EXPERIMENTAL STUDY OF ALTERNATIVE TIRE PYROLYSIS OIL PERFORMANCE OPERATING IN SINGLE CYLINDER DIESEL ENGINE

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Thesis submitted in partial fulfillment of the requirements
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BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **EXPERIMENTAL STUDY OF ALTERNATIVE TIRE PYROLYSIS OIL (TPO) PERFORMANCE IN SINGLE CYLINDER DIESEL ENGNINE**

SESI PENGAJIAN: 2012/2013

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MH09018
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Thank you to my family for all of your kindness and love.

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I acknowledge my gratitude to my parent for their love and patient raising me from I was a child. Give encouragement that they always give on doing what the best for me in the future to carry on my further study in Universiti Malaysia Pahang (UMP).

ABSTRACK

This thesis deals with alternative Tire Pyrolysis Oil (TPO) and diesel fuel that will be use to find out the different performance on single cylinder diesel engine by both fuels. The objective of this thesis is to find out the performance of single cylinder diesel engine in term of torque and power and also to find out the fuel consumption of each fuel. Engine use is YANMAR TF120M that has maximum 12 hp. The thesis then describe on how doing the experiment. Performance of the engine experiment is doing by several engine speeds and the performance of torque and power will be find out automatically by using TFX software. The fuel consumption is measure by calculating the volume flow rate of the fuel by time. By getting this result, the comparison between both fuels can be made and then will figure out either TPO can replace diesel fuel or not in future. The properties of each fuel are figure out either it will affect the performance or not. In diesel fuel engine there are commonly problem that can be occur which is knocking effect and ignition delay. This thesis then will explain detail about the effect of this problem to performance of diesel engine.

ABSTRAK

Tesis ini membincangkan tentang bahan api alternatif Pirolisis Minyak Tayar (TPO) dan bahan api diesel untuk mengetahui perbezaan prestasi pada enjin diesel silinder tunggal. Objektif projek ini adalah untuk mengetahui prestasi enjin diesel silinder tunggal dari segi torque dan kuasa engine serta untuk mengetahui kadar penggunaan bahan api bagi setiap bahan api ini. Menggunakan enjin YANMAR TF120M yang mempunyai maksimum 12 hp. Tesis ini kemudian akan menerangkan bagaimana melakukan setiap eksperimen. Eksperimen bagi prestasi engine dilakukan dengan beberapa kelajuan enjin dan mendapatkan prestasi torque dan kuasa engine menggunakan perisian TFX software. Langkah bagi mengira penggunaan bahan api adalah dengan mengira kadar aliran isipadu bahan api oleh masa. Dengan mendapat keputusan ini, perbandingan di antara kedua-dua bahan api boleh dibuat dan kemudian akan dikenal pasti sama ada TPO boleh menggantikan bahan api diesel atau tidak pada masa depan. Sifat-sifat setiap bahan api akan dijelaskan sama ada akan memberi kesan kepada prestasi engin atau tidak. Dalam enjin diesel biasanya terdapat masalah yang boleh berlaku antaranya fenomena knocking dan kelambatan kadar suntikan bahan api ke dalam engin. Seterusnya, tesis ini akan menjelaskan dengan lebih terperinci tentang kesan masalah ini kepada prestasi enjin diesel.

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LIST OF SYMBOLS

Cs	Centistokes
m	Meter
°C	Degree Celsius
in	Inch
rpm	Revolution Per Minute
°	Degree
hp	Horse Power
Pa	Pascal
W	Walt
N.m	Newton Meter
L/s	Liter Per Second
HO	Hydrocarbon
CO	Carbon Monoxide
NO_2	Nitrogen Oxide
H_2S	Hydrogen Sulphate
H	Hydrogen
S	Sulphur
O_2	Oxygen
SO_2	Sulphur Dioxide
SO_3	Sulphur Trioxide
H_2O	Water
H_2SO_4	Sulfuric Acid
H_2SO_3	Sulfurous Acid
ppm	Part Per Million
L	Liter
KOH/g	Acidity

Kg/m3	Density
PAH	Polycyclic Aromatic Hydrocarbon

LIST OF ABBREVIATION

TPO	Tire Pyrolysis Oil
IGT	Ignition Quality Tester
PM	Particular Matter
HFRR	High Frequency Reciprocating Rig
WSD	Wear Scar Diameter
DTPO	Distill Tire Pyrolysis Oil
CI	Compression Ignition
SI	Spark Ignition
TDC	Top Dead Centre
BDC	Bottom Dead Centre

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Tire Pyrolysis Oil (TPO) is one of alternative fuel that we assume can bring benefit to replace diesel as a fuel for diesel engine. By this way, we can overcome the problem of lack of diesel fuel in the future. TPO is form by using pyrolysis process. This process is the thermal degradation of waste with present of oxygen at high temperature and pressure. Usually the temperature use is about 430°C. The main reason we must searching the alternative fuel is because to minimize the usage of diesel fuel and we hope by this study we can also reduce the rate of pollution. Furthermore, waste tire are increasing by time and this in other way can cause pollution also.

Diesel engine is internal combustion engine that uses compression of heat to ignite the fuel that injected inside the combustion chamber. This engine is totally different compare to spark engine because it does not involve spark to burn the fuel. The air is compresses inside the compression chamber generate high temperature which then burn the diesel fuel when the fuel enter the combustion chamber. These processes of combustion release the chemical energy within the diesel fuel and change it into mechanical energy. In this project, engine that use is single cylinder engine type YANMAR TF 120M. We choose this type of engine because it cheap and can do with more quantity of experiment.

1.2 PROBLEMS STATEMENT

Diesel fuel is a type of substance that cannot be renewed. Rapid adoption of diesel fuel can cause lack of diesel fuel thus make diesel engine not useful anymore. Because of these phenomena, we should think anything that can support or replace the usage of diesel fuel as combustion fluid. The increasing of vehicle because many scrap tires produced and this can be a good way to recycle it into fuel and then mixed it with diesel fuel.

By this doing this project, we will go to find out what is the different of engine performance and the fuel consumption between TPO with diesel fuel.

1.3 OBJECTIVES

i) To investigate the performance of diesel engine by using diesel fuel and Tire Pyrolysis Oil (TPO)

ii) To analyze the fuel consumption of diesel engine operating with Tire Pyrolysis Oil (TPO) compared to diesel fuel

1.4 PROJECT SCOPE

i) Investigate the performance by measuring the engine torque and power

ii) Measure the fuel consumption of Tire Pyrolysis Oil (TPO) and diesel fuel w the fuels are use.

CHAPTER 2

LITERATURE REVIEW

2.1 Diesel Fuel

Cetane number is important in fluid combustion. It is defined to represents the measure of the ignition delay of diesel fuel. Higher cetane number means time of fuel injected and fuel begin to burn is shorter. This means higher cetane number make a good performance to diesel engine. Lower cetane number give performance of diesel engine not efficient because of ignition delay which make difficult to start and engine knock or loss power of engine. Average cetane number is about 25 until 55. Below is some example of cetane number depending on type of diesel:

- Regular diesel ----- 48
- Premium diesel ----- 55
- Biodiesel (B100) ---- 55
- Biodiesel blend (B20) ---- 50
- Synthetic diesel ---- 55

One of way to measuring cetane number is by Ignition Quality Tester (IGT). Diesel fuel will inject into constant volume combustion chamber with the temperature 575°C. Time taken for combustion start is measure when the high rate of pressure changes and for time taken the fuel combust is when the fuel start injected. Time difference between this two then been used to calculated the cetane number using empirical inverse relationship to ignition delay.

