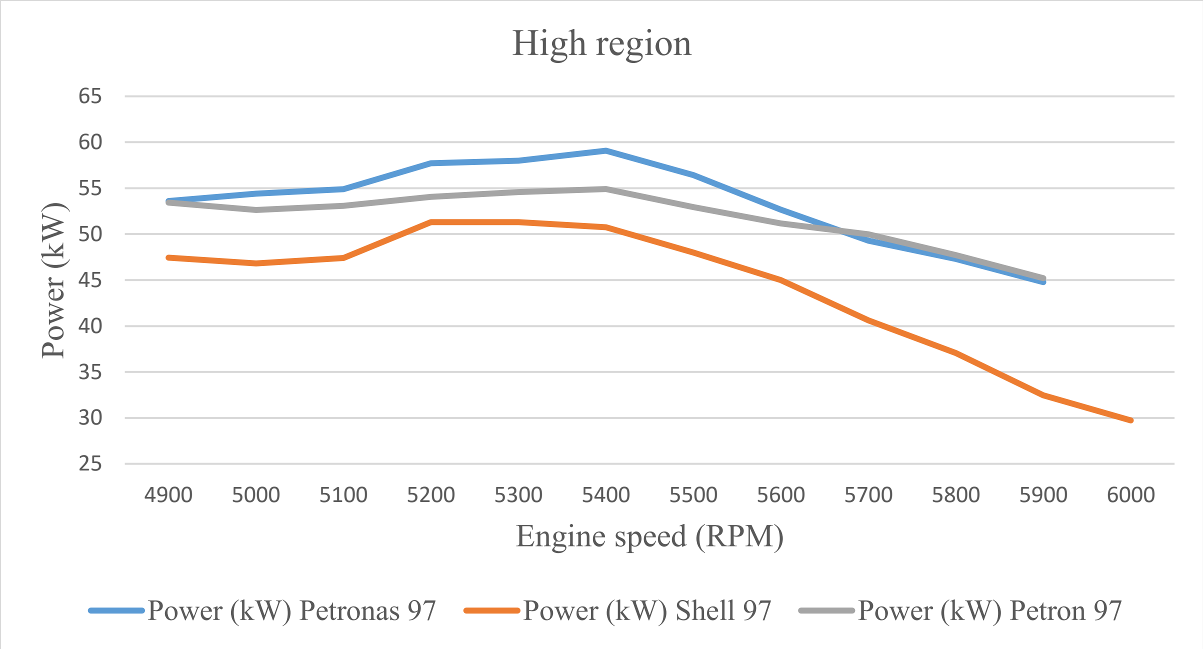


Figure 4.24: High region of graph of power against engine speed by using RON 97 with different fuel brands.

For low region, the difference was picked at the 2400 RPM because it shows the biggest difference in this region. PETRONAS 97 fuel reached power to 33.698 kW compare to the SHELL 95 where it reached lower than baseline fuel which is 30.656 kW. When SHELL 97 fuel were tested, the power at 2400 RPM was dropped to 3.042 kW equals to 9.03 % compared to the baseline result. Besides, the power that PETRON 97 fuel can reached at 2400 RPM is 32.296 kW which is lower than baseline fuel. The power reached by PETRON 97 was dropped by 1.402 kW equals to 4.16 % compared to the baseline fuel.

For middle region of power against engine speed of RON 97 fuel with different fuel brands, the bigger difference that show in figure 4.23 above is at 4000 RPM. The result of power of PETRONAS 97 as a baseline is 54.011 kW while SHELL 97 is 51.528 kW. The result of SHELL 97 is decreased by 4.60 % equals to 2.483 kW. The result of PETRON 97 is also decreased compared to baseline by 4.70 % equals to 2.535 g/kWh where the result is 51.476 kW.

Besides, for high region, the range is from 4900 RPM to 6000 RPM show the biggest different of power between fuel brands at 5400 RPM. The baseline result which is PETRONAS 97 has reached power to 59.082 kW while SHELL 97 fuel has reached to 50.737 kW where the power is dropped by 8.345 equal to 14.12 %. For PETRON 97 fuel, the power reached is lower than baseline by 4.176 kW equal to 7.07 % compared to the baseline fuel where the power reached to 54.906 kW.

4.2.2.2 Comparison of the torque by using RON 95 with different type of brands.

The result of the comparison of power by using RON 97 with different fuel brands are shown below in figure 4.25, 4.26, 4.27 and 4.28.

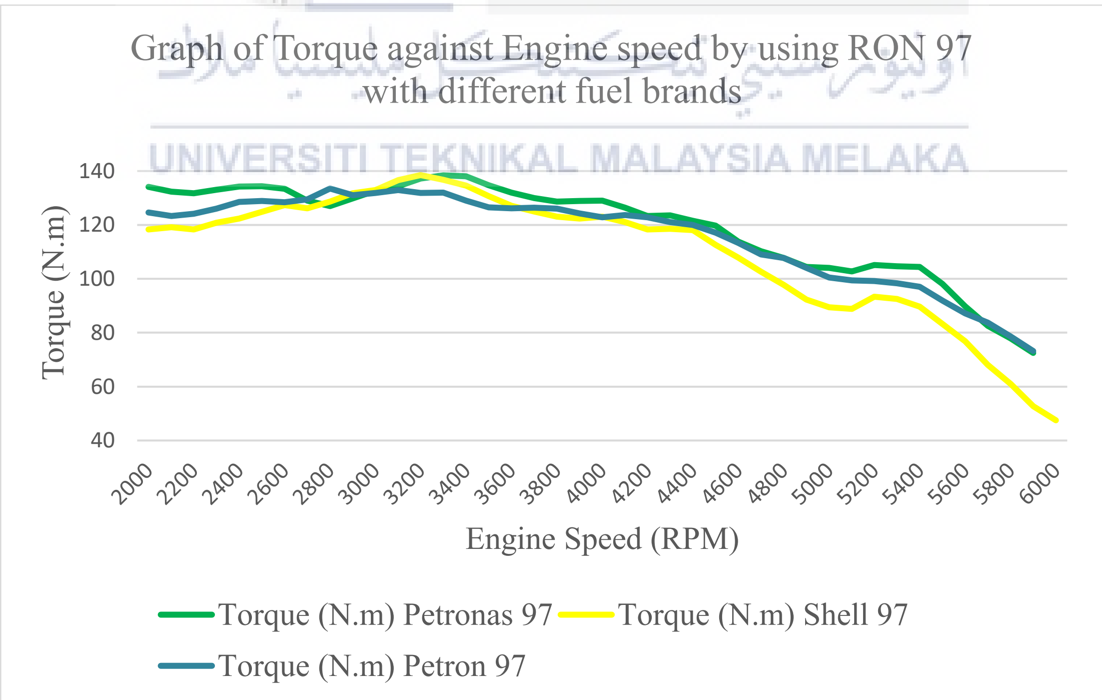


Figure 4.25: Graph of torque against engine speed by using RON 97 with different fuel brands.

From the figure 4.25 above show the highest value of torque was produced by SHELL 975 fuel which is 138.5 Nm at 3200 RPM followed by PETRONAS 97 and PETRON 97 which are 138.4 Nm at 3300 RPM and 133.5 Nm at 2800 RPM respectively. To see the different between the torque produced by different fuel brands, the graph were divided to three region which are low region at range from 2000 RPM to 3000 RPM, mid region at range 3100 RPM to 4400 RPM and high region at range 4500 RPM to 6000 RPM.

