CHAPTER 1

INTRODUCTION

1.1 Project Background

Farrington Daniels, a professor of Chemistry at the University of Wisconsin made a remark that few people paid attention to: *"… our fuels were produced millions of years ago and through geological accident preserved for us in the form of coal, oil and gas. These are essentially irreplaceable, yet we are using them up at a rapid rate. Although exhaustion of our fossil fuels is not imminent, it is inevitable"* [1]. Many regarded his remark as the usual doomsday commentary of the day.

Increasing concerns about global climate change and energy security call for cost effective new approaches to reduce the consumption of fossil fuels in cars and other light duty vehicles. Cost effective approaches using near term technology are needed to achieve the widespread use necessary to meet the goals for reduced fossil fuel consumption. Ethanol could play an important role in meeting these goals by enabling a substantial increase in the efficiency of spark ignition engines.

1.2 Problem Statement

The world is too dependent on fossil fuels. Malaysia alone consumes on average 515,000 barrels per day (bbl/day) meanwhile produces 770,000 barrels per day (bbl/day) [2]. 1 barrel of oil is approximately 159 litres. Developed and industrialized nations consume more energy than developing or third world countries, this is due to economic growth. Growth in economy will push the thirst for this kind of energy. At the current global rate of consumption, 80 million barrels per day, take the amount of proven oil reserves and we are faced with a problem.

Recent increase in crude prices has demonstrated the need for countries to look for alternatives for fossil fuels. The barrel price of crude oil is highly volatile, reaching a high of USD$ 129.89 per barrel in 8th of August 2008 while the highest crude price had gone as high as USD$ 151.97 per barrel in 18th of July 2008. Hence the limited resource of fossil fuels had encouraged many countries to develop their own alternative fuel such as bio-ethanol in order to compensate the demand in energy for future use.

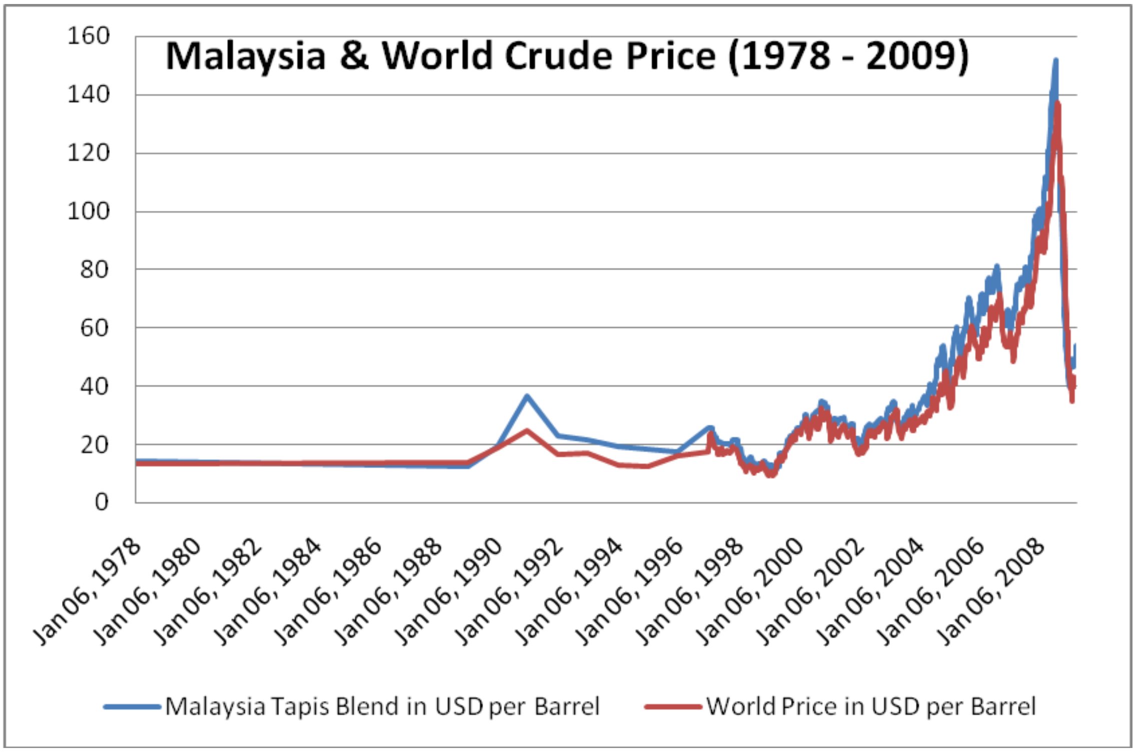


Figure 1: Malaysia & World Crude Price from 1978 until 2009

The figure above shows the Malaysia (Tapis Blend) and World crude price from year 1978 until 2009 (present). It is acknowledged that the crude price went sky-rocketing in year 2008 aforementioned and then gradually decrease to USD$ 53.94 and USD$ 50.10 for Malaysia and World crude price on 27th March 2009, respectively. Even though the crude price is decreasing, there is no assurance that the price will went up sky-rocketing again in the next few years. By looking at weekly data for crude prices from 7th January 2000 to 27th December 2002 (refer to Figure 1 in Appendix), the behavior of crude prices showed that there was a bit stability, around a mean of US$27 per barrel. However, from 3rd January 2003 to 18th July 2008, the crude prices went strong upward deterministic trend, with prices rising progressively to cross USD$ 151.97 per barrel mark in 18th July 2008 and showing no sign of stability around a mean. As from 25th

July 2008 to 27th March 2009, the crude prices were gradually decreasing with latest price of USD$ 53.94 per barrel. Although this is a good news to the world with the fact that the price has decreased nowadays, the price might someday increased again by the same trend which happened throughout 2003 till 2009.

The crude prices might fluctuate again in the future but the fact that the consumption of the fossil fuel will continuously increase is to be aware of and not be taken for granted. Consequently the development of alternative fuels must be done in order to compensate our proven crude reserve with daily consumption. Waiting for the time when the maximum rate of global petroleum extraction is reached, after which the rate of production enters terminal decline (refers to "peak oil") while doing nothing is something that must be avoided.

Bio-ethanol is an effective substitute for the conventional gasoline as it can be extracted from natural resources. Red Caveney, the President and CEO of American Petroleum Institute, stated in the Congressional Testimony *"…renewables utilized in gasoline (ethanol) play an important role and will continue growing well into the future"* [3]. Using blended mixture of ethanol with gasoline must be studied in order to determine the fuel efficiency and the engine performance. Ethanol is well known in recent years as prospective material for use in automobiles as an alternative to petroleum based fuels.

1.3 Objectives and Scope of Study

The main objective of the project is to study the performance of spark ignition engine by using ethanol blended with gasoline. The engine performance in which becomes the focus in this study is the fuel consumption, engine's torque and the power produced. Experiment will be conducted for various blended mixtures of ethanol with gasoline which are E-0, E-5, E-10, E-15, E-20 and E-85, by percentage volume. Then, the result will be analyzed to investigate the relationship between the ethanol-gasoline blends percentage with the engine parameters aforementioned.

The word 'E' stands for ethanol and the number that comes after the dash stands for the percentage of ethanol by volume that contains in the blend mixture. There is a reason behind the selection of blend percentage up to 20%. If there is any ethanol addition beyond this blend percentage, it will require modification to the fuel system due to the chemical properties of ethanol itself which is corrosive [11]. The presence of high concentration of ethanol in the fuel blend will attack the fuel system of which is mostly made of rubber and plastic. Since the modification on the fuel system might find to be bothersome to the consumers, any blend percentage more than 20% is out of the scope of this study. However, the curiosity of the results in terms of engine performance of blend percentage more than 20% has provoked to investigate as the extreme blend percentage (E-85) in the experiment.