Other important characteristic is the volatility of diesel fuel. The volatility of the fuel is determined in term of temperature. The boiling range of fuel depend on the chemical composition of the fuel itself and this will influence others properties such as density, viscosity, cetane number and auto ignition temperature (the minimum temperature to ignite the fuel). When the volatility of the fuel reduced, it will increase hydrocarbon (HO) and carbon monoxide (CO) emissions and a slightly decrease in nitrogen oxide (NO_2). Reducing the volatility of fuel does not change on particular matter (PM) emission (can be understood as atmospheric aerosol), thus we can said that the volatility of fuel is a minor factor for determining emission performance.

For a certain fuel, it must have an ideal viscosity because it cannot be too low or too high. Too high fuel viscosity tend to form larger droplet which can increase gear train, cam and other wear on fuel pump because of higher injection pressure. It also give the fuel atomize be less efficient and engine will difficult to start because of poor combustion and increased the exhaust smoke. Fuel with too low viscosity cannot give enough lubrication for precision fit of fuel injection pump or injector then cause leakage or increase wear. Viscosity of diesel fuel is 5.5Cs@40°C.

Flash point is the point of the lowest temperature of fuel to be combust. Lower flash point can make the fuel easily to combust thus make the combustion is more perfectly. Based on Bhatt Prathmesh M*, Patel Paresh D in their research paper about Suitability of Tire Pyrolysis Oil (TPO) as an Alternative Fuel for Internal Combustion Engine, the flash point of diesel fuel is 42°C.

High content of sulfur in diesel fuel is not good for engine. When combined sulfur with water vapor it can cause corrosive wear on valve guide and cylinder liner which can cause early stage of engine failure. This also can give negative effect on nature due to acid rain.

At high temperature sulfur combined with hydrogen to form H_2S and with oxygen to form SO_2:

$$H_2 + S \rightarrow H_2S$$

$$O_2 + S \rightarrow SO_2$$

Engine exhaust can up to 20ppm of SO_2 the combine with oxygen in the air to form SO_3:

$$2\ SO_2 + O_2 \rightarrow 2\ SO_3$$

These molecules when combined with water vapor in the atmosphere then became sulfuric acid (H_2SO_4) and sulfurous acid (H_2SO_3) which cause of acid rain:

$$SO_3 + H_2O \rightarrow H_2SO_4$$

$$SO_2 + H_2O \rightarrow H_2SO_3$$

Cloud point defines as the temperature when the diesel fuel turns cloudy. When the fuel temperature drop to cloud point, paraffin waxes in diesel fuel will start to crystallize and cling together thus make diesel fuel cloudy. This process is known as ‘waxing’ and it is not good for diesel fuel because it can clog filter and block the fuel flow to the engine. To solve this problem, we can use fuel that have lower cloud point or provide enough heat to the tank. By doing this, it can separate clinging wax particle and then the fuel can pass the engine filter. It found out by Bhatt Prathmesh M*, Patel Paresh D in their research paper about Suitability of Tire Pyrolysis Oil (TPO) as an Alternative Fuel for Internal Combustion Engine, contain of sulphur in diesel fuel is 0.32%.

Other characteristic of diesel fuel is lubricity. To minimize the content of sulfur in diesel fuel, it is hydrogenated. This hydrogenation process may remove ionic fuel component that aid lubrication. Problem occur after desulfurized diesel fuel on distributor fuel-injection pump because lack of lubricity. Because of this, it will be replaced with diesel fuel containing lubricity enhancer. Rate of lubricity is measured by using High-Frequency Reciprocating Rig (HFRR method). A fixed, clamped steel ball is ground on a plate by fuel at high frequency. Result flattening magnitudes are Wear Scar Diameter (WSD) measure in μm, specify the amount of wear and also measure the fuel lubricity. Diesel fuel complying with EN590 must have a WSD of $\leq$ 460 μm.

2.2 Tire Pyrolysis Oil (TPO)

Pehlken and Essadiqi(2005) reported that largest market for scrap tire was rubber crumb in Canada during 2003/2004. About 240,000 tons of scrap tires were process to almost 100,000 tons rubber crumb or about 40% of the total scrap tire usages in the market. This show work on recycling the scrap tire to useful one is now having brighter in the future. Thus it a good try to use Tire Pyrolysis Oil (TPO) as alternative fuel changing diesel fuel or it can be combined together. By doing this research we will know either our prediction or assumption about the effectiveness of performance of single cylinder diesel engine by combining the diesel fuel with tires fuel.

Based from Arabiourrutie et al. (1995), state about the problem of waste tires around this globe which about 5×10^6 tons per year. The complex particle of tire makes them difficult to recycle. Other alternative for recycle this tire such as retreading, reclaiming, incineration, grinding and other have been used but all of this have the limitation or significant drawback. Pyrolysis process can be considered as nonconventional way too recycling the tire.

From Murugan et al. (2008) explained about the increasing demand for energy liked stringent emission norm and depletion of oil resources that force researcher to find the alternative fuel for internal combustion engine. Alternative fuel such as alcohols, biodiesel and many more is currently wide now day. Pyrolysis of solid waste is currently in progress now and we may use tire to become another of alternative fuel. Tire Pyrolysis Oil (TPO) contains higher viscosity and sulfur content compare to diesel fuel and with their study came out that diesel fuel can be combined with Tire Pyrolysis Oil (TPO). The maximum concentration in Tire Pryloysis Oil (TPO) blend with TPO-diesel was 70% and the engine fail to operate further than this concentration. The experiment has been conducted in ways to study about the performance, emission and combustion characteristic of a single cylinder diesel engine. From this experiment, it shown that the engine able to run up to 90% Distill Tire Pyrolysis Oil (DTPO) and 10% diesel fuel (DTPO90) and failed to run with 100% DTPO. Increasing of break thermal efficiency will increase the percentage of DTPO blend but lesser the diesel fuel. It noticed about 3% drops in the thermal efficiency. NOx is lower about 21% for DTPO80 and 18% lower for DTPO90 operation compare with diesel fuel. Contain of hydrocarbon and carbon monoxide is higher than diesel fuel. This may because of presence of unsaturated hydrocarbon in DTPO. Tire Pyrolysis Oil (TPO) also made lots of smoke compare to diesel fuel.

Pyrolysis is the process of changing a substance into smaller or less complex molecule by thermally. This process produces three main products such as pyrolysis oil, gas and char. The quality and quantity of the product depend on the reactor temperature and the reactor design. In a certain temperature, the larger hydrocarbon chains break down with addition of oxygen end up with products contain solid, liquid and gases. At temperature 550°C, the product became liquid with a mixture of various hydrocarbons. At above 700°C, the gas will became the main product because of the further cracking of the fluid. Figure 2.1 show exactly the detail about this process.