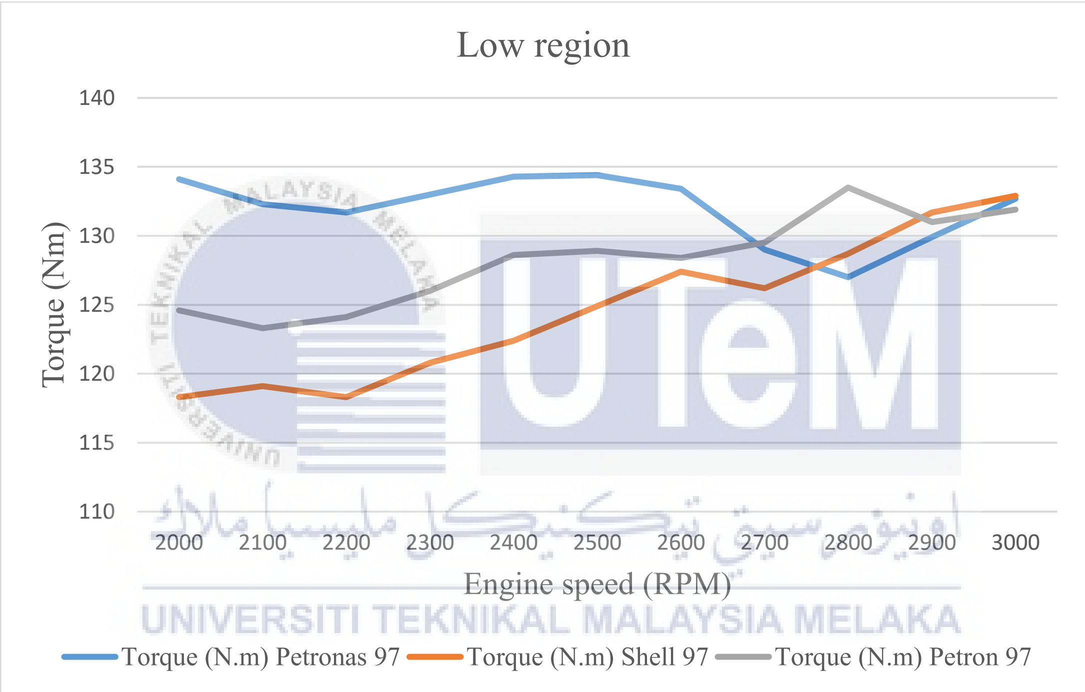


Figure 4.26: Low region of graph of torque against engine speed by using RON 97 with different fuel brands.

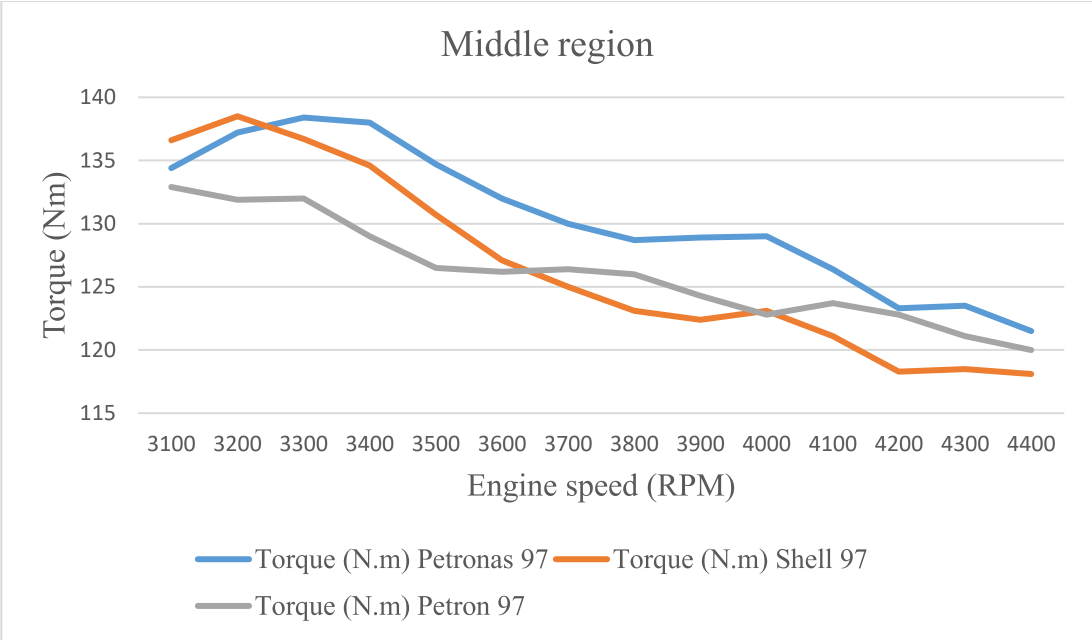


Figure 4.27: Middle region of graph of torque against engine speed by using RON 97 with different fuel brands.

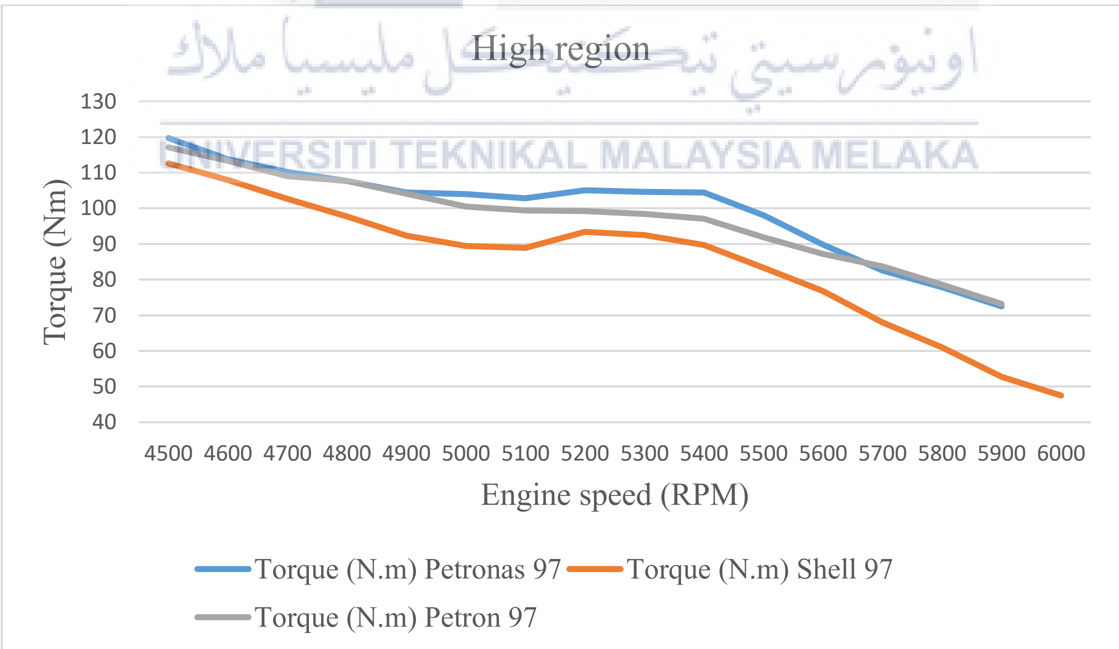


Figure 4.28: High region of graph of torque against engine speed by using RON 97 with different fuel brands.

For low region, the bigger different is at 2800 RPM. The baseline fuel which is PETRONAS 97 fuel was produced 134.3 Nm of torque while SHELL 97 fuel produced 122.4 Nm torque where it is lower than baseline fuel about 0.924 % equals to 1.20 Nm as shown above in figure 4.28. Besides, PETRON 95 fuel was produced 128.6 Nm torque where it is higher than baseline about 4.85 % equal to 6.30 Nm compared to baseline fuel.

For middle region, the torque produced by the PETRONAS 97 as a baseline fuel is 134.7 Nm which become the highest value of torque produced compared to SHELL 97 which is 130.7 Nm. SHELL 97 fuel produced torque 2.97 % lower than baseline which is equal to 4 Nm. PETRON 97 also produced lower of torque compared to baseline which is 6.09 % which equals to 8.2 Nm.

Refer to figure 4.28 above, in the high speed region, PETRONAS 97 fuel produced the highest torque compared to SHELL 97 and PETRON 97 which is 102.8 Nm. SHELL 97 produced 88.9 Nm of torque lower than baseline fuel about 13.52 % which equals to 13.9 Nm. PETRON 97 also produced torque lower than baseline which is 99.4 Nm where the value had dropped by 3.31 % equals to 3.4 Nm.

4.2.2.3 Comparison of the brake specific fuel consumption (BSFC) by using RON 95 with different type of brands.

The result of the comparison of BSFC by using RON 97 with different fuel brands are shown below in figure 4.29, 4.30, 4.31 and 4.32.