The scope of study in this project is to study the ethanol's chemical and physical properties in order to compare with that of conventional gasoline. This study will help in determining the advantages and disadvantages of ethanol over gasoline. In addition, fundamental understanding of spark ignition engine must be studied in order to know the performance in terms of torque and power produced. Other than that, study on how to determine the fuel efficiency will also be carried out to compare the fuel economy between the various blended ethanol-gasoline mixtures.

CHAPTER 2

LITERATURE REVIEW

2.1 Alcohol Fuel History

Alcohol has been used as a fuel for internal combustion engines since 1872 when Nikolaus Otto invented them [4]. Historically, the first large scale usage of ethanol as fuel occurred during the early 1900's when petroleum supplies in Europe were short. Henry Ford's Model T and other early 1920s automobiles were originally designed to run on alcohol fuels. Henry Ford claimed that ethyl alcohol was "the fuel of the future" and expressed his opinion in the article "Ford Predicts Fuel from Vegetation" in New York Times.

According to Henry Ford (1925)

> The fuel of the future is going to come from fruit like that sumac out by the road, or from apples, weeds, sawdust -- almost anything. There is fuel in every bit of vegetable matter that can be fermented. There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the fields for a hundred years. (p. 24)

After World War II, oil prices decreased which caused the use of ethanol to decrease as well. The limited use of ethanol continued until the oil crisis in 1973. The oil crisis showed the fact that the world was extremely dependent on fossil fuels. The focus shifted once again to alternative fuels such as ethanol. At that time gasoline containing ethanol was called "gasohol".

2.2 Properties of Ethanol

Ethanol is a volatile, colorless liquid that has a strong characteristic odor. It burns with a smokeless blue flame that is not always visible in normal light. The physical properties of ethanol stem primarily from the presence of its hydroxyl group and the shortness of its carbon chain. Ethanol's hydroxyl group is able to participate in hydrogen bonding, rendering it more viscous and less volatile than less polar organic compounds of similar molecular weight.

Table 1: Properties of Ethanol and Iso-octane

Properties	Gasoline (Iso-octane)	Ethanol
Chemical Formula	C_8H_{18}	C_2H_5OH
Molecular Weight	114.15	46.07
Appearance	Colourless liquid	Colourless liquid
Density, g/cm^3	0.688	0.789
Oxygen content, wt%	0	34.8
Melting Point, °C	-107.38	−114.3
Boiling Point, °C	99.3	78.5
Solubility in water	Immiscible	Fully miscible
Lower Heating Value, MJ/kg	42.7	26.8
Heat of Vaporization, MJ/kg	0.18	0.93
Stoichiometric Air-Fuel Ratio	15:1	9.0:1
Research Octane Number (RON)	90-100	110
Motor Octane Number (MON)	80-90	90
Anti Knock Index (AKI)	90	100

2.3 Anti-Knock Index

Usages of ethanol as a fuel for spark ignition engines have some advantages to compare with the gasoline. One of the obvious advantage is that ethanol has better anti-knock characteristics than gasoline, which is 110 compared to 92 for regular gasoline and 97 for premium gasoline. Octane rating is a measure of the resistance of gasoline and other fuels to auto-ignition in spark ignition internal combustion engine [4]. High performance engine have higher compression ratio, therefore more prone to "engine knocking", hence require higher octane fuel. Lower performance engine will not perform well with high octane fuel since the compression ratio is fixed by the engine design. The octane rating or better known as anti knock index (AKI) of a motor fuel is given by following formula;

$$Octane\ Rating\ = \frac{RON\ Number + MON\ Number}{2}$$

Premature detonation, or engine knocking, occurred when the fuel-air mixture ignites spontaneously toward the end of the compression stroke because of intense heat and pressure within the combustion chamber. Since the spark plug is supposed to ignite the mixture at a slightly later point in the engine cycle, pre-ignition is undesirable, and can actually damage or even ruin an engine.

In the experimental study by Serdar *et al.* [5], a single cylinder spark ignition engine was used in order to investigate the effect of usage of unleaded gasoline (E-0) and unleaded gasoline-ethanol blends (E-10, E-20, E-40 and E-60). The experiments were performed at variable ignition timing at a constant speed of 2000 rpm. From the results, the experiment performed with E-40 and E-60 ethanol blends were not observed knock formations with MBT (Maximum Brake Torque timing). When the ignition timing increased above the MBT, the knock phenomena can be seen with E40 and E60. Hence, it can be concluded that higher octane number of ethanol and blends compared with gasoline yield better detonation resistance.

2.3.1 Cause of Engine Knocking

During normal burning of fuel in the combustion chamber, the spark plug starts the burning process. A wall of flame spreads out in all directions from the spark (moving outward almost like a rubber balloon being blown up). The wall of flame travels rapidly outward through the compressed mixture until all the charge is burned. The speed with which the flame travels is called the flame speed or the rate of flame propagation [6].

If the flame travels too rapidly through the mixture (rate of flame propagation is too high), the pressure will increase too rapidly. The rapid pressure reached causing the last charge to detonate, or explode with hammer-like suddenness. The effect is almost the same as if the piston head had been struck a heavy hammer blow. In fact it sounds as though this had happened. The sudden shock load due to detonation of the last part of the charge increases wear on bearings and may actually break engine parts if the knocking is severe enough.

2.4 Oxygenates Additive

One of the most important additives to improve fuel performance is oxygenates (oxygen containing organic compound). Several oxygenates have been used as fuel additives such as methanol, ethanol, ethyl tertiary butyl alcohol (ETBE) and methyl tertiary butyl alcohol (MTBE). From the past study of the effect of oxygenates on fuel economy, it is proven that by using gasohol or specifically, E-10 (ethanol 10% and gasoline 90% by volume), the fuel economy is less 2% to 5% compared with using gasoline. It is due to lower mass energy density of ethanol than gasoline. However, the interesting fact is that by using ethanol as fuel additive can make a contribution of improvement in the fuel economy from 1% to 4% [7].

Methyl tertiary-butyl ether (MTBE) was authorized by USA for use as a gasoline additive in late 1979 (Braids, 2001). From then on, MTBE has been used worldwide for its compatibility with gasoline and functional benefit to the fuel’s chemical and physical characteristics. MTBE, as an oxygenate additive in gasoline, has been forbidden adding into gasoline since 31 December 2002 and 1 January 2004 in California and New York, respectively, since its presence in the exhaust gas when MTBE containing gasoline is used [8]. Furthermore, MTBE not only has high mobility in aquatic environment and drinking water system due to its solubility and lack of polarity, but also has resistance to decomposition for it is not significantly affected by microorganisms. This adds cost and longevity to gasoline cleanups and moreover, inhalation of MTBE at high concentrations may have adverse health effects. Therefore, it is necessary to find a substitute for MTBE. On all aforementioned accounts, the additive of ethanol has better effect than MTBE on the regulated emissions for using as a gasoline oxygenate additive.

From ethanol chemical formula, C_2H_5OH, ethanol has 34.8% oxygen content [9]. Due to the oxygen content in ethanol compared to gasoline, ethanol fuel is considered as a predominant alternative to MTBE for its biodegradable, low toxicity, persistence and regenerative characteristic. Since oxygen mass content in an ethanol molecule is approximately twice that of MTBE, less ethanol is required to meet specified oxygen content in fuel.

2.5 Optimum Blending Percentage

Gasohol is the blending mixture of alcohol and gasoline. By blending ethanol with gasoline, better characteristics of fuel are formed while advantages from both fuels are taken into account. M. Al-Hassan [10] studied the effect of ethanol-gasoline blends on spark ignition engine performance. The performance tests were conducted using different percentages of ethanol–gasoline up to 40% with increment of 10% blend percentage under at three-fourth throttle opening position and variable engine speed ranging from 1000 to 4000 rpm. The effect of various blend of ethanol-gasoline in terms of fuel consumption, equivalence air-fuel ratio, volumetric efficiency, thermal efficiency, torque and power produced by the engine will be discussed as in this chapter.