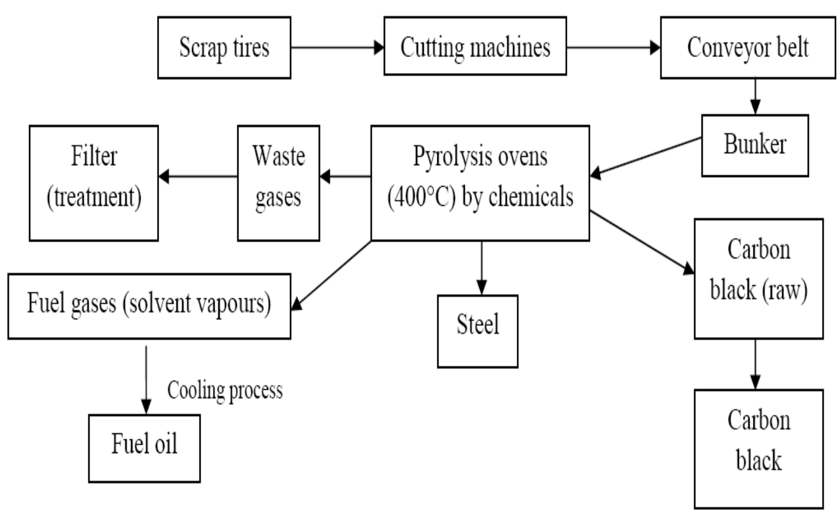

Figure 2.1: pyrolysis process flow diagram

Source: Exhaust Emission of Single Cylinder Diesel Engine by Using Tire,
Mohd Herzwan bin Hamzah

Cetane number of Tire Pyrolysis Oil (TPO) is about 42 that are lower than cetane number of diesel fuel. By this value, theoretically the ignition delay for Tire Pyrolysis Oil (TPO) is longer than diesel fuel and this can cause knocking effect for Tire Pyrolysis Oil (TPO) is more than diesel fuel. It also might come that there are lots of power loss for Tire Pyrolysis Oil (TPO) due to the knocking effect.

Viscosity of Tire Pyrolysis Oil (TPO) is 6.3Cs@40°C that is higher that viscosity of diesel fuel. When we compare both viscosity values, the value of diesel fuel can be accepted because it is not too low or too high. We know that when there is too high of viscosity for fuel, it can increase gear train, cam and other wear on fuel pump because of higher injection pressure. It also contributes for knocking effect of the engine.

Then we look for the flash point of the Tire Pyrolysis Oil (TPO). According to by Bhatt Prathmesh M*, Patel Paresh D in their research paper about Suitability of Tire Pyrolysis Oil (TPO) as an Alternative Fuel for Internal Combustion Engine, it mention that the flash point of Tire Pyrolysis Oil (TPO) is 32°C which is lower compare to the diesel fuel that is 42°C. This is good sign because lower the flash point means easily the fuel can be combust.

Condition of sulphur in Tire Pyrolysis Oil (TPO) is 0.88% that is higher than contain in diesel fuel. This condition can make trouble for the engine where it can make combustion chamber deposits, exhaust system corrosion, and wear on pistons rings and cylinders, particularly at low water-jacket temperatures. Tables 2.1 show the comparison between both properties:

Table 2.1: Comparison Properties for Diesel Fuel with Tire Pyrolysis Oil (TPO)

Standard Euro iv Diesel		**Diesel Sample**	**TPO**
Characteristic	Requirement	Actual Result	
Acidity (mgKOH/gm)	Nil	Nil	Nil
Ash percent by mass	0.01	Nil	0.04
Carbon residue percent by mass	0.3	0.8	0.85
Cetane number	51	52	42
Cetane index	46	48	38
Density at 15°C (kg/m^3)	820-845	828	880
Kinematic viscosity (cS) at 40°C	2.0-4.5	2.59	6.3
Flash Point (°C)	35	42	32
C%		86	84
H%		23	22
S%		0.32	0.88
N%		Trace	Trace
Water content (mg/kg)	200	Nil	Nil
Copper strip corrosion	Not worse than 1	1a	1a
Pour point at winter (°C)	3°C	5	6
PAH % by mass	11	6	24
Sediment % by mass	Nil	Nil	Nil

Source: Bhatt Prathmesh M*, Patel Paresh D, Suitability of Tire Pyrolysis Oil (TPO) As an Alternative Fuel for Internal Combustion Engine

According by this table, we may say that Tire Pyrolysis Oil (TPO) can be used as another fuel to minimize or to replace of diesel fuel. By this, we are going to do the experiment and see how the exactly the effect occur to the engine performance.

2.3 Factors That Affect the Ignition Delay

The first factor that can affect the ignition delay is the compression ratio. Increasing of compression temperature will increase the compression ratio. It also found that when the compression temperature is increasing it will decrease the minimum auto ignition of the fuel. To summarize, compression ignition (CI) engine need high compression ratio to get the minimum possible of auto ignition to make the fuel easily to combust thus shorter the time delay to ignite. But there is some reason that we cannot use to high compression ratio. When compression ratio high it will lower the mechanical efficiency of the engine. Although we can get the minimum auto ignition but if the engine cannot perform well it is no use.

The second factor is by the engine speed. Increasing the engine speed can make the loss of heat during compression decreasing. It then wills increase the temperature and pressure of the compressed air that than reducing the ignition delay. But there disadvantage when have the high engine speed. High engine speed will inject more fuel inside the combustion chamber because the fuel pump is geared to the engine. More fuel is needed to give work to get the engine in high speed.

Other factor is the ignition timing. The injected quality of fuel per cycle is constant. At the beginning of ignition, the pressure and temperature is lower for higher ignition advance. Increasing ignition advance cause longer ignition delay. Optimum ignition advance related to many factor but it commonly at 20° before top dead centre.

Quality of fuel also gives the effect to the ignition delay. Cetane number of the fuel lowers the ignition delay and makes the engine smoother.

The ignition delay related to the engine knock. Knocking in the engine is violet gas vibration and audible sound produce by extreme pressure differential leading to the rapid rise during the early state of uncontrolled second phase of combustion.

2.4 Diesel Engine

Holt D.J (2004) define diesel engine as a four-stroke, compression ignition engine with mixing of fuel and air in the engine. The air is needed for combustion process inside the combustion chamber that occurs with the help of high pressure. Highly pressure inside the combustion chamber generates high temperature which then cause the diesel fuel ignite when it injected to the cylinder. This following process then will release the chemical energy in diesel fuel and convert it into mechanical energy. Diesel engine has 4 stages:

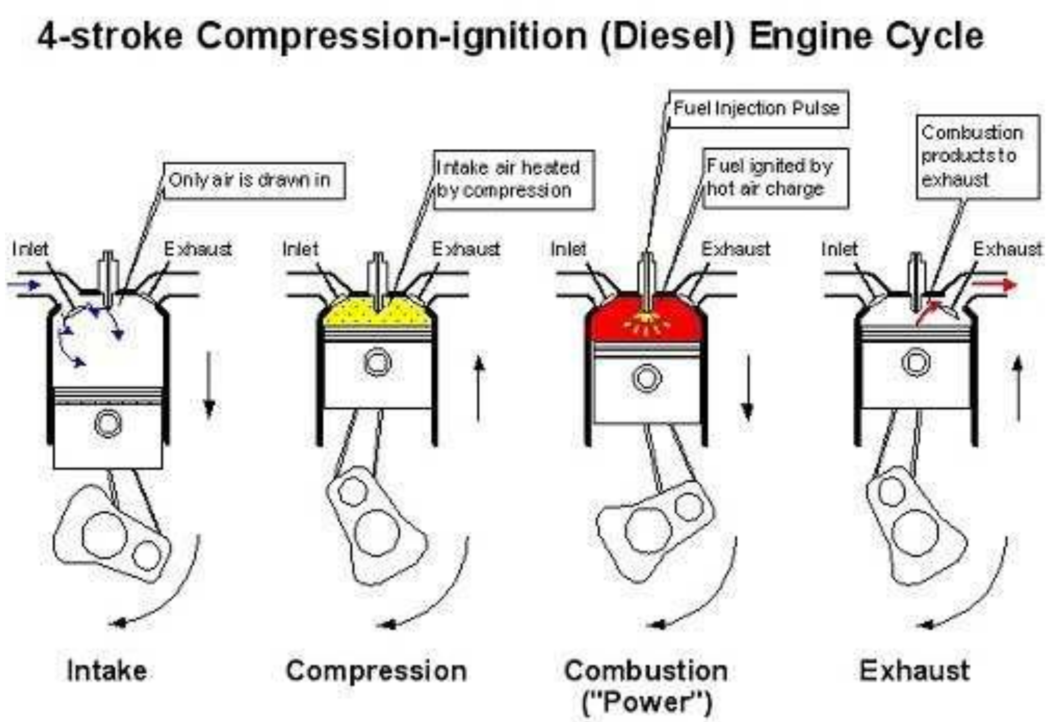

Figure 2.2: Four Stroke Diesel Engine Cycle

Source: Holt D.J (2004)