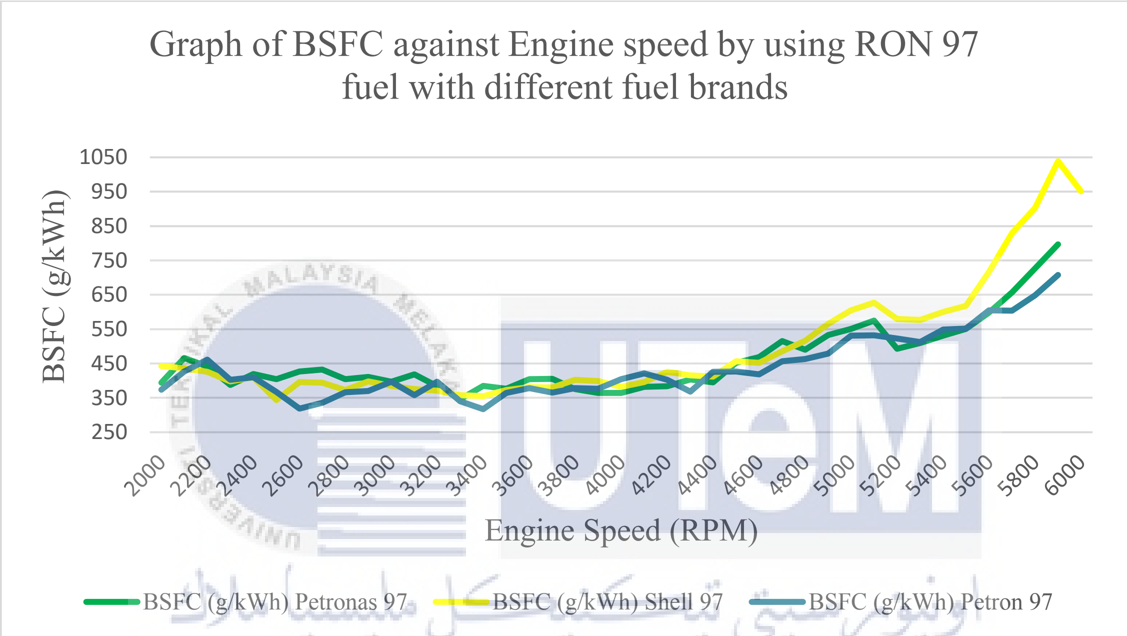


Figure 4.29: graph of brake specific fuel consumption (BSFC) against engine speed by using RON 97 fuel with different fuel brands.

From the figure 4.29 above show the graph of brake specific fuel consumption (BSFC) against engine speed by using RON 97 fuel with different type of fuel brands. The highest value of BSFC was produced by SHELL 97 fuel which is 1038.67 g/kWh at 5900 RPM followed by PETRONAS 97 and PETRON 97 which are 796.71 g/kWh at 5900 RPM and 707.67 g/kWh at 5900 RPM respectively. To compare the difference between the BSFC produced by different type of fuel brands, the graph in figure 4.29 above were divided to three region which are low speed region at range from 2000 RPM to 3000 RPM, middle speed region at range 3100 RPM to 4500 RPM and high speed region at range 4600 RPM to 6000 RPM.

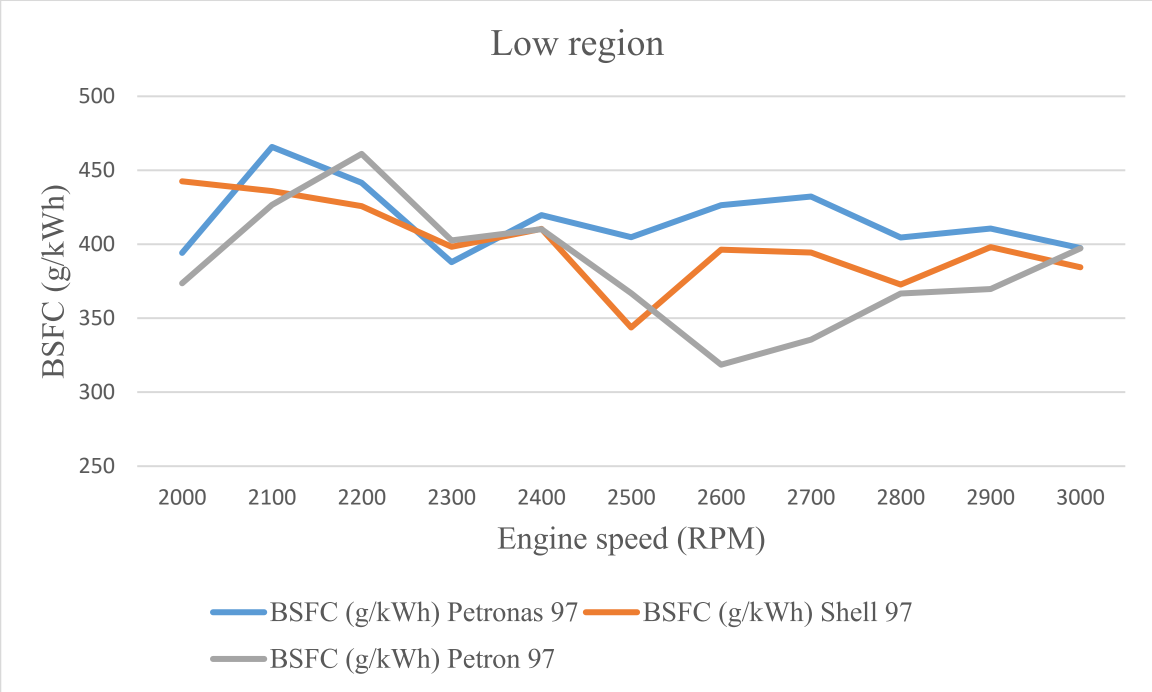


Figure 4.30: Low speed region of graph of BSFC against engine speed by using RON 97 fuel with different fuel brands.

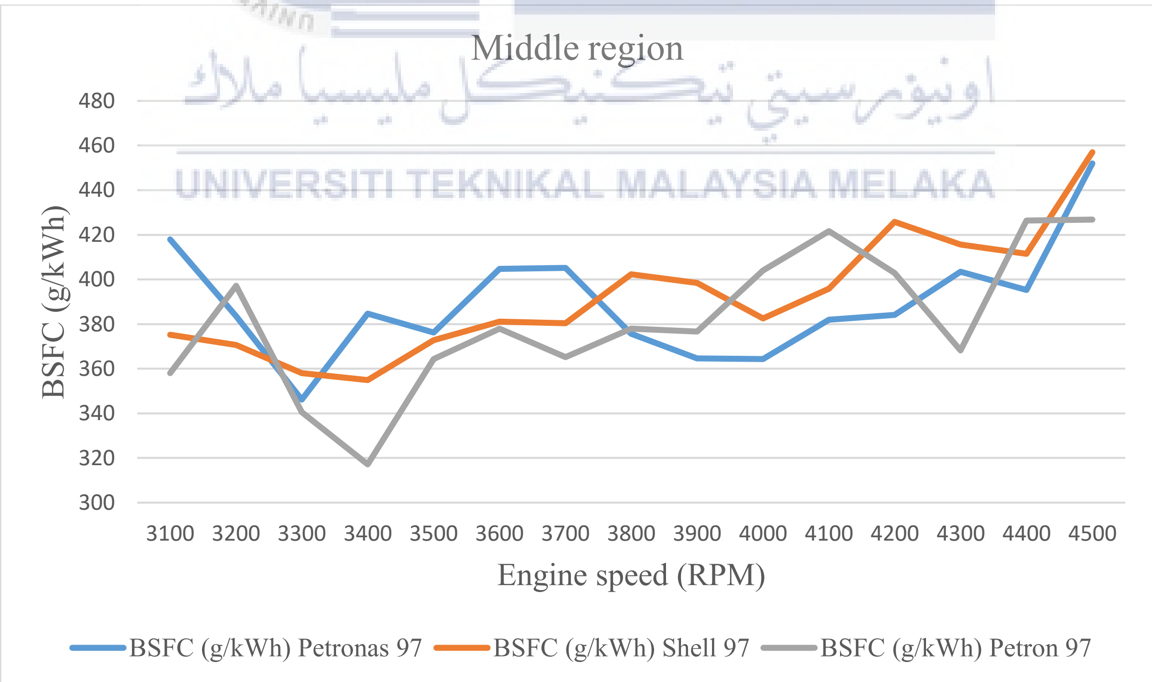


Figure 4.31: Middle speed region of graph of BSFC against engine speed by using RON 97 fuel with different fuel brands.