2.5.1 Fuel Consumption

The fuel consumption increases as the ethanol percentage increases for all engine speeds. This behavior is attributed due to the low heating value (LHV) per unit mass of the ethanol fuel, which is distinctly lower than that of the unleaded gasoline fuel. The lower heating value for gasoline and ethanol is 42.7 MJ/kg and 26.8 MJ/kg, respectively [9]. Therefore, the amount of fuel introduced into the engine cylinder for a given desired fuel energy input has to be greater with the ethanol fuel.

As the result of experimentation conducted by M. Al-Hassan [10], the relative increase of fuel consumption rate for E-10 is approximately 3 kg/h for engine speed of 1000 rpm and 12kg/h for engine speed of 4000 rpm. Meanwhile for E-20, the fuel consumption rate is approximately 3.1 kg/h for engine speed of 1000 rpm and 12.2 kg/h for engine speed of 4000 rpm. In other way of interpretation, it means that E-20 consumes 3.3% and 1.7% more fuel than E-10 for engine speed of 1000 rpm and 4000 rpm, respectively. In general, it can be known that with increasing ethanol volume in the blending mixture will increase the fuel consumption.

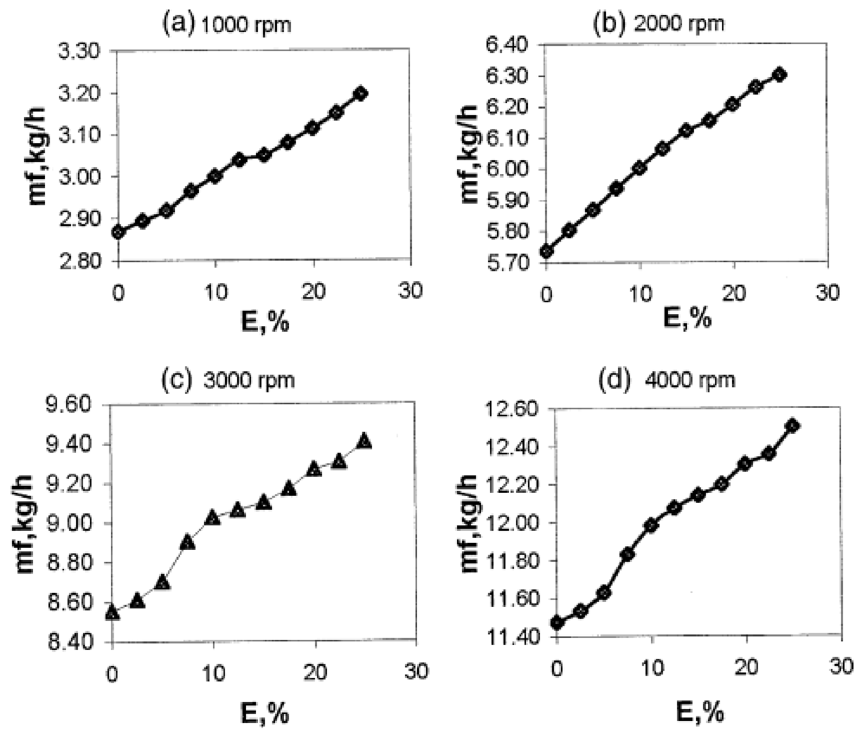


Figure 2: The effect of ethanol addition on the fuel consumption rate by M. Al-Hassan.

The fuel consumption rate increases about 4.5 times as the engine speed increases from 1000 to 4000 rpm. This increment could be explained by the fact that as the engine speed increases, the air velocity increases and the pressure decreases at the carburetor venturi. Consequently, the pressure drop between the pressure at the carburetor venturi and the pressure (atmospheric) inside the float chamber increases, which causes more fuel consumption [10].

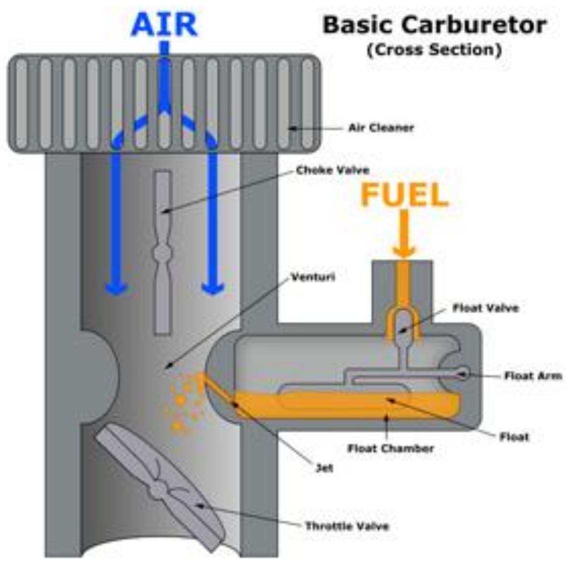


Figure 3: Cross section illustration of a basic carburetor for car.

2.5.2 Equivalence Air-Fuel Ratio

The equivalence air–fuel ratio decreases as the ethanol blend percentage increases. This effect is attributed to two factors. The first factor is the decrease in the stoichiometric air–fuel ratio of the fuel blends. The stoichiometric air–fuel ratio of ethanol fuel is usually lower than that of the gasoline with 9.0:1 and 14.7:1, respectively [11]. The second factor is the increase of actual air–fuel ratio of the blends as a result of the oxygen content in ethanol.

For the percentage of ethanol blends exceeding 20%, the behavior is reversed because the actual air–fuel ratio decreases. From the result of experimentation by M. Al-Hassan [10], as the engine speed increases to 3000 rpm, the equivalence air-fuel ratio decreases. This is due to the amount of air introduced into the engine cylinder increases, increases the pressure drop from atmospheric pressure to cylinder pressure. Therefore, a greater pressure decrease occurs in the cylinder.

Ethanol is an oxygenated fuel, which presents itself an advantage over gasoline. Hence, it has high stoichiometric fuel-air ratio. For this reason, ethanol addition to gasoline leads to leaner operation and improves combustion. In other words, combustion becomes more complete or more stoichiometric, causing the flame temperature and cylinder pressure rise to their maximum values as fuel-air equivalence ratio approaches 1 [9].

2.5.3 Volumetric Efficiency

The engine's volumetric efficiency is the amount of air-fuel mixture taken into the cylinder on the intake stroke [6]. The relationship between ethanol-gasoline blends mixture is that with the increment of ethanol addition to gasoline raises engine volumetric efficiency and causes leaner operation. This is due to the decrease of the charge temperature at the end of the induction process (T_a). This decrease is attributed to the increase in the charge temperature by an amount of T_h as a result of the heat transfer from the hot engine parts and the residual gases in the charge. At the same time, the charge temperature drops by an amount of T_v due to vaporization of the fuel blend in the inlet manifold and engine cylinder. Therefore, the total change in the charge temperature (ΔT) could be expressed by the following simple equation:

$$\Delta T = T_h - T_v \qquad while \qquad T_a = T_h + \Delta T$$

As the ethanol percentage in the fuel blend increases, the volatility and the latent heat of the fuel blend increases. The volatility of a fuel refers to its ability to be vaporized. The latent heat of ethanol is the certain amount of additional heat that it must absorb from its surroundings in order for the change to take place to undergo a change in form, from a liquid to a vapor) [11].

Therefore, with increasing volatility and latent heat of the fuel blend, the drop of the charge temperature T_v increases. At the same conditions, the total heat capacity of the charge increases, since the specific heat of the ethanol fuel is higher than that of the gasoline, and this led to decreases in the drop of the charge temperature T_v. Therefore, increasing the ethanol in the fuel blend has two contradicting effects on T_v. Hence, the value of T_v depends upon which effect is more dominant. Hence, it is clear that as the ethanol blend percentage in the fuel blend increases, the volumetric efficiency increases due to the ΔT decrease and T_v increase [10].