In intake stage, piston move from top to the bottom of the cylinder. This lowers the pressure inside the cylinder and then forced the air into the cylinder. For compression stage, both intake and exhaust valves is closed. Piston will return to the top position compressing the mixture of air and fuel. At the combustion stage, piston is at Top Dead Centre (TDC). At this stage, the fuel is injected to combustion chamber and ignites because of heat due to the compression. Resulting from the pressure cause by combustion, the piston now forces to move downward to Bottom Dead Centre (BDC). This is the power stroke where the main source of torque and engine power. Lastly, the piston came back to the TDC and the exhaust valve is open. This helps remove away product of combustion from the cylinder by pushing the result of combustion mixture through exhaust valve.

By the research of Bosch at 2005, with the same work, diesel fuel burn less compare to petrol because of higher combustion temperature and compression ratio. Below is the list of advantages:

1. Gasoline engine have 25% efficient on converting fuel energy to mechanical energy engine can give up to 30% more efficient than gasoline engine.
2. High reliability and easy to adapt rough environment because of it have no high-tension electrical ignition system. This engine not use spark plug, coil, wires and etc. make it free radio frequency. Source of radio frequency can interfere with navigation and communication and this is really helpful for the marine and the aircraft area.
3. More power rated can be generated than gasoline engine.
4. Diesel fuel has the better lubrication properties than petrol thus make diesel engine twice more life longer.
5. Less waste heat in cooling and exhaust.
6. More safe because do not release large flammable vapor with can cause explosion. Diesel engine is fewer tendencies to explode.

2.3.1 Compression Ignition (CI) Engine vs. Spark Ignition Engine (SI)

In compression ignition (CI) engine only air in being compress in the compression engine and fuel is injected by using fuel injector pump at high pressure because of the self ignite diesel fuel condition. Fuel is not injected at once for CI engine but it spread over the time. Initial droplet of fuel meet up with air that has temperature above self ignition temperature and the fuel then will ignite after ignition delay. Swirl is required to get the effective CI engine. This will implies an orderly the movement of air particle with particular direction of flow. This carry continues deliver of air to each of burning droplet and then aid swept away the product of combustion. The ignition in this engine happens at various points simultaneously. Other than that, combustion is control by the physical delay of the engine. Also in CI engine, the quantity of fuel is change with load vary to A/F ratio. Lastly, the CI engine need short ignition delay period thus need high cetane number.

It is different with spark ignition (SI) engine where the mixture of air and fuel are compress. Spark plug is needed to ignite the fuel but for CI engine spark plug is not needed. In SI engine, the mixture of air and fuel is igniting at once. SI engine need turbulence than swirl for CI engine. Turbulence can make disorder air motion with no general direction of flow to break up the surface of flame front and the sheared of flame is distributed thought out in externally prepare homogenous combustible mixture. Other than that, the ignitions in SI engine occur at single point only with a slow rise of pressure. Physical delay by this engine is almost zero and chemical delay control the combustion. A/F ratio by this engine stays close to stoichiometric value from no load to full load. Different with CI engine, this engine need long ignition delay period and this make it need low cetane number.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This project use single cylinder diesel engine and by this, we try to investigate or study the characteristic of both fuel.

3.2 Literature Analysis

3.2.1 Journal

This is the main sources that I use to study this project. We may use any the previous study that related to my project. The information about characteristics of diesel fuel, Tire Pyrolysis Oil (TPO) and diesel engine can be determined. This journal is get from Science Direct.

3.2.2 Google Search Engine

The basic tool that I use to get the detail from what I have study from the journals. From this we may know about the topic in an easy way.

3.3.3 Project Supervisor

Not all the information we can understand by just read by our self. It must have some particular thing that we cannot understand. Project supervisor advice is important when it come by this part. The finalized the information and make sure our report follow the rules.

3.4 Engine Rig Design

The engine rig design must be finished before preceding the experiment. The dimension of this must be larger that engine itself because this will be the base. Hollow mild steel is used for fabricate this engine rig. The dimension is 2 in x 2 in.

3.4 Tools

This project is experimental project that focus on emission of diesel fuel combined with Tire Pyrolysis Oil (TPO) and the engine performance with aspect of torque and power and the fuel consumption of this two fuel. Tools that used is disk cutter, MIG welding, hand drill and hand grinder. Disk cutter is used to cut material and MIG welding is use for assemble the parts. Hand drill then is used to make a hole and the hand grinder is for remove the burr after cutting process.

3.5 Fabrication

This process is important before go on to the next steps. A part such as engine rig, display panel table, rack, exhaust manifold and exhaust gas traps.

.

3.6 Exhaust Manifold

Exhaust manifold have been modified because to ensure that thermocouple hole and valve can be inserted.

3.7 Apparatus

3.7.1 YANMAR Engine

This engine is single cylinder diesel engine type of YANMAR TF 120M.

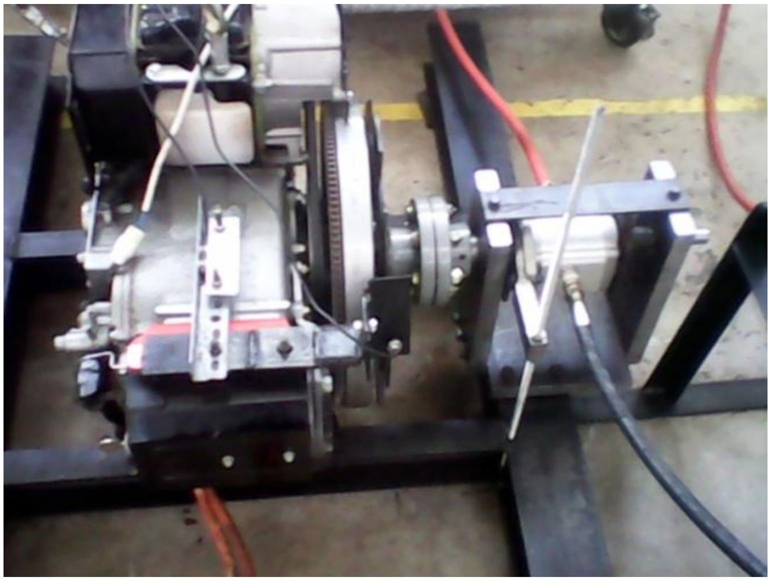

Figure 3.7.1: YANMAR TF 120M Engine

Model	TF120M
Bore x Stroke (mm)	92 x 96
Maximum Revolution (rpm)	2400
Cooling system	Radiator
Combustion system	Direct injection
Lub. Oil Capacity (L/Hours)	2.8
Fuel tank capacity (L)	11
Starting system	Hand starting
Horse Power	12 hp

Table 3.7.1: Engine Specification

3.7.2 TFX Analysis Software

Measure the torque and power of the engine. This software also will show the graph of compression pressure with crank angle.