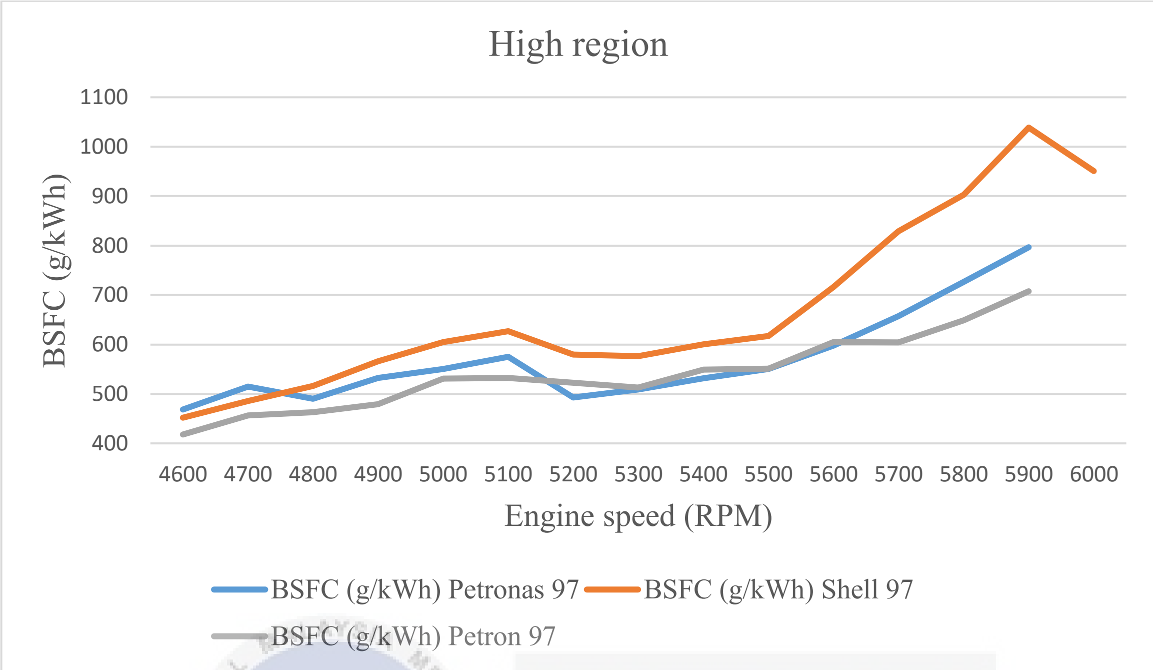


Figure 4.32: High speed region of graph of BSFC against engine speed by using RON 97 fuel with different fuel brands.

Refer the low region in figure 4.30 above, the biggest difference of the BSFC between RON 97 fuel brands is at 2600 RPM. PETRONAS 97 fuel as a baseline reached 426.338 g/kWh of BSFC compared to SHELL 97 fuel only reached 396.323 g/kWh. The reading of BSFC of SHELL 97 fuel was dropped by 30.015 g/kWh equals to 7.04 % compared to baseline fuel. The result of BSFC of PETRON 97 fuel is 318.596 g/kWh also show the decreasing of BSFC value which is decreased by 107.742 g/kWh equals to 25.27 % compared to baseline result.

For mid region of BSFC against engine speed of RON 97 fuel with different fuel brands, the bigger difference that show in figure 4.31 above is at 3400 RPM. The result of BSFC of PETRONAS 97 as a baseline is 384.663 g/kWh while SHELL 97 is 354.909 g/kWh. The result of SHELL 97 is decreased by 7.74 % equals to 29.754 g/kWh. The result of PETRON 97 is also decreased compared to baseline by 17.55 % equals to 67.524 g/kWh where the result is 317.139 g/kWh.

For high region as shown in figure 4.32 above, there is biggest difference in this region at 5800 RPM. The reading of BSFC of PETRONAS 97 is 726.739 g/kWh while SHELL 97 is 902.652 g/kWh and PETRON 97 is 648.719 g/kWh. The result of SHELL 97 is higher than baseline result where it increased by 24.21 % equals to 175.913 g/kWh while the result of PETRON 97 also higher than baseline where it is increased by 10.74 % equals to 78.02 g/kWh.

4.3 EMISSION TESTING RESULT.

Emission testing result were recorded at the same time with engine performance testing. Emission testing were conducted by using EMS 5002 Portable Gas Exhaust Analyzer. This analyzer was connected to the data acquisition of engine dynamometer to record the data at the same time with engine performance into a file. This analyzer able to measure Carbon Monoxide (CO), Carbon Dioxide (CO_2), Oxygen (O_2), Hydrocarbon (HC) and NO (Nitric Oxide) but in this research only focused on Carbon Monoxide (CO), Carbon dioxide (CO_2) and Hydrocarbon (HC).

Emission testing were conducted with engine performance testing at the same time so data of the emission were recorded when engine performance test is start from 2000 RPM until 6000 RPM with full throttle of engine. The emission test also performed to test different type of fuel brands and fuel grades which are RON 95 and 97 from PETRONAS, SHELL and PETRON. The PETRONAS fuels were acted as a baseline to make comparison with others.

Data were recorded after the engine had idling process because the engine must be reheating before starting the test. The analyzer should have warm up process before start the test. The result of the emission test were interpreted into graphs below.

4.3.1 Comparison of Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Hydrocarbon (HC) produced by RON 95 with different type of fuel brands.

The result of the emission were shown in the graph in figure 4.33, 4.34 and 4.35 below. The baseline result if the comparison is PETRONAS 95 fuel.

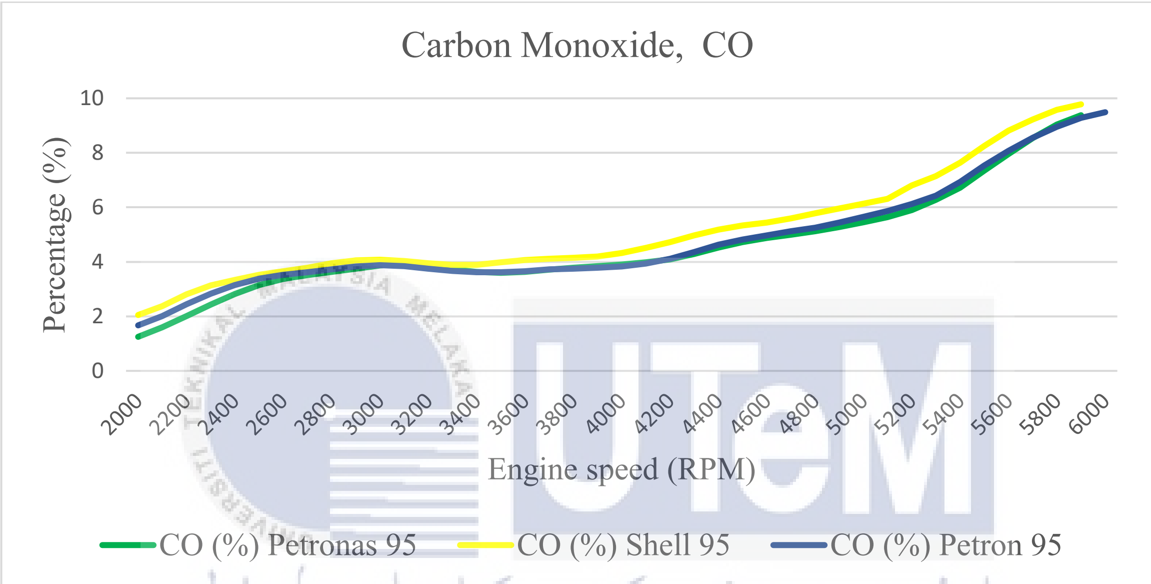


Figure 4.33: Comparison of Carbon Monoxide produced by RON 95 with different type of fuel brands.

By referring the figure 4.33 are shown the graph of comparison of carbon monoxide produced by RON 95 with different type of fuel brands. At the lowest engine speed which equal to 2000 RPM the baseline fuel which PETRONAS 95 produced the lowest of carbon monoxide which is 1.25 % of carbon monoxide while the highest value of carbon monoxide is SHELL 95 which produced 2.05% of carbon monoxide where it is higher than baseline about 64 %. PETRON 95 fuel produced 1.67 % of carbon monoxide where it is higher than baseline fuel about 33.6 %. At the highest engine speed which equal to 5900 RPM, the baseline fuel produced 9.38 % of carbon monoxide. For SHELL 95 fuel also produced higher carbon monoxide than baseline about 4.26 %. But PETRON 95 produced lower carbon monoxide than baseline fuel about 5.33 % which is 9.28 % of carbon monoxide.