2.5.4 Torque & Power Output

The effect of ethanol-gasoline blends mixture on brake torque and brake power is known that both torque and power increases with increasing of ethanol volume for all engine speeds. However, the increment of torque and power continues until the ethanol blend percentage reaches 20% [10]. After this blend percentage, the torque and power start to decrease slightly. This behavior agrees with that of the volumetric efficiencies aforementioned.

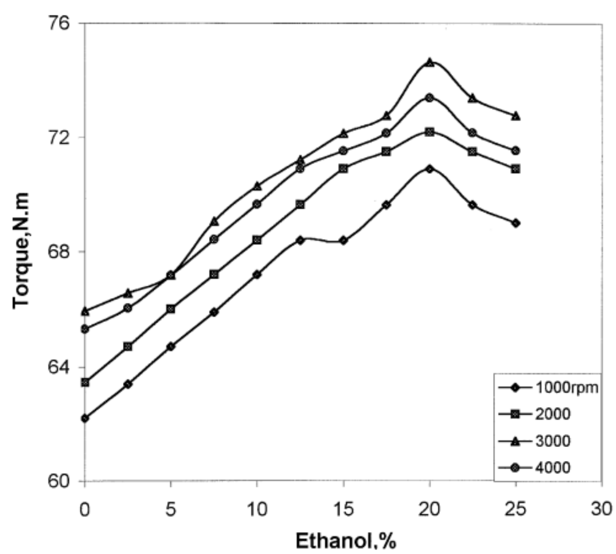


Figure 4: The effect of ethanol addition on the brake torque by M. Al-Hassan.

In general, the brake torque depends on the volumetric efficiency and slightly depends on the engine speed. As a consequence, the influence of engine speed on the brake torque is similar to its influence on the volumetric efficiency. From the following equation, the brake power is calculated by measuring the engine speed and the engine torque and is given;

$$B_p = \frac{NT}{9549.29}$$

Hence, the brake power is proportional to the product of the engine torque and speed, which suggests that the brake power increases as the engine speed increases. The gain of the engine power can be attributed to the increase of the indicated mean effective pressure for higher ethanol content blends. The heat of evaporation of ethanol is higher than that gasoline, this provides fuel–air charge cooling and increases the density of the charge, and thus higher power output is obtained [11]. With the increase in ethanol percentage, the density of the mixture and the engine volumetric efficiency increases and this causes the increase of power.

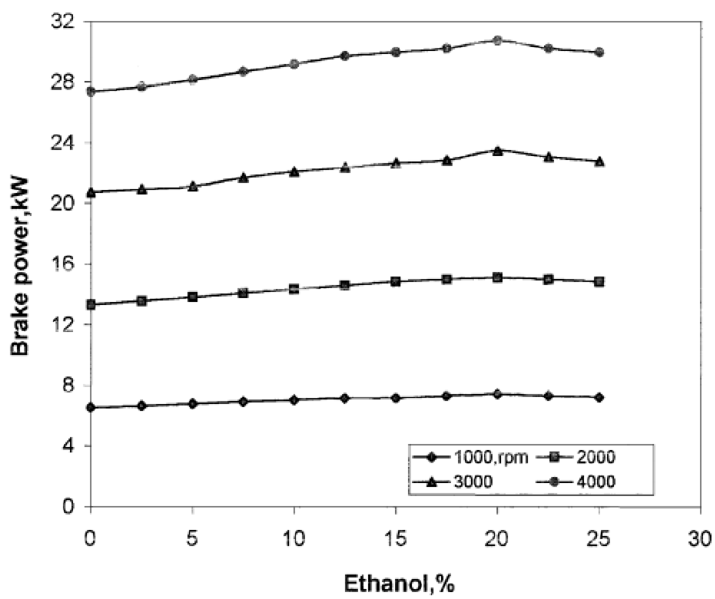


Figure 5: The effect of ethanol addition on the brake power by M. Al-Hassan.

2.6 Availability and Usability of Ethanol as Fuel

As the crude prices went sky-rocketing for the recent years, many countries such as United States of America, Australia, Brazil and Europe have conduct studies in order to commercialize the usage of ethanol as fuel additive as well as blending it with gasoline for certain percentages or gasohol. Any material which can be converted to fermentable sugars and synthesis gas which is mainly consist of CO and H_2 can be used to produce ethanol.

Suitable feedstocks for ethanol production are agricultural products such as corn, sugar cane and grains, agricultural solid wastes, cellulosic materials such as wood and coal. Simple sugars can be obtained from agricultural raw materials by direct treatment or by acid hydrolysis and then they can be fermented by yeast to yield raw ethanol. Furthermore, ethanol can also be produced by fermentation of the synthesis gas, which can be manufactured by gasification of coal [8]. The purity of ethanol produced via fermentation is approximately 96% by volume. To remove the water in the alcohol or to improve the purity of ethanol requires additional costly distillation processes. Such processes further raise the cost of ethanol. For this reason, many studies on the various method production of ethanol from renewable sources are still going on in order to achieve the most effective net energy balance.

Sugar cane and sugar beets are the most common ingredients for ethanol in other parts of the world. Since alcohol is created by fermenting sugar, sugar crops are the easiest ingredients to convert into alcohol. Brazil, the country with the world's largest ethanol production, makes most of its ethanol this way. Today, many cars in Brazil operate on ethanol made from sugar cane. A new experimental process which breaks down cellulose in woody fibers, is called "cellulosic ethanol". With this process we can make ethanol from trees, grasses, and crop wastes. Trees and grasses need less energy than grains, which must be replanted every year. Scientists have developed fast-growing trees that grow to size in ten years. Many grasses can produce two harvests a year for many years.

2.7 Fuel Efficiency

Fuel efficiency is the efficiency of a process that converts chemical potential energy contained in a fuel into kinetic energy or work. The specific energy content of a fuel is the heat energy obtained when a certain quantity is burned. The mass energy density of ethanol is 27 MJ/kg while 42.7 MJ/kg for gasoline which means ethanol has lower miles per gallon [4]. Hence, it takes nearly one and one half gallons of ethanol to equal one gallon of gasoline by ratio, if pure ethanol (ethanol 100%) is used. However, with blending ethanol up to just 10%, this is not a major problem with slightly reduced miles per gallons. Fuel economy can be measured in form of:

- Liters per 100 kilometers (L/100 km)
- MYR per 100 kilometers (RM/100 km)
- Kilometers per liter (kmpl) or miles per gallon (mpg)

According to a 2001 EPA study, only about 15% of the energy content of the gasoline in a vehicle's tank actually moves the car down the road. About two-thirds of the available energy in the fuel is rejected as heat in the exhaust and coolant or frictional losses. Energy is lost to engine friction, pumping losses, drive-train friction and slippage, the operation of accessories such as air-conditioning, aerodynamic drag, tire rolling resistance and idling in traffic. Each of these losses is an opportunity for advanced technology to improve fuel economy [8].

CHAPTER 3

METHODOLOGY

3.1 Process Flow

Methodology plays an important role in completing a project. It is an abstract representation of each system processes. The purpose of having methodology is to guarantee system is developed within the scope planned and ensure consistency of each process. Before the project begins, basic knowledge on the project is learned and understands. This is done through reading text books, journal and thesis in the library or in the internet on the subject matter. The methodology starts with theory understanding and parameters acquisition as shown in Figure 3.