3.7.3 Tachometer

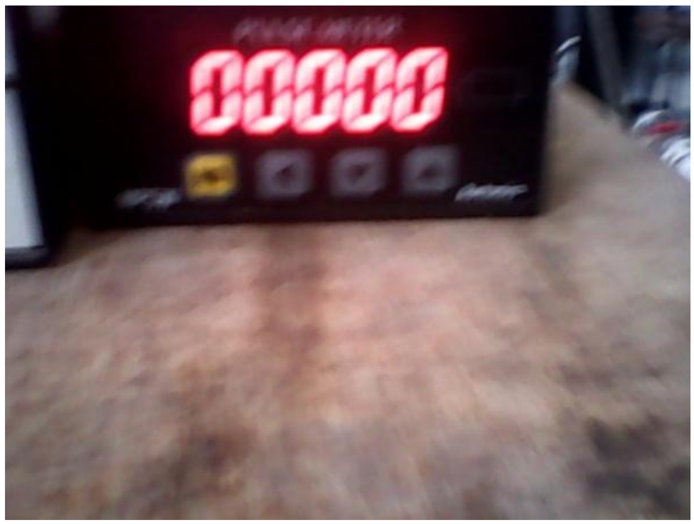

Figure 3.7.2: Tachometer

3.7.4 Fuel Consumption Measurement

Figure 3.7.3: Flow rate

3.8 Fuel

Two fuels are used in this experiment which is diesel fuel and Tire Pyrolysis Oil (TPO).

3.9 Procedures

3.9.1 Torque and Power Analysis

Run the engine with 100% diesel fuel with 1200 rpm and the result will come out based on the data. Repeat this with 1500rpm, 1600rpm, 1800rpm and 2100 rpm. Then the experiment is repeated by using 100% Tire Pyrolysis Oil (TPO). The result is fill in the table on comparison can be made.

3.9.2 Fuel Consumption Analysis

First, the engine is set to be 1100 revolution per minute (rpm). The time taken for 100mL fuel and the fuel consumption can be determined by 100mL fuel to time to consume the 100mL fuel. Amount of fuel consumed for 5 minute is measure from the board computer unit directly. Then we change the engine speed to 1500rpm, 1600rpm, 1700rpm and 2100rpm. Then the experiment is repeated by using 100% Tire Pyrolysis Oil (TPO). The result is fill in the table on comparison can be made. We measure the fuel consumption based on the volume flow rate.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

On this chapter there will be the result for each objective that we want to find out and discussion on what exactly happen on the result. The result from this project is based on experimental. Here we will analyses the torque and power and fuel consumption between Tire Pyrolysis Oil (TPO) and diesel fuel. Parameters than we going to figure out is about the knocking, torque and power and also the maximum pressure. Ignition delay is the period between time injections with the first spark on the fuel. Faster the ignition delay result more completes the combustion process. Knocking phenomena is about incomplete combustion where this will affect the performance of the engine. It usually occurs because of flame quenching at the combustion chamber walls which then leaving some unburned fuel/air mixture. This cause some waste of power because the mixture is not completely combust. In further experiment of diesel fuel we can see this knocking effect occur. In the diesel engine, it is about compression to ignite the fuel. That mean, if we can get more higher maximum pressure than means the power will increasing because of the effect of self ignite diesel fuel engine is based on pressure. We read the result based on line of blue color which represents combustion/compression pressure.

4.2 PERFORMANCE STUDY

4.2.1 Combustion Analysis

A) Diesel Fuel Performance

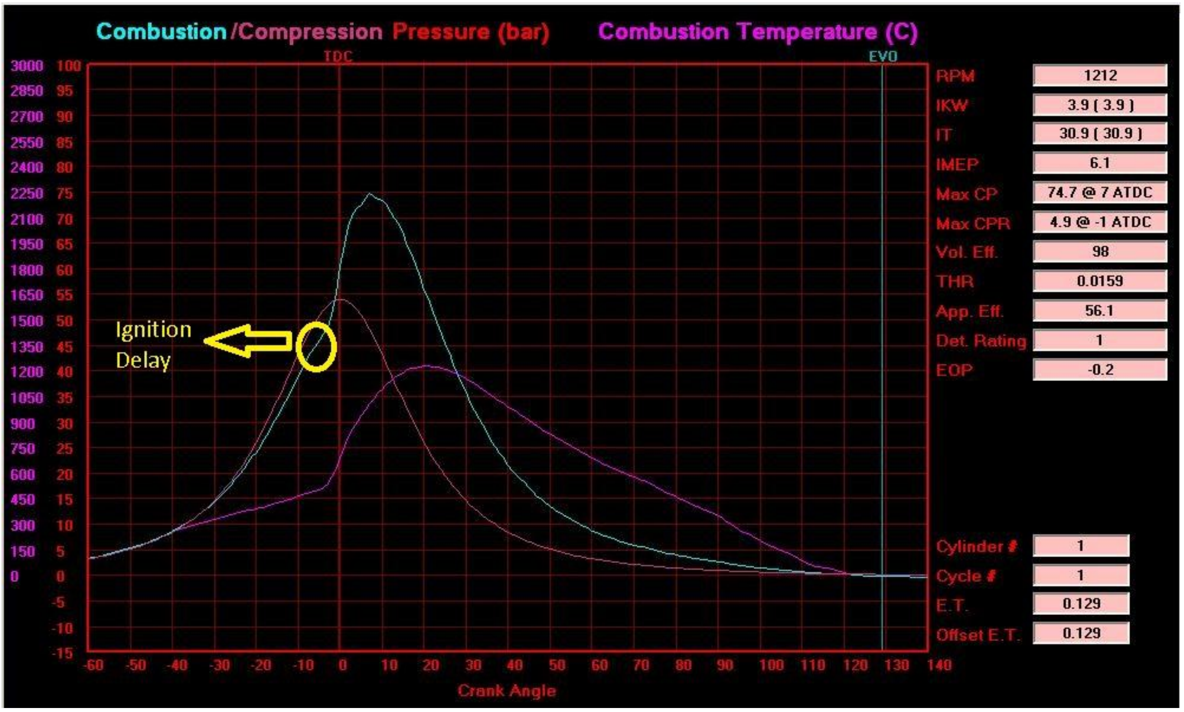

Figure 4.2.1(a): Diesel fuel combustion at 1200 rpm engine speed

Figure 4.2.1(a) show combustion graph of diesel fuel running at 1200 rpm engine speed. The purple line is for combustion temperature, red line for compression pressure and line that we are going to refer is the blue line that is for combustion pressure. Pressure value show by bar at left hand side with red color. Referring to the figure, the ignition delay occurs at -8° to -2° with have different 6°. The maximum combustion pressure is about 73.8 bar@7380kPa at crank angle 7°. The indicate power and indicate torque of this experiment is 3.9hp@2.9kW and 30.9kN.m respectively. In the experiment of diesel fuel with 1200 rpm there is less knocking due to the smooth graph shape after the maximum pressure. So we can say that for 1200 rpm diesel fuel performance is still good in term of efficiency.