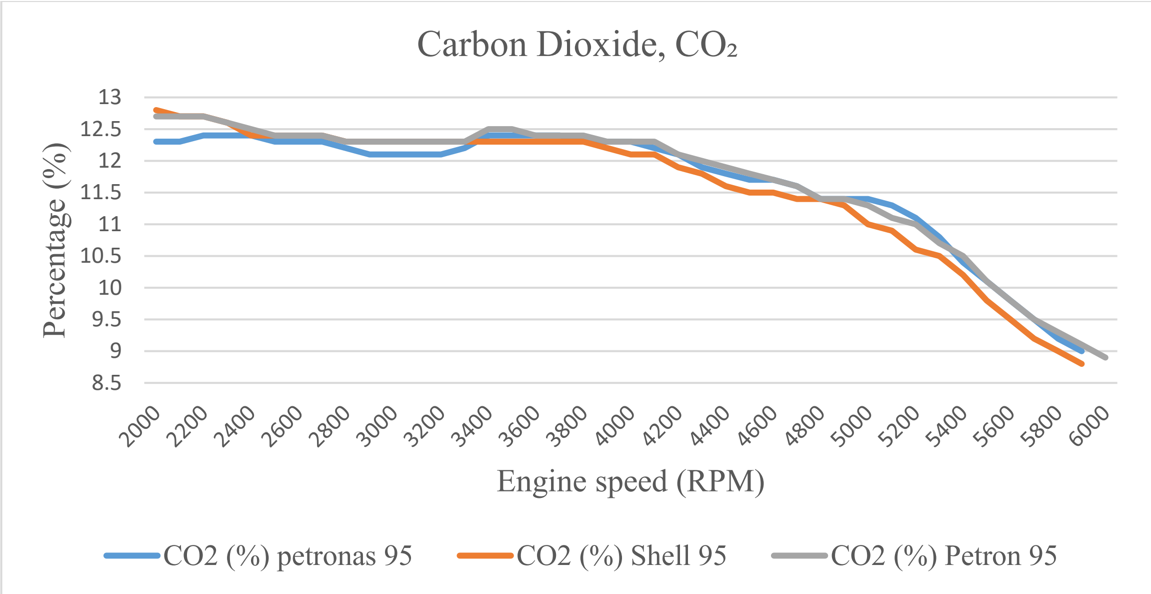


Figure 4.34: Graph of Carbon dioxide against Engine speed.

For carbon dioxide that produced by the RON 95 between different type of fuel brands are shown in figure 4.34 above. At the lowest engine speed (2000 RPM), the baseline fuel which is PETRONAS 95 fuel produced the lowest of carbon dioxide which equal to 12.3 % of carbon dioxide. SHELL 95 produced higher carbon dioxide than baseline fuel about 4.06 % which mean SHELL 95 produced 12.8 % of carbon dioxide become the highest fuel produced carbon dioxide in this RPM. Besides, PETRON 95 also produced 12.7 % of carbon dioxide which is higher than baseline fuel about 3.25 %. For the highest engine speed (5900 RPM), the fuel produced the highest carbon dioxide is PETRON 95 which higher than baseline fuel about 1.11 % where it equal to 9.1 % of carbon dioxide. The baseline fuel produced 9.1 % of carbon dioxide. SHELL 95 fuel recorded the lowest of number of carbon dioxide produced at this RPM which is 2.22 % lower than baseline where the number of carbon dioxide produced by SHELL 95 is 8.8 % of carbon dioxide.

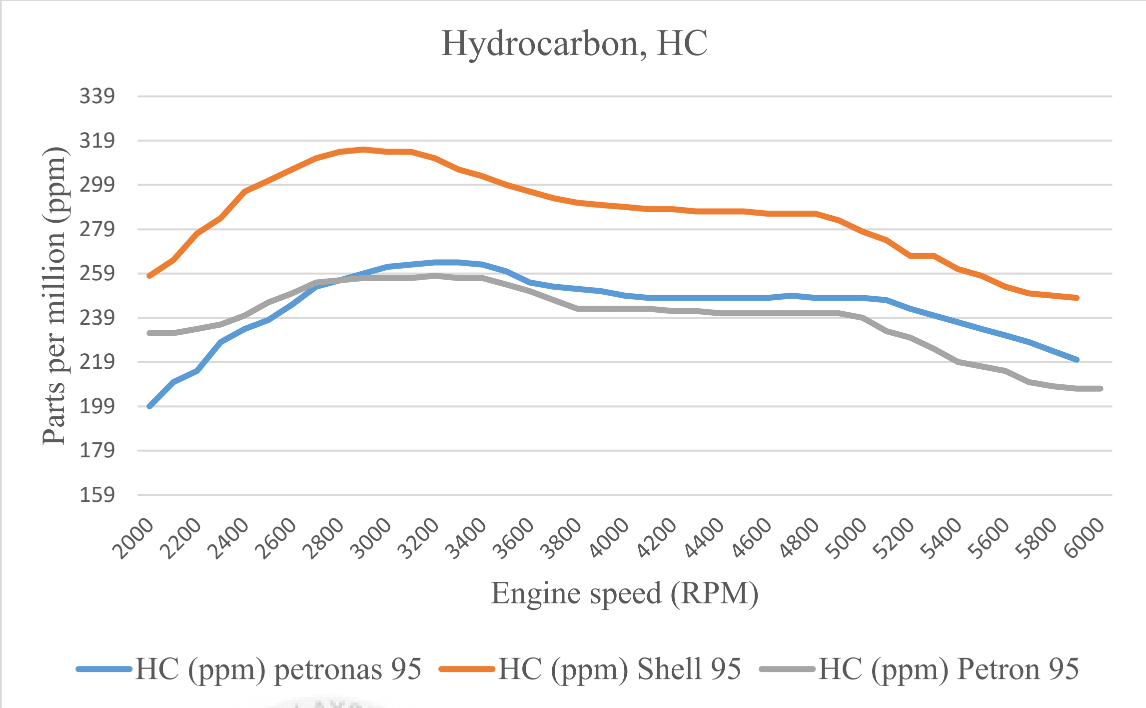


Figure 4.35: Graph of Hydrocarbon against Engine speed.

Based on figure 4.35 above show the graph of hydrocarbon against engine speed. The comparison at the 2000 RPM, the graph show hydrocarbon produced by SHELL 95 is the highest value in this speed. SHELL 95 fuel produced 258 ppm of hydrocarbon is higher than baseline fuel about 29.6 % while the PETRONAS 95 as a baseline fuel produced only 199 ppm of hydrocarbon. For PETRON 95 fuel, it produced 232 ppm of hydrocarbon which means higher than baseline fuel about 16.5 %. At the highest speed which is 5900 RPM, SHELL 95 recorded the highest of hydrocarbon result where the value is 248 ppm of hydrocarbon compared to baseline fuel, PETRONAS 95 fuel produced 220 ppm of hydrocarbon. So, SHELL 95 produced 12.7 % higher than baseline fuel. The graph also indicate the PETRON 95 fuel is the lowest fuel produced hydrocarbon in this speed. PETRON 95 produced 5.91 % lower than baseline fuel where the value is 207 ppm.

4.3.2 Comparison of Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Hydrocarbon (HC) produced by RON 97 with different type of fuel brands.

The result of the emission for RON 97 between different type of fuel brands were shown in the graph in figure 4.33, 4.34 and 4.35 below.