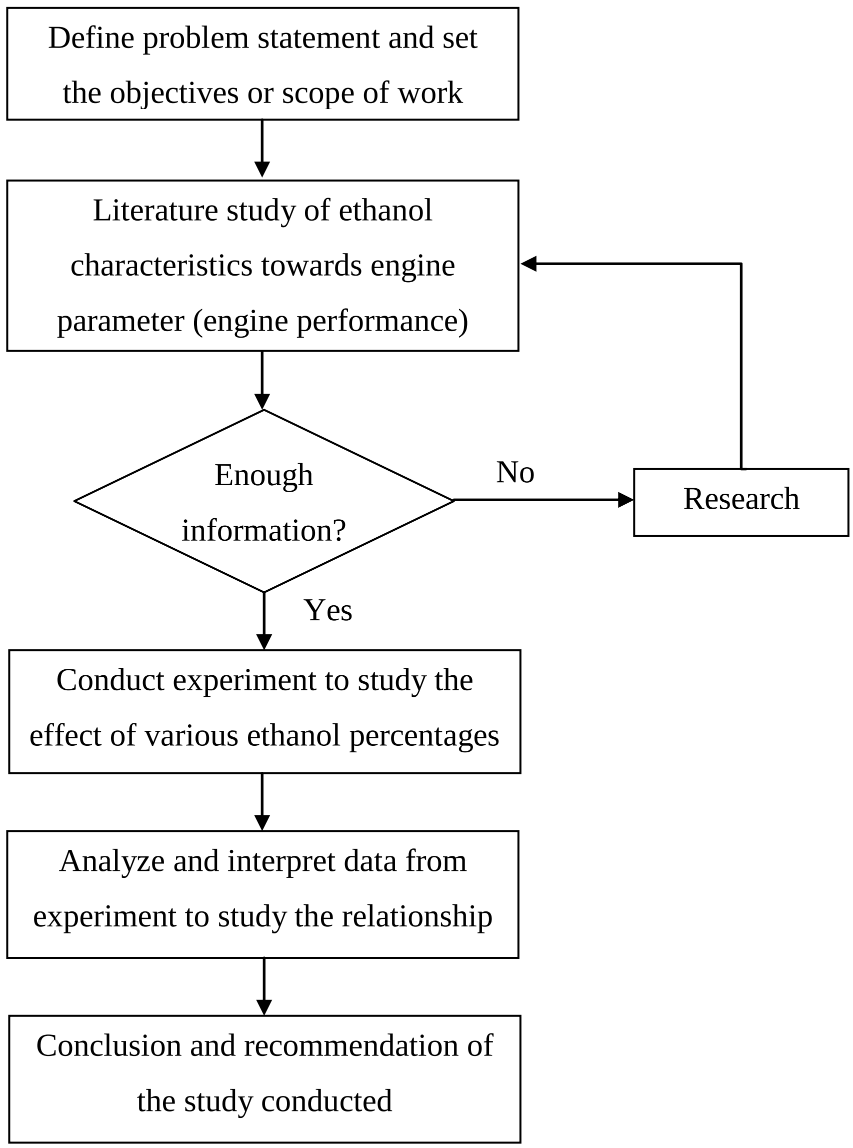


Figure 6: Project Workflow

3.2 Project Planning

Planning and scheduling is very important before any project is taken place. Consequently, planning is essential to decide on what and how to do and to ensure the project could be completed within the given time period while scheduling is needed to manage the activities accordingly.

Table 2: Project Gantt Chart

No.	**Detail/ Week**	**Semester 1**							**Semester 2**						
		2	4	6	8	10	12	14	2	4	6	8	10	12	14
1	**Selection of projects topics**														
	Propose topic	•													
	Topics assigned to student	•													
2	**Preliminary research work**														
	Project background		•												
	Set objectives for project		•												
	Project planning		•												
3	**Literature studies**														
	Study on ethanol properties		•	•	•	•	•	•	•	•	•	•	•	•	
	Study on engine parameters		•	•	•	•	•	•	•	•	•	•	•	•	
	Study on past works done		•	•	•	•	•	•	•	•	•	•	•	•	
4	**Methodology**														
	Equipment familiarization								•	•	•				
	Experiment preparation								•	•	•	•			
	Conduct experiment								•	•	•	•			
5	**Analyze & interpret results**										•	•	•	•	
6	**Seminar**					•						•			
7	**Report submission**							•							•
8	**Oral Presentation**							•							•

3.3 Experimental Setup

It is well understood from the above literature review that using ethanol in spark ignition engines by blending with gasoline is more practical than using it alone. If ethanol production can meet the demand and the cost of blended fuels can compete with that of conventional gasoline, widespread use of ethanol-gasoline blends can be possible. However, before using these blends in engines, the effects on engine must be evaluated. For this reason, the present study is focused on this topic. Here, the effects of ethanol addition to gasoline in various concentrations on engine performance are examined by conducting experimental studies.

3.3.1 Tools and Equipments Required

During experimentation phase, various tools and equipments will be utilized in order to be able to achieve accurate experiment results. Therefore, various tools and equipments need to be identified in order to assist the methodology planning.

The experiment will be conducted by using standard engine test equipment which consists of a dynamometer and measurement instruments. The selected engine speeds or the operation conditions for this experiment are at 1000 rpm, 1500 rpm, 2000 rpm, 2500 rpm, 3000 rpm and 3500 rpm while the throttle valves is maintained at three-quarter opening, envisaged the common driving manner. The experiment will utilize a four cylinder spark ignition engine and the specifications are shown in Table 2;

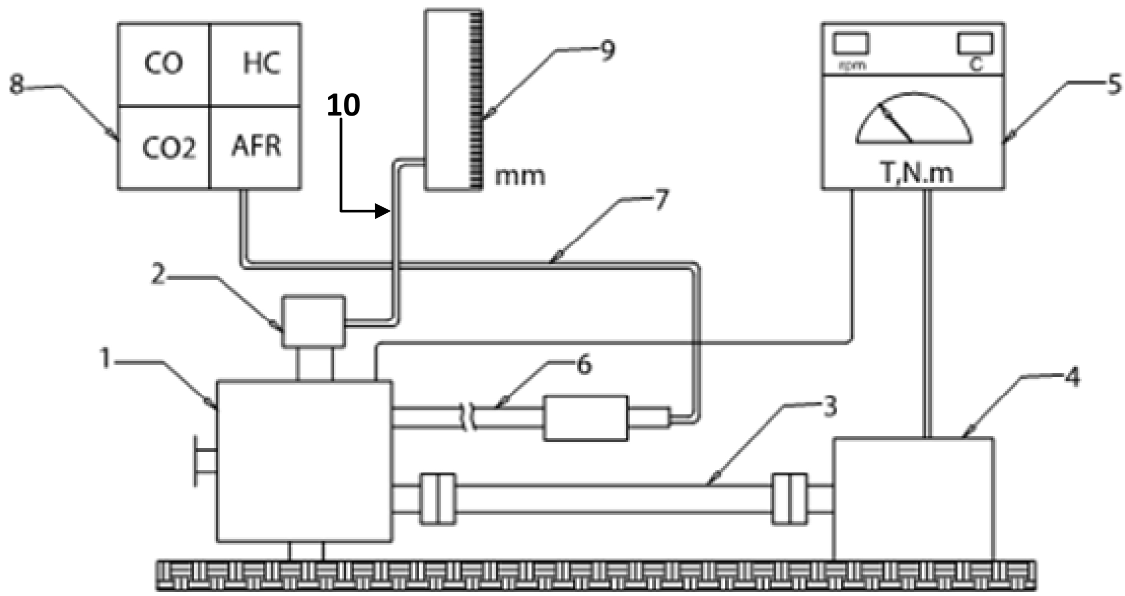
Table 3: Engine Specification

Type	Spark ignition engine
Stroke	4
No. of Cylinder	4
Cylinder Bore	80.6 mm
Cylinder Stroke	88.0 mm
Displacement	1796 cc
Compression Ratio	10 : 1
Fuel system	Direct injection
Max. Power	77 kW at 5500 rpm
Max. Torque	153 Nm at 4000 rpm

In the experiment, the concentration of carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbon (HC) in the exhaust gas will be measured by the gas analyzer. The concentration of each gas is measured continuously and digitally. The air–fuel ratio (AFR) and equivalence air–fuel ratio (Φ) can be calculated by the measurement instrument according to the compositions of the exhaust. The fuel consumption is measured by the control panel of dynamometer. The sample line tube is fitted to the tailpipe 0.3 m away from the exhaust port in order to allow sufficient mixing of the exhaust gases. The engine output power is also metered by the dynamometer.