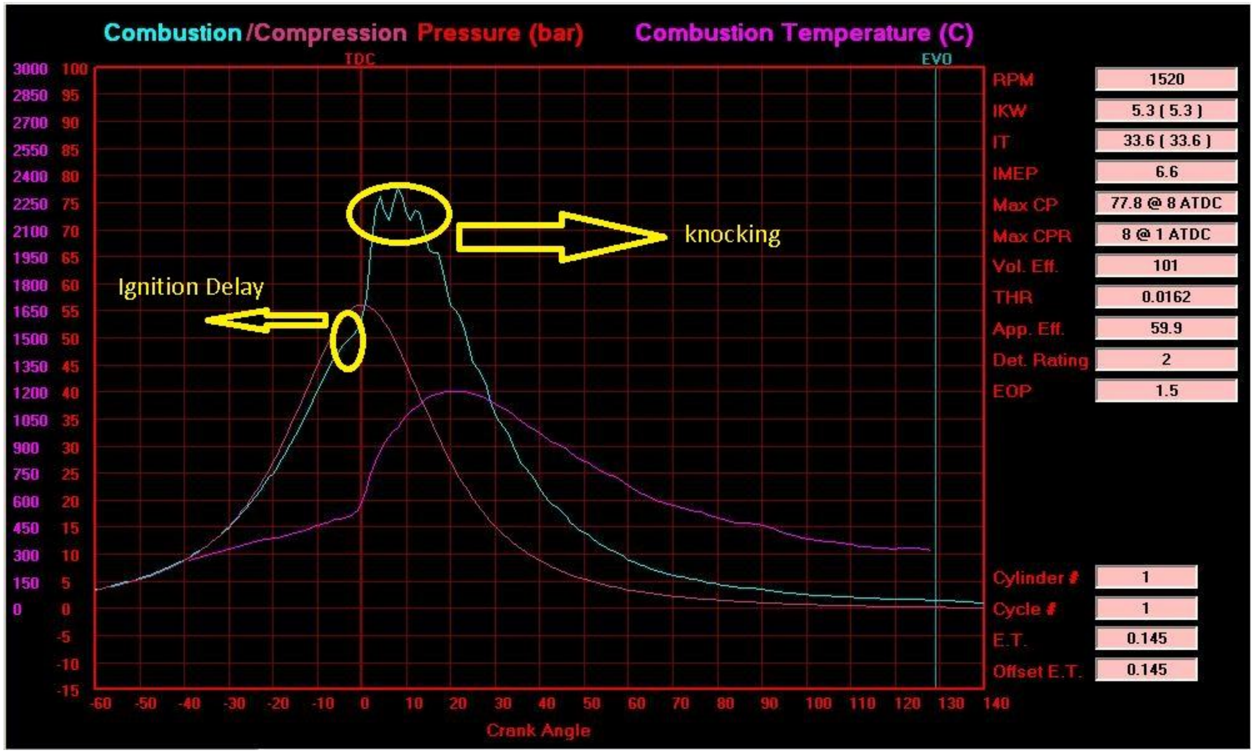

Figure 4.2.1(b): Diesel fuel combustion at 1500 rpm engine speed

Figure 4.2.1(b) represent for graph of diesel fuel combustion at 1500 rpm engine speed diesel fuel. The ignition delays occurs at -5° to -1° crank angle and have different 4°.So the ignition delay at 1500 rpm engine speed is going to get better than 1200 rpm engine speed. For maximum combustion pressure is about 76.2 bar@7620kPa occur at crank angle 8°. The indicate power and indicate torque of this experiment is 5.3hp@4.0kW and 33.6kN.m respectively. Now we could see some different with the shape of the graph when higher rpm. In this engine speed, knocking effect start from 3° crank angle after Top Dead Centre (TDC). This means, knocking start occur when engine speed exceed 1500 rpm.

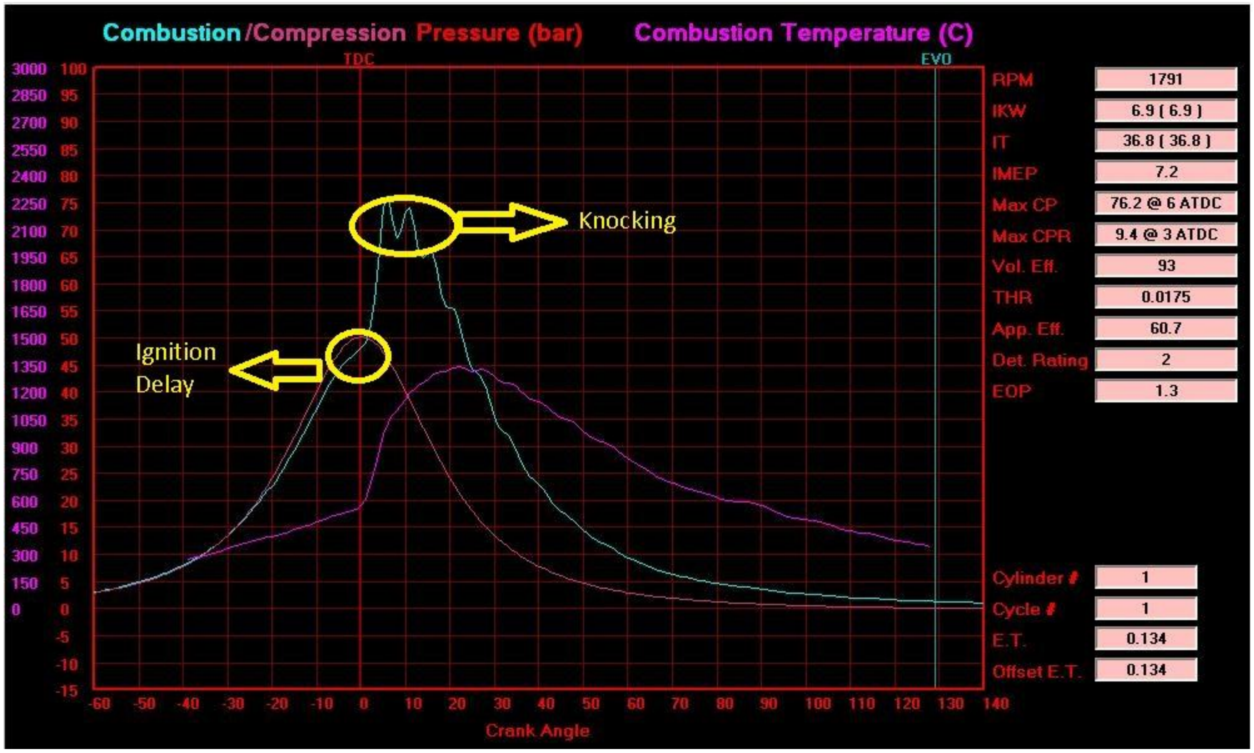

Figure 4.2.1(c): Diesel fuel combustion at 1800 rpm engine speed

Figure 4.2.1(c) show graph of diesel fuel combustion at 1800 rpm engine speed. The ignition delay occurs at -3° to 1° with have different 4°. The maximum combustion pressure is about 74.0 bar@7400kPa at crank angle 6°. The indicate power and indicate torque of this experiment is 6.9hp@5.1kW and 36.8kN.m respectively. In the experiment of diesel fuel with 1800 rpm engine speed, knocking effect start from 6° crank angle after Top Dead Centre (TDC). Now we can see in this result the knocking effect to value of maximum combustion pressure and torque. It shows that knocking effect can decrease the maximum combustion pressure and torque for this engine.