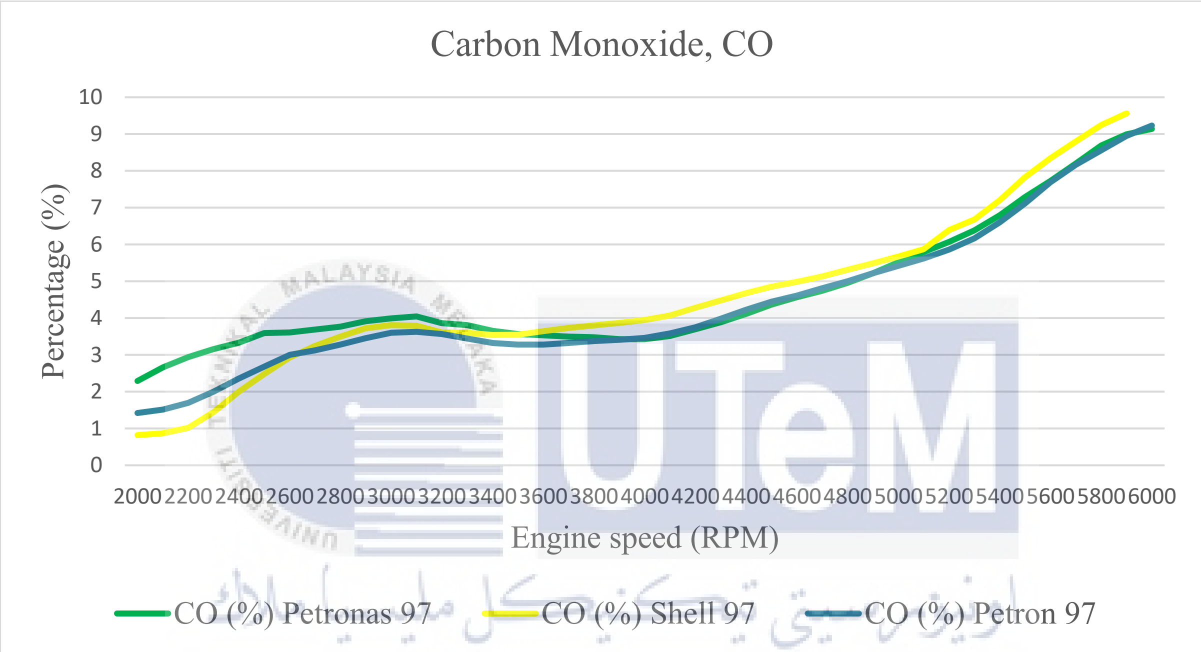


Figure 4.36: Graph of Carbon monoxide against Engine speed.

Based on the figure 4.36 above, the graph show the comparison of carbon monoxide produced RON 97 between different type of fuel brands. The baseline fuel is PETRONAS 97. At the lowest speed region, PETRONAS 97 had recorded the highest value of carbon monoxide produced which is 2.29 % of carbon monoxide. SHELL 97 had produced 0.82 % of carbon monoxide which is lower than baseline fuel about 64.2 % while PETRON 97 had produced 1.42% of carbon monoxide which 38 % lower than baseline. At the highest speed, the graph indicate the highest of carbon monoxide produced is from SHELL 97 fuel. SHELL 97 fuel had produced 8.99 % of carbon monoxide where it is 6.34 % higher than baseline fuel while PETRON 97 produced hydrocarbon by 0.44 % lower than baseline fuel.

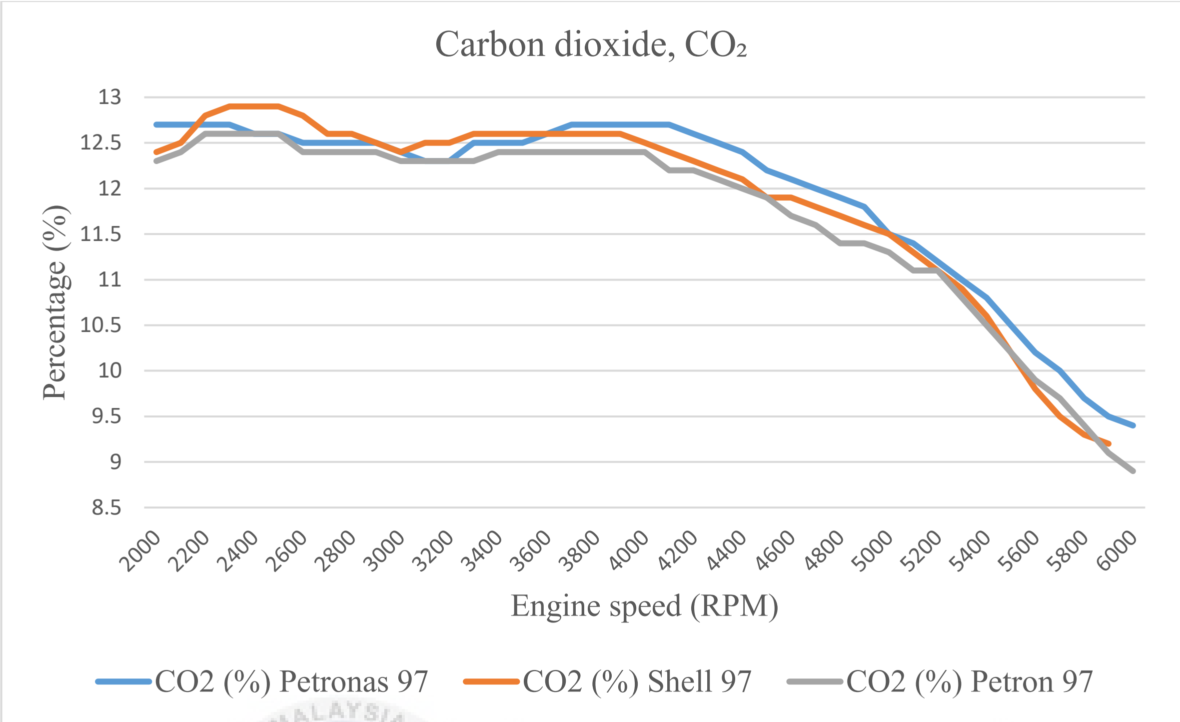


Figure 4.37: Graph of Carbon dioxide against engine speed.

By referring figure 4.37, carbon dioxide that produced by the RON 97 between different type of fuel brands. At the lowest engine speed which equal to 2000 RPM, the baseline fuel which is PETRON 97 fuel produced the lowest of carbon dioxide which equal to 12.3 % of carbon dioxide. SHELL 97 produced lower carbon dioxide than baseline fuel about 2.36 % which mean SHELL 97 produced 12.4 % of carbon dioxide. Besides, PETRON 97 produced 12.3 % of carbon dioxide which is lower than baseline fuel about 3.15 % and become the lowest value of carbon dioxide produced. For the highest engine speed which equal to 5900 RPM, the fuel produced the highest carbon dioxide is PETRONAS 97 which the value is 9.5 % of carbon dioxide. SHELL 97 fuel had produced 9.2 % of carbon dioxide where it is 3.15 % lower than baseline. PETRON 97 fuel was recorded the lowest of carbon dioxide produced at this RPM which is 4.21 % lower than baseline where the number of carbon dioxide produced by PETRON 97 is 9.1 % of carbon dioxide