Two different fuel samples will be experimentally investigated during this study. For the gasoline fuel, iso-octane with octane rating of 90 will be used. Meanwhile, the ethanol with a purity of 95% will be used in preparing the blends. The gasoline will be blended with ethanol to get 6 test blends ranging from 0% to 20% ethanol with an increment of 5%.

3.3.2 Experiment Setup



1	Engine	6	Exhaust Pipe
2	Fuel Injector	7	Sampling Tube
3	Drive Shaft	8	Gas Analyzer
4	Dynamometer	9	Fuel Tank
5	Control Panel	10	Fuel Supply Tube

Figure 7: Schematic diagram of the experimental setup

The ethanol-gasoline blend of 85% is to be considered in order to investigate as the ‘extreme’ blend percentage in the experiment. The selection of blend percentage up to 20% is because any ethanol addition beyond this blend percentage will require modification to the fuel system due to the chemical properties of ethanol itself which is corrosive [11]. The presence of high concentration of ethanol in the fuel blend will attack the fuel system of which is mostly made of rubber or plastic. The fuel blends will be prepared just before starting the experiment to ensure that the fuel mixture is homogenous and to prevent the reaction of ethanol with water vapor.

3.4 Experimental Procedures

The engine is started and allowed to warm up for a period of 10 to 15 minutes. The air–fuel ratio was adjusted to yield maximum power or the maximum brake torque timing (MBT) on pure gasoline (E-0). Engine tests are performed at 1000, 1500, 2000, 2500, 3000 and 3500 rpm engine speed at three-fourth throttle opening position. The required engine load is obtained through the dynamometer control.

Before running the engine to a new fuel blend, it will be allowed to run for sufficient time to consume (flush) the remaining fuel from the previous experiment. For each experiment, three runs will be performed to obtain an average value of the experimental data. The variables that were continuously measured include engine rotational speed (rpm), torque and output power and fuel consumption. These parameters are obtained from the control panel of the dynamometer.

3.5 Fabrication of Mini Fuel Tank

A mini fuel tank that will be utilized during the experiment has been fabricated. The capacity of the mini fuel tank is 10 litres meanwhile the mixture that will be consumed per run is 3 litres. The mini fuel tank is fabricated using water container, 2 PVC joints (3/4”) and 4 pieces of rubber gaskets (3/4”). The pictures of the mini fuel tank are shown in the Appendices.

Below is the table for calculation that has been done for the accuracy of running the experiment:

Table 4: Volume of Ethanol and Gasoline

Percentage of Ethanol	Volume (Litre)	Percentage of Gasoline	Volume (Litre)
0%	0.000	100%	3.000
5%	0.150	95%	2.850
10%	0.300	90%	2.700
15%	0.450	85%	2.550
20%	0.600	80%	2.400
85%	2.550	25%	0.450
Total Volume Ethanol	4.050	Total Volume Gasoline	13.950

CHAPTER 4

RESULT & DISCUSSION

4.1 Experiment Result

The anticipated result can be known from the relationship between the ethanol–gasoline blends percentage with the engine parameters. From the literature review of past studies conducted and reference books, the anticipated result can be summarized as shown in table below:

Table 5: Relationship between Ethanol Additions in Gasoline with Engine Parameter

Engine Parameters	Analysis of the Relationship to Ethanol-Gasoline Blend Percentage
Fuel Consumption	• As the blend percentage increases, the fuel consumption rate will increase
Engine's Torque	• As the blend percentage increases, the brake torque will increase
Power Produced	• As the blend percentage increases, the brake power will increase

4.1.1 Fuel Consumption vs. Ethanol Blend

As stated in Table 5, the fuel consumption will increase as the ethanol blend increases. This is due to the lower heating value (LHV) of ethanol (26.8 MJ/kg) is less than gasoline (42.7 MJ/kg). With increasing of the ethanol blend percentage, the heating value of the blended fuel decreased. The heating value of a fuel is a measure of how much energy we can get from it on a per-unit basis. Hence, more amount of fuel need to be introduced into the engine cylinder for a given desired fuel energy input. In other words, consequently, much more fuel is needed to obtain same performance when ethanol or ethanol–gasoline blends are used.