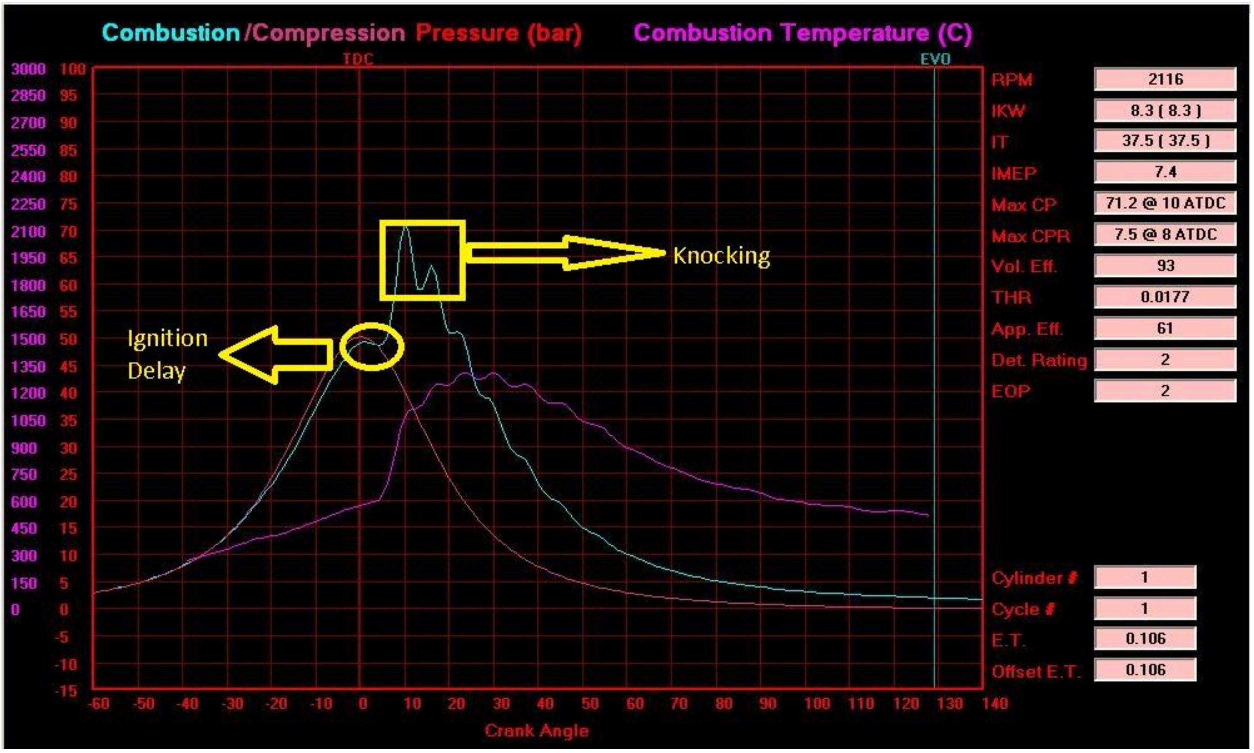

Figure 4.2.1(d): Diesel fuel combustion at 2100 rpm engine speed

Figure 4.2.1(d) for diesel fuel combustion at 2100 rpm engine speed. Ignition delay start occurs at 0° to 4° crank angle with have different 4°. The maximum combustion pressure is about 71.1 bar@7110kPa at crank angle 10°. Then for indicate power and indicate torque of this experiment is 8.3hp@6.2kW and 37.5kN.m respectively. Knocking effect is getting increasing when higher rpm. In this 2100 rpm engine speed, knocking effect start at 13° crank angle after Top Dead Centre (TDC). Although engine run at high rpm at 2100rpm engine speed, the maximum pressure is much lower than maximum pressure at low engine speed. For ideal engine, the result can be differently because effect of knocking is ignore but in actual, higher rpm cause knocking effect getting more worst thus decreasing value of maximum pressure.

Table 4.21(a): Data for torque, power and maximum pressure with engine speed for diesel fuel

Engine Speed (rpm)	Indicate Torque (kN.m)	Indicate Power (kW)	Max. Pressure (kPa)
1200	30.9	2.9	7380
1500	33.6	4.0	7620
1800	36.8	5.1	7400
2100	37.5	6.2	7100

As the engine speed is increasing, the engine power is getting increase but it came differently to maximum pressure. Power of the engine is highest at 2100 rpm that is 6.2 kW and low power at 1200 rpm that is 2.9 kW. As engine speed increasing, torque of engine also increasing. Highest torque appears at engine speed 2100 rpm that is 37.5kN.m. The lowest torque is 30.9 kN.m when engine speed 1200 rpm. Maximum pressure is not stable at engine speed 2100 rpm because the maximum pressure is lower compare to lower rpm. Highest maximum pressure is 7620 kPa with engine speed 1500 rpm and lowest maximum pressure is 7620 kPa with engine speed 1500 rpm. This because of the knocking effect when the engine speed getting higher.

B) Tire Pyrolysis Oil Performance (TPO)

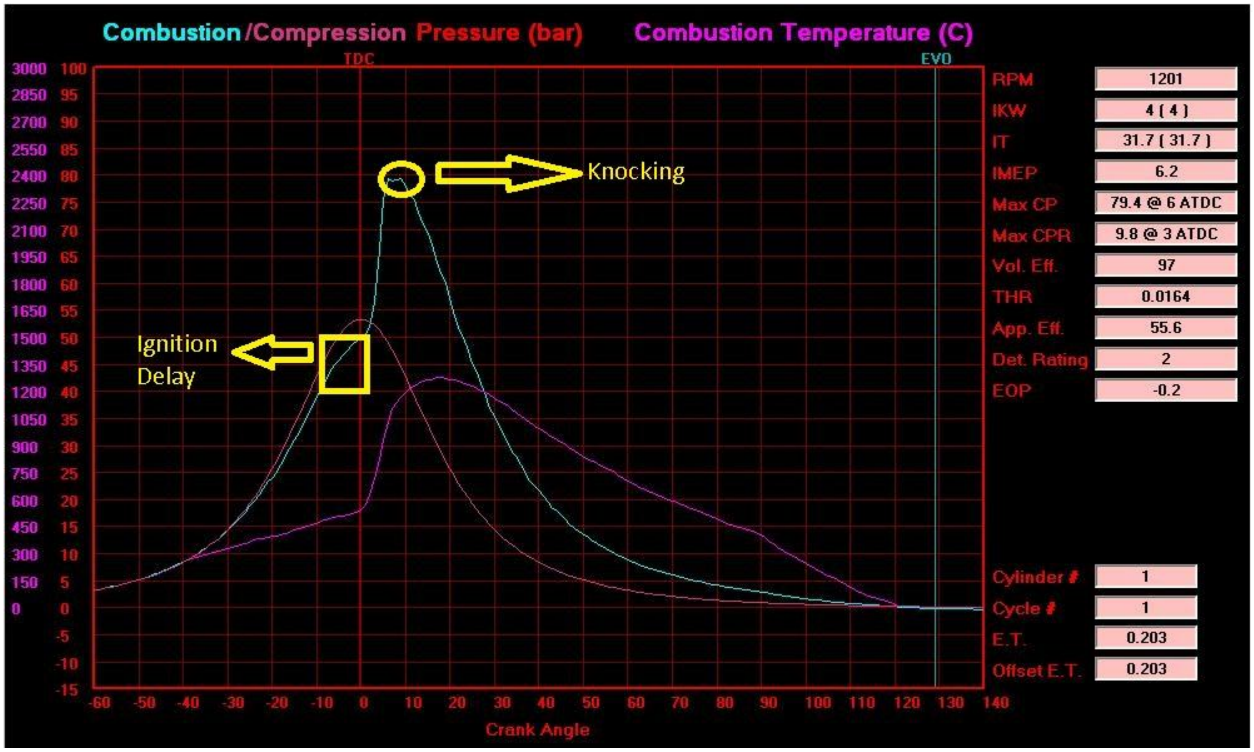

Figure 4.2.1(e): Tire Pyrolysis Oil (TPO) combustion at 1200 rpm engine speed

Figure 4.2.1(e) shows graph of Tire Pyrolysis Oil (TPO) combustion at 1200 rpm engine speed. We could see the ignition delay occurs at -6° to 1° with have different 7°. The maximum combustion pressure is about 79.4 bar@7940kPa at crank angle 6°. The indicate power and indicate torque of this experiment is 4.0hp@2.9kW and 31.7kN.m respectively. It occur little knocking effect start from 6° crank angle after Top Dead Centre (TDC). But this little knocking effect can be ignore because it effect is too small but it still might have to be consider.