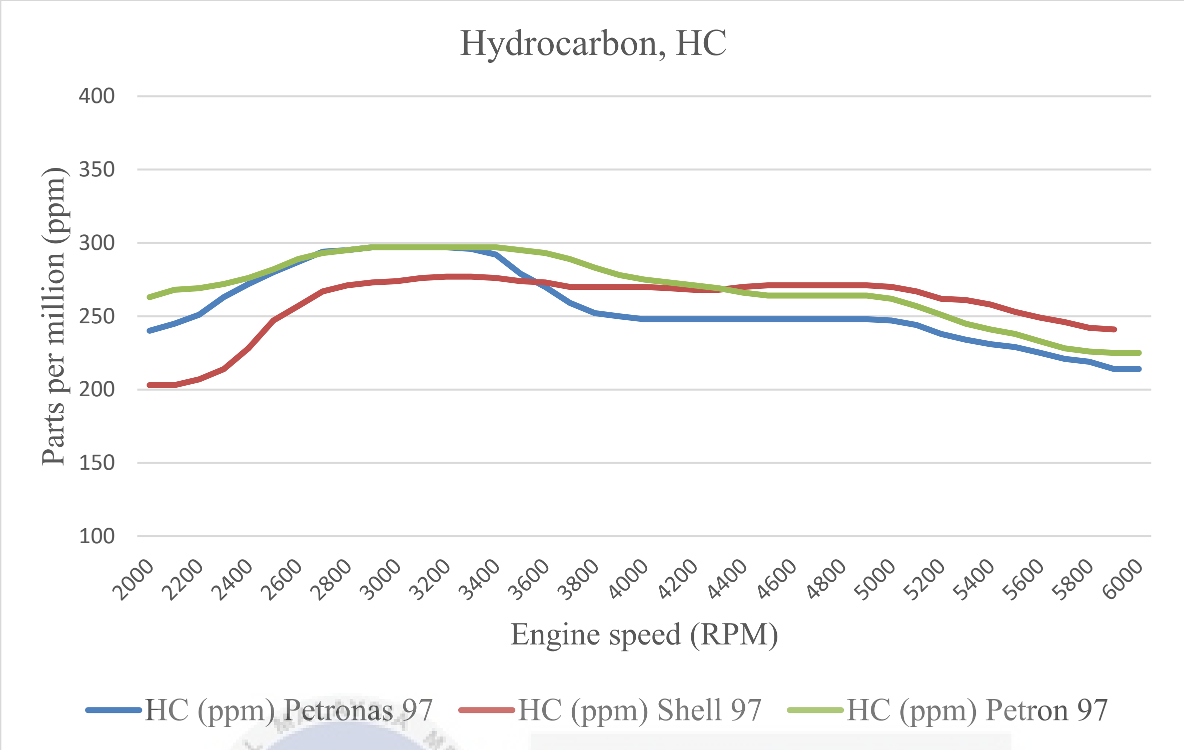


Figure 4.38: Graph of Hydrocarbon against Engine speed

Based on figure 4.38 above show the graph of hydrocarbon against engine speed. The comparison at the 2000 RPM which is the lowest engine speed, the graph show hydrocarbon produced by PETRON 97 is the highest value. PETRON 97 fuel produced 263 ppm of hydrocarbon is higher than baseline fuel about 9.58 % while the PETRONAS 97 as a baseline fuel produced 240 ppm of hydrocarbon. For SHELL 97 fuel, it produced 203 ppm of hydrocarbon which means lower than baseline fuel about 15.42 %. At the highest speed which is 5900 RPM, SHELL 97 recorded the highest of hydrocarbon result where the value is 241 ppm of hydrocarbon compared to baseline fuel, PETRONAS 97 fuel produced 214 ppm of hydrocarbon. So, SHELL 97 produced 12.62 % higher than baseline fuel. The graph also indicate the PETRON 97 fuel produced 5.14 % lower than baseline fuel where the value is 225 ppm.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.0 CONCLUSION

In this research, all the method that have been used were established and acceptable to determine the performance of RON fuel with different fuel grades and type of fuel brands. Based on the result of the experiment that have been conducted, the comparison of fuel performance prove that the RON 97 fuels produced higher performance than RON 95 fuels. These are because for three perimeter which are power, torque and brake specific fuel consumption that have been tested in engine performance test show the higher result for RON 97 fuels compared to RON 95 fuels.

Based on RON 95 fuels, PETRONAS 95 indicate the higher performance compared to the SHELL 95 and PETRON 95 which are produced highest value of power and torque where the value of power is 58.88 kW and torque is 137.6 Nm. For RON 97 fuels, PETRONAS 97 also show the higher performance compared to the SHELL 97 and PETRON 97. PETRONAS 97 produced highest value of power and second highest of torque compare to PETRON 97 which the value of power is 59.08kW while torque is 138.4 Nm. Meanwhile, one of the factor influence the engine performance is depended on the technology of designing engine produced from the manufacturer.

The comparison of the emission level with different type of fuel grades indicate the fuel produced better emission is RON 95 fuels. Besides, based on the comparison of emission level between fuel brands, for RON 95 the fuel produced better emission is PETRONAS 95 while PETRON 97 is the fuel produced better emission of RON 97 fuels.

Based on the result of the experiments that have been done, the objectives of this research were completely achieved where this project covered from the fuel properties, engine performance and emission level were successfully obtained.

5.1 RECOMMENDATION

Based on this project, there are a few things to focus for improvement action to ensure the research covered many aspect to achieve. For future improvement, the research must covered more sample of fuel for example conduct the test on all fuel brands that have in Malaysian market. This is because the user not only have to compare for three type of brands but sometime they want to know which the fuel is best between all brands in Malaysian market.

Besides, for future study, the new characteristics of RON fuel should be test to determine what are the characteristics of RON fuel are mostly affected to the result of engine performance. Then, the study of the characteristic of engine is necessary because as we know different manufacturer have secret design by its own to produce the engine to have comparison with other manufacturer.

Lastly, the research about the evaluation of RON fuels performance in Malaysian market had conducted and discussed successfully. So, to further on study and analysis in detail of the effect of different fuels to the engine performance is strongly accepted.

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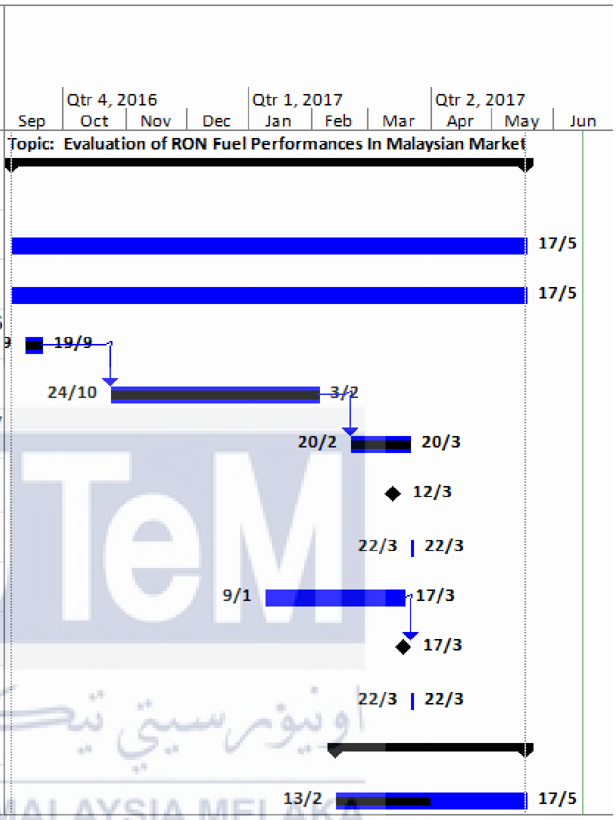
APPENDICES

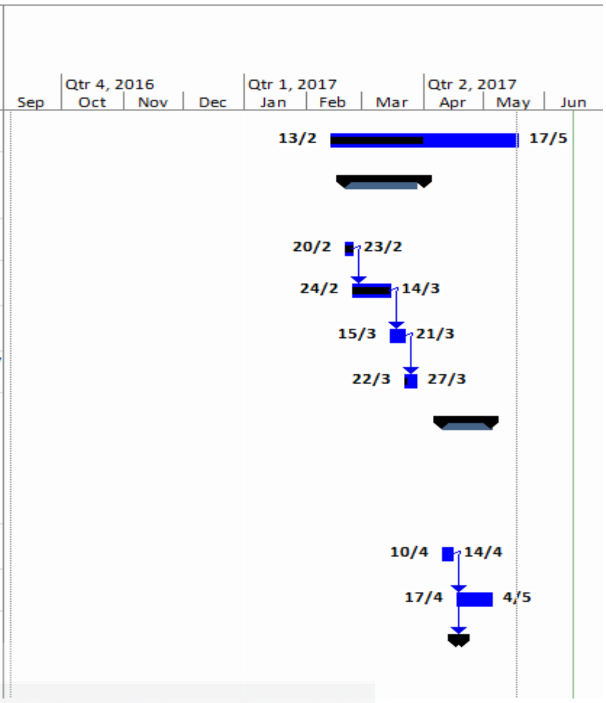
Appendix A: Gantt Chart of PSM

ID	Task Name	Duration	Start	Finish
1	**Topic: Evaluation of RON Fuel Performances In**	**183 days?**	**Mon 5/9/16**	**Wed 17/5/17**
2	PSM 1	183 days?	Mon 5/9/16	Wed 17/5/17
3	Literature Review	183 days	Mon 5/9/16	Wed 17/5/17
4	Psm 1 Briefing	6 days	Mon 12/9/16	Mon 19/9/16
5	Project Discussion	75 days	Mon 24/10/16	Fri 3/2/17
6	Project Introduction	21 days	Mon 20/2/17	Mon 20/3/17
7	Submission Progress Report	0 days	Sun 12/3/17	Sun 12/3/17
8		1 day?	Wed 22/3/17	Wed 22/3/17
9	Research Method	50 days	Mon 9/1/17	Fri 17/3/17
10	Submission Final Report PSM 1	0 days	Fri 17/3/17	Fri 17/3/17
11	PSM 1 Presentation	1 day	Wed 22/3/17	Wed 22/3/17
12	**PSM 2**	**68 days**	**Mon 13/2/17**	**Wed 17/5/17**
13	Literature Review	68 days	Mon 13/2/17	Wed 17/5/17