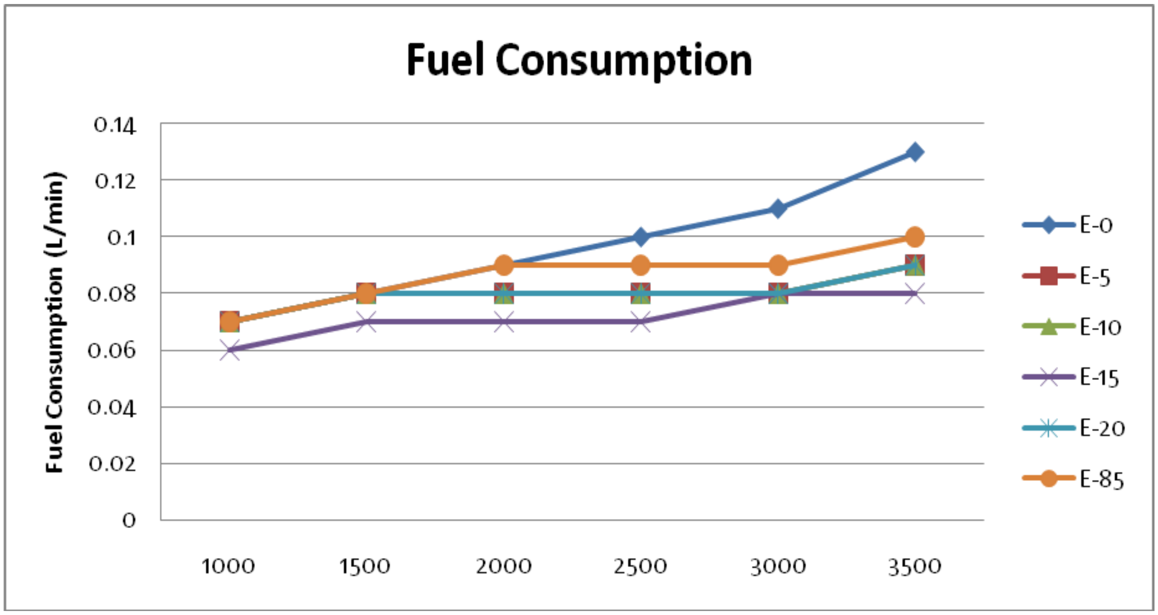


Figure 8: Fuel Consumption Rate vs. Engine Speed

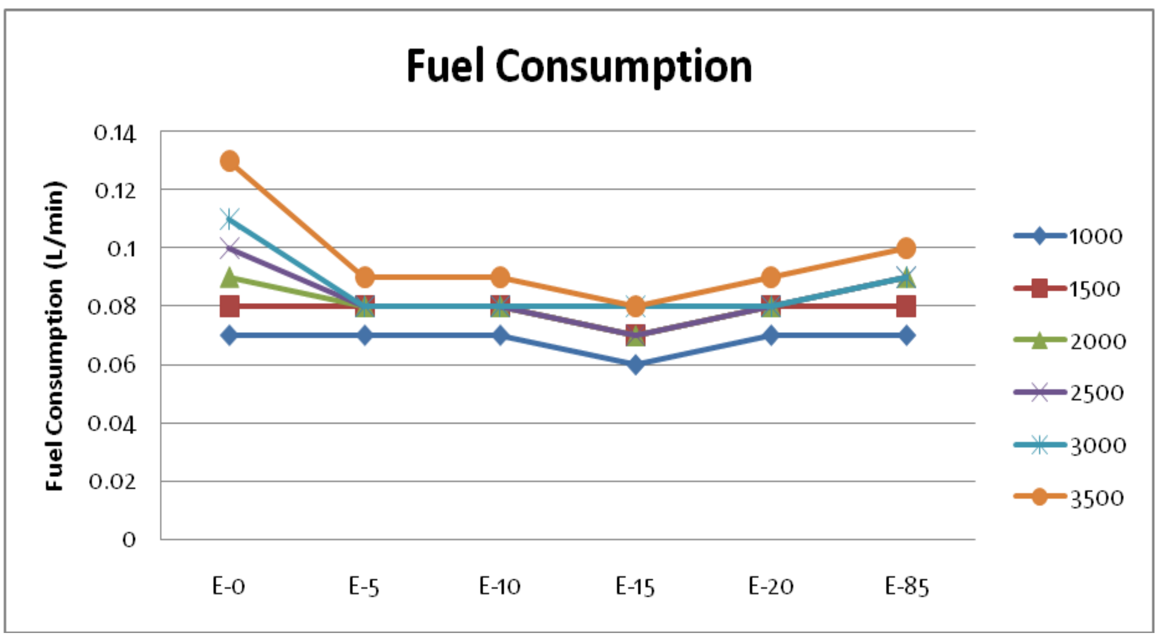


Figure 9: Fuel Consumption Rate vs. Ethanol Percentage

Figure 8 shows the result of fuel consumption rate when the engine speed is increased. From the results, it is known that increasing of ethanol blend percentage in the fuel mixture lowers the fuel consumption. The highest fuel consumption shown is the Figure 5 is E-0 while the lowest fuel consumption is E-15. The low blends of ethanol such as E-5, E-10, E-15 and E-20 showed in the results, yield lower fuel consumption when compared to the extreme blend, E-85.

Based on the literature review, when comparing ethanol to gasoline, it is obvious that alcohol contains only about 63% of the energy that gasoline does mainly because of the presence of oxygen in the alcohol's structure (C_2H_5OH). As a disadvantage for ethanol, the fuel economy or the vehicle range per liter is decreased. Hence, the fuel consumption rate for ethanol is higher than gasoline. In addition, the oxygen content in the ethanol decreases the equivalence air-fuel ratio which means that less oxygen needed to be introduced into the combustion chamber than that of gasoline (9:1 for ethanol compared to 14.7:1 for gasoline).

4.1.2 Engine’s Torque and Power vs. Ethanol Blend

Figure 10 shows the result of engine’s brake torque when the engine speed is increased. From the results, it is known that increasing of ethanol blend percentage in the fuel mixture increase the brake torque. However, the increment of the brake torque is small, less than 10% increment. The highest brake torque shown is the Figure 6 is E-85 while the lowest brake torque is E-0. The highest blend of ethanol, E-85 showed in the results, yield high brake torque compared to the low blends of ethanol.