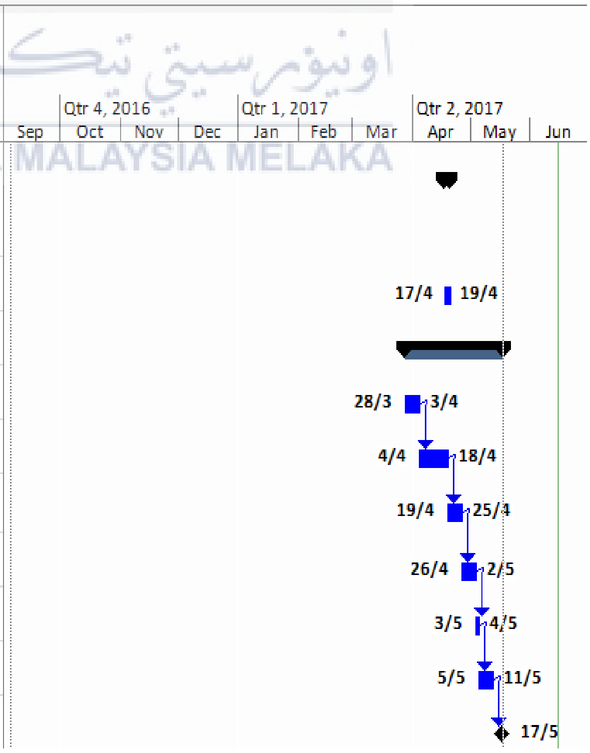
Appendix B: Continue Gantt Chart of PSM

ID	Task Name	Duration	Start	Finish
13	Literature Review	68 days	Mon 13/2/17	Wed 17/5/17
14	**Obj1 : To study the various of RON fuel properties in state of**	**30 days**	**Mon 20/2/17**	**Fri 31/3/17**
15	FTIR Testing	4 days	Mon 20/2/17	Thu 23/2/17
16	Energy Bomb Calorimeter Testing	13 days	Fri 24/2/17	Tue 14/3/17
17	Energy Bomb Calorimeter Testing	5 days	Wed 15/3/17	Tue 21/3/17
18	Hydrometer Testing	4 days	Wed 22/3/17	Mon 27/3/17
19	**Obj2: To compare the performance of engine with different types of RON fuel grades and brands (power, torque and**	**19 days**	**Mon 10/4/17**	**Thu 4/5/17**
20	Engine test matrix planning	5 days	Mon 10/4/17	Fri 14/4/17
21	Engine performance test	14 days	Mon 17/4/17	Thu 4/5/17
22	**Obj3 : To compare the emission level from vehicle by using different types of RON**	**3 days**	**Mon 17/4/17**	**Wed 19/4/17**



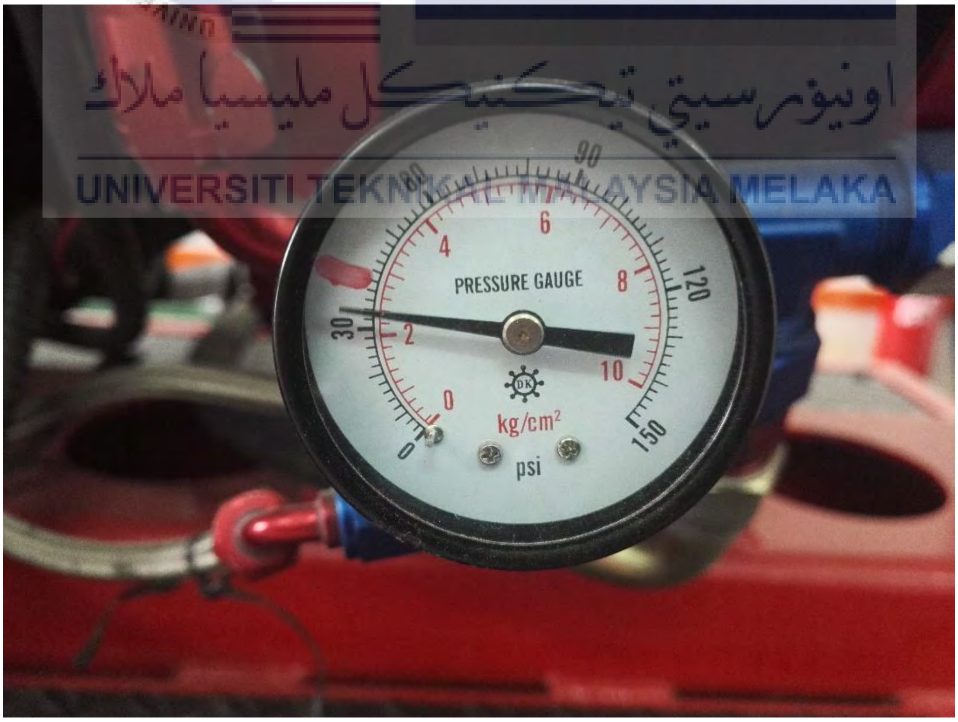
Appendix C: Continue Gantt Chart of PSM

ID	Task Name	Duration	Start	Finish
22	**Obj3 : To compare the emission level from vehicle by using different types of RON**	**3 days**	**Mon 17/4/17**	**Wed 19/4/17**
23	Emission Test	3 days	Mon 17/4/17	Wed 19/4/17
24	**Thesis Writing**	**37 days**	**Tue 28/3/17**	**Wed 17/5/17**
25	Chap 3 :Methodology	5 days	Tue 28/3/17	Mon 3/4/17
26	Chap4 : Results & Discussion	11 days	Tue 4/4/17	Tue 18/4/17
27	Chap 5: Conclusion & Future Studies	5 days	Wed 19/4/17	Tue 25/4/17
28	Chap2: Literature Review	5 days	Wed 26/4/17	Tue 2/5/17
29	Chap1: Introduction	2 days	Wed 3/5/17	Thu 4/5/17
30	Thesis Review	5 days	Fri 5/5/17	Thu 11/5/17
31	PSM Thesis Submission	0 days	Wed 17/5/17	Wed 17/5/17



Appendix D: Assistant Engineer change the Electronic Controller Unit of the engine

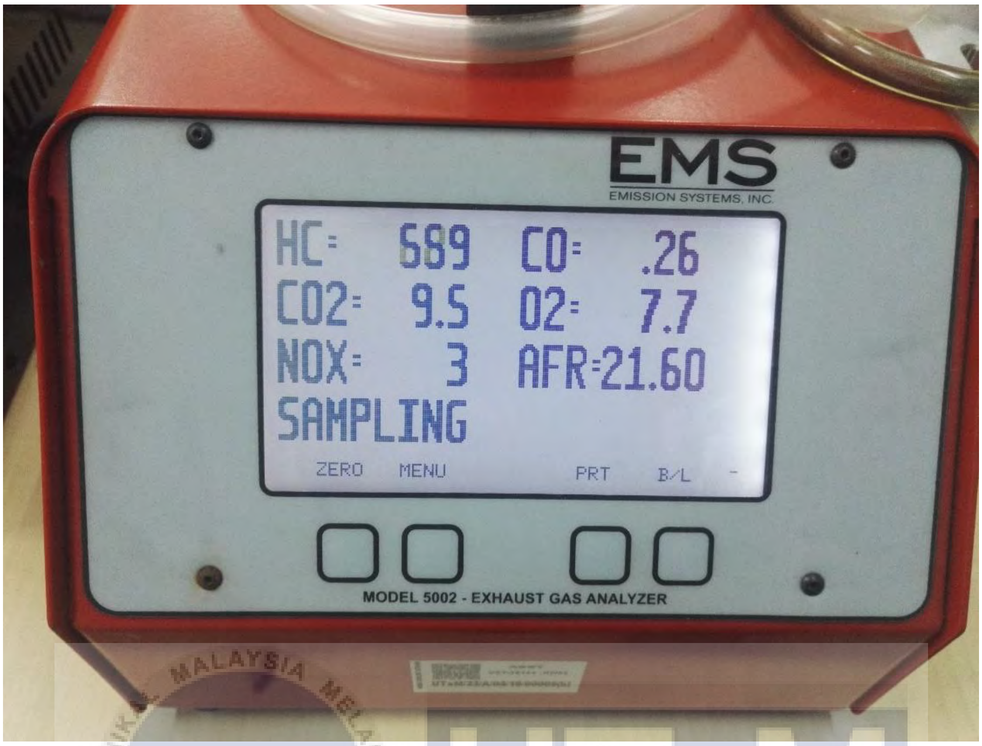
Appendix E: Pressure gauge of dynamometer



Appendix F: Monitor of data acquisition of engine dynamometer

Appendix G:Probe was inserted in exhaust pipe

Appendix H: Data were recorded by portable exhaust gas analyzer



Appendix I: Blower was switched on to decrease the engine temperature