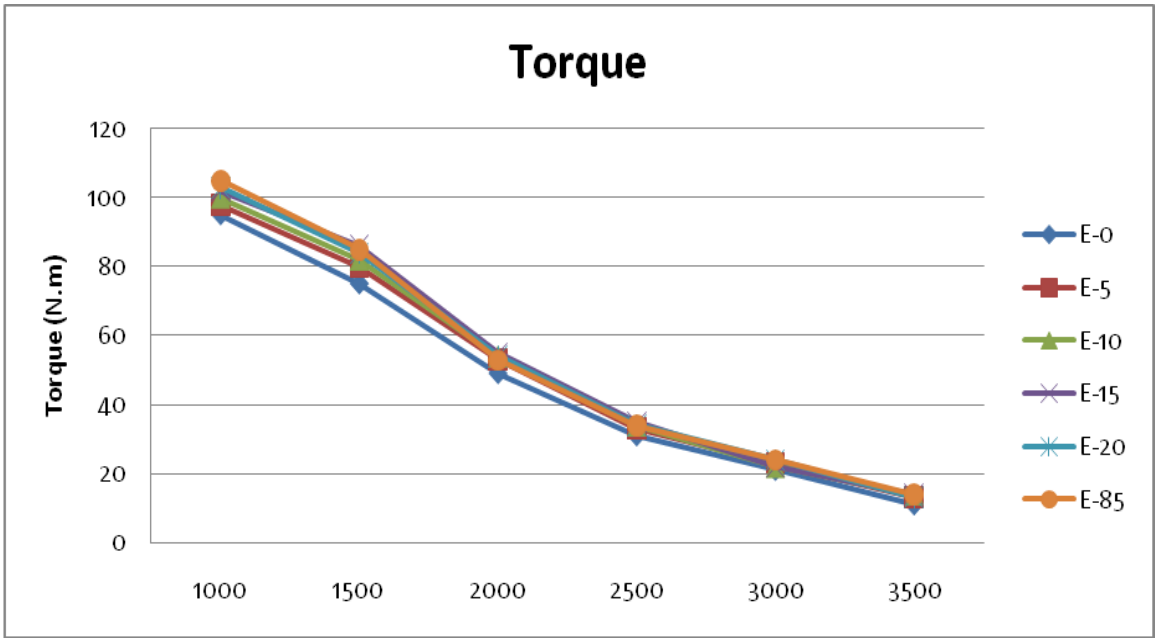


Figure 10: Brake Torque vs. Engine Speed

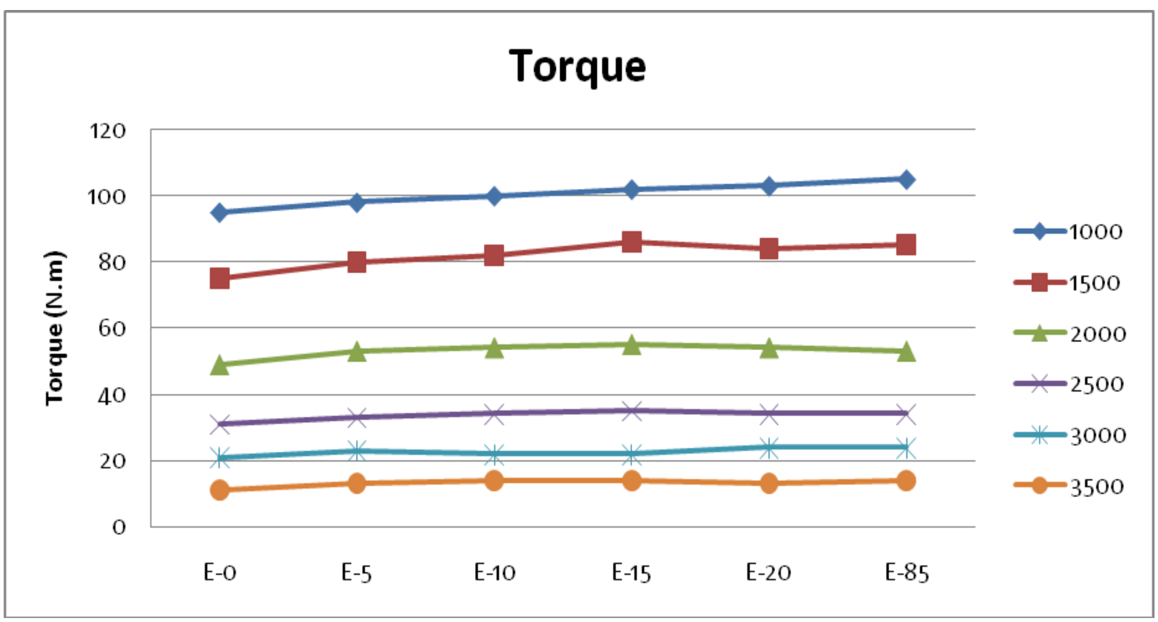


Figure 11: Brake Torque vs. Ethanol Percentage

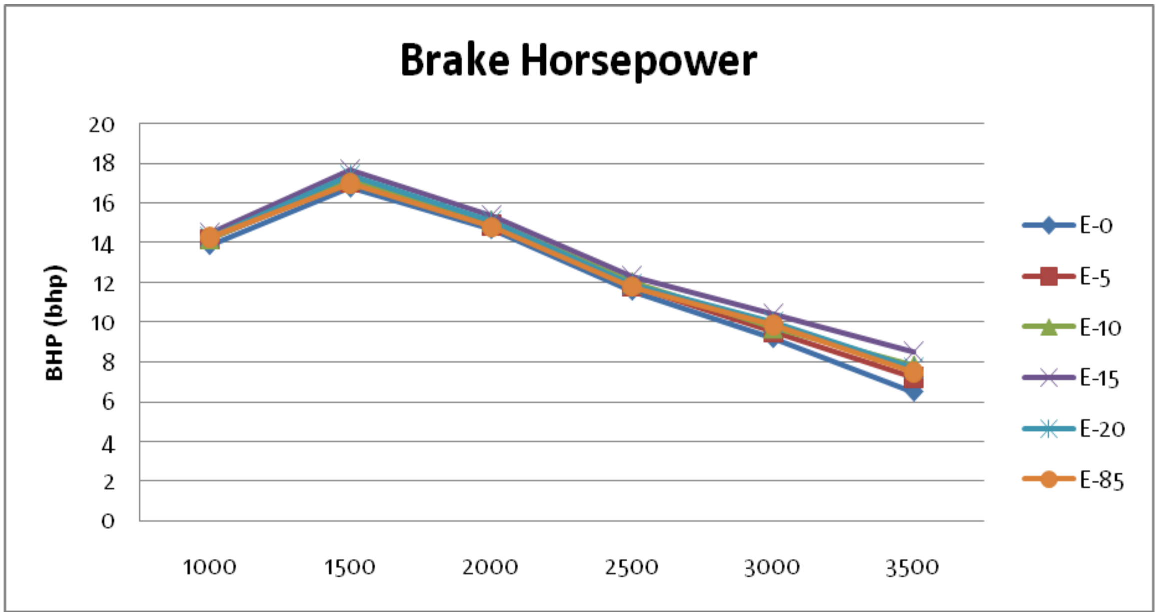


Figure 12: Brake Power vs. Engine Speed

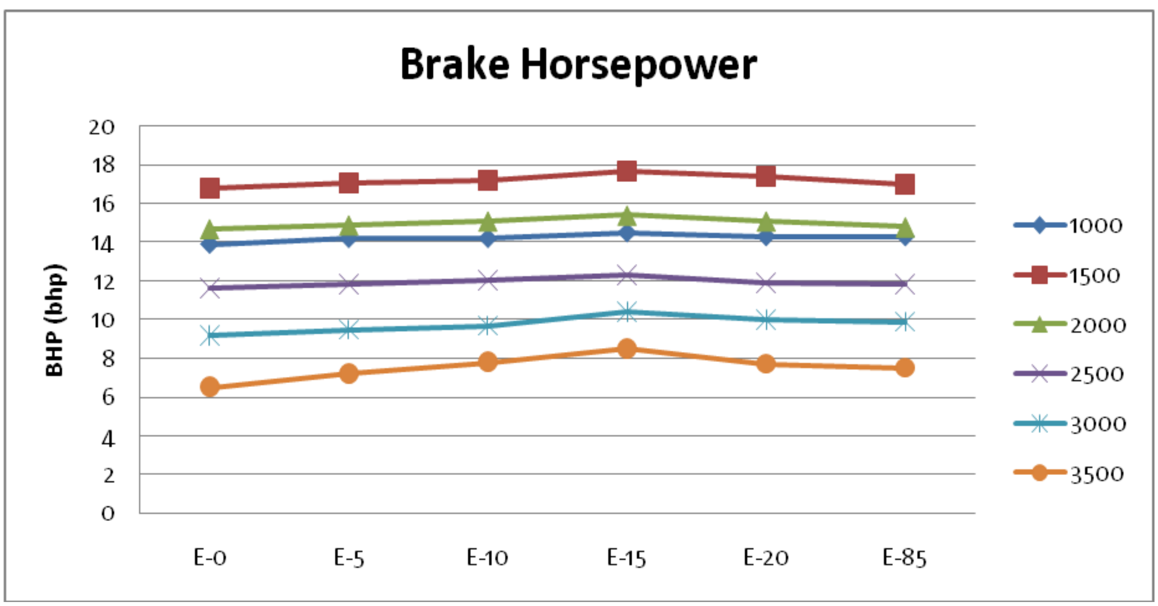


Figure 13: Brake Power vs. Ethanol Percentage

Figure 12 shows the result of engine's brake power when the engine speed is increased. From the results, it is known that increasing of ethanol blend percentage in the fuel mixture increase the brake power. Likewise the brake torque, the increment of the brake power is very small, less than 5% increment. The highest brake power shown is the Figure 6 is E-15 while the lowest brake torque is E-20.

As stated in Table 4, the engine's torque and power produced will increase as the ethanol blend increases. The brake torque depends on the volumetric efficiency and slightly depends on the engine speed. From the Equation (7) in the Appendix, the brake power is proportional to the product of the engine torque and speed, which suggests that the brake power increases as the engine speed increases. This is due to the heat of vaporization of ethanol higher than gasoline (0.93 MJ/kg compared to 0.18 MJ/kg) [11].

Table 6: Results from Experiment

Blend	**Engine Speed**	**Torque (Nm)**	**BHP (bhp)**	**Fuel Consumption (L/min)**
E-0	1000	95	13.9	0.07
	1500	75	16.8	0.08
	2000	49	14.7	0.09
	2500	31	11.6	0.10
	3000	21	9.2	0.11
	3500	11	6.5	0.13
E-5	1000	98	14.2	0.07
	1500	80	17.1	0.08
	2000	53	14.9	0.08
	2500	33	11.8	0.08
	3000	23	9.5	0.08
	3500	13	7.2	0.09

Blend	Engine Speed	Torque (Nm)	BHP (bhp)	Fuel Consumption (L/min)
E-10	1000	100	14.2	0.07
	1500	82	17.2	0.08
	2000	54	15.1	0.08
	2500	34	12	0.08
	3000	22	9.7	0.08
	3500	14	7.8	0.09
E-15	1000	102	14.5	0.06
	1500	86	17.7	0.07
	2000	55	15.4	0.07
	2500	35	12.3	0.07
	3000	22	10.4	0.08
	3500	14	8.5	0.08
E-20	1000	103	14.3	0.07
	1500	84	17.4	0.08
	2000	54	15.1	0.08
	2500	34	11.9	0.08
	3000	24	10	0.08
	3500	13	7.7	0.09
E-85	1000	105	14.3	0.07
	1500	85	17	0.08
	2000	53	14.8	0.09
	2500	34	11.8	0.09
	3000	24	9.9	0.09
	3500	14	7.5	0.1

CHAPTER 5

CONCLUSION & RECOMMENDATION

Regarding from the experiment results, it can be concluded that the fuel consumption decrease as the ethanol blend percentage increases. Meanwhile, for the engine's torque and power produced slightly increases as the ethanol blend percentage increases. The increasing of the engine's torque and power produced with the increase of ethanol addition in gasoline will prove as the advantages of ethanol over gasoline.

From the literature studies, the lower heating value for ethanol is 26.8 MJ/kg, which is 27% less than gasoline. This is due to the oxygen content in the ethanol structure (C_2H_5OH) which is 34.8% by weight. However, this characteristic of ethanol can be exempted as a disadvantage because the oxygen content actually brings ethanol much more advantages over gasoline.

If ethanol can be produced abundantly, economically and efficiently, it will be an attractive alternative fuel for spark ignition engine. It can be used either as a pure fuel or as a blended fuel. Both options can provide some advantages for engine performance, especially on the fuel economy and exhaust emissions. In fact, the ethanol-gasoline blends at low proportions (less than 30%) can be used at instant without any need for engine modification. Consequently, the usage of ethanol-gasoline blends in spark ignition engines is more practical than using ethanol alone due to the combined characteristics. For this reason, presented experimental studies have been focused on the effects of using ethanol-gasoline blends on spark ignition engine performance.

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