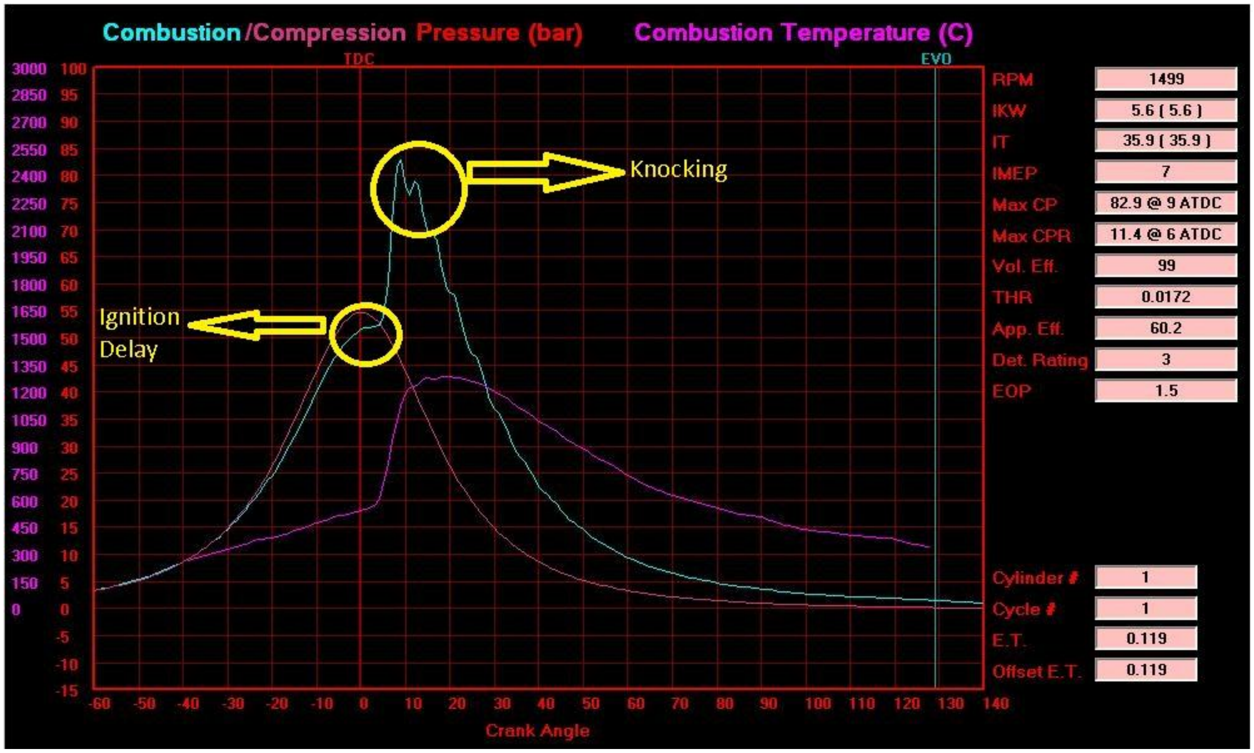

Figure 4.2.1(f): Tire Pyrolysis Oil (TPO) combustion for 1500 rpm engine speed

Figure 4.2.1(f) show graph for Tire Pyrolysis Oil (TPO) combustion 1500 rpm engine speed. Ignition delay at this engine speed occurs at -1° to 4° with have different 5°. The maximum combustion pressure is about 81.8 bar@8180kPa at crank angle 9°. The indicate power and indicate torque of this experiment is 5.6hp@4.1kW and 35.9kN.m respectively. It appears that knocking effect start at 11° crank angle after Top Dead Centre (TDC).

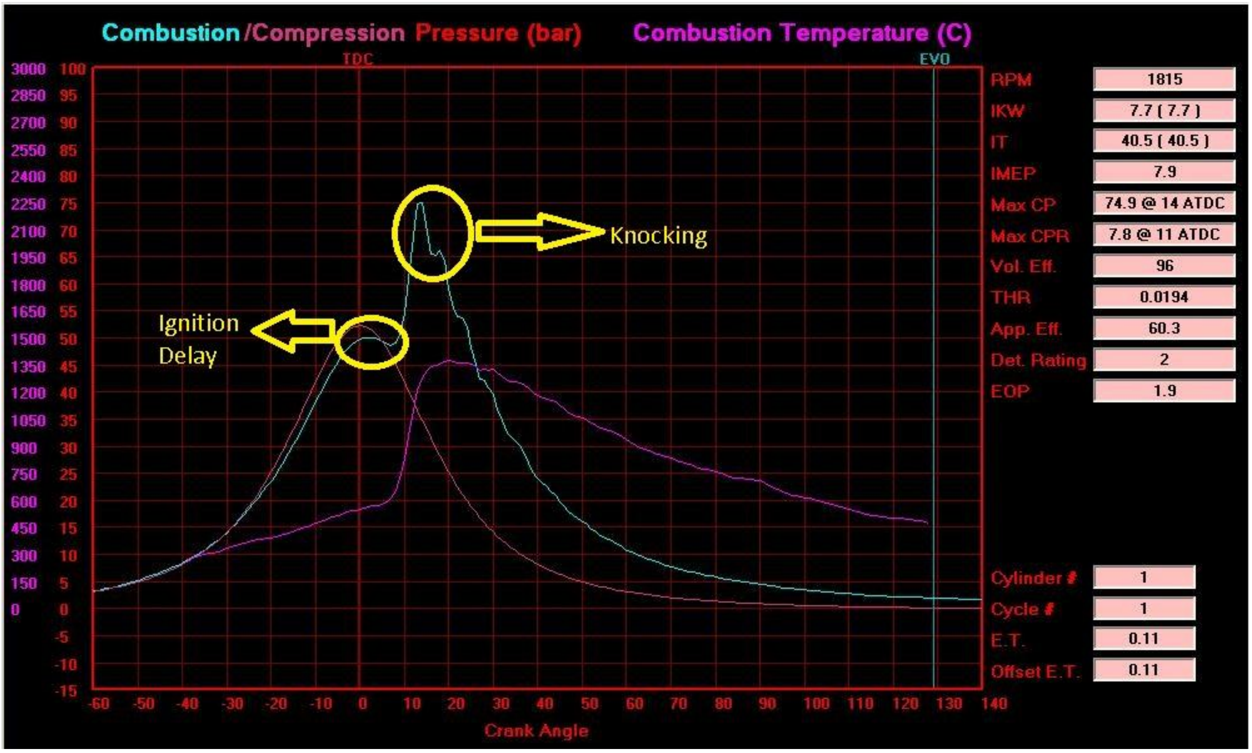

Figure 4.2.1(g): Tire Pyrolysis Oil (TPO) combustion at 1800 rpm engine speed

Figure 4.2.1(g) is graph for Tire Pyrolysis Oil (TPO) combustion at 1800 rpm engine speed. The ignition delay occurs at 0° to 8° with have different 8°. The maximum combustion/compression pressure is about 74.7 bar@7470kPa at crank angle 11°. The indicate power and indicate torque of this experiment is 7.7hp@5.7kW and 40.5kN.m respectively. In the experiment of Tire Pyrolysis Oil (TPO) with 1800 rpm knocking effect start from 18° crank angle after Top Dead Centre (TDC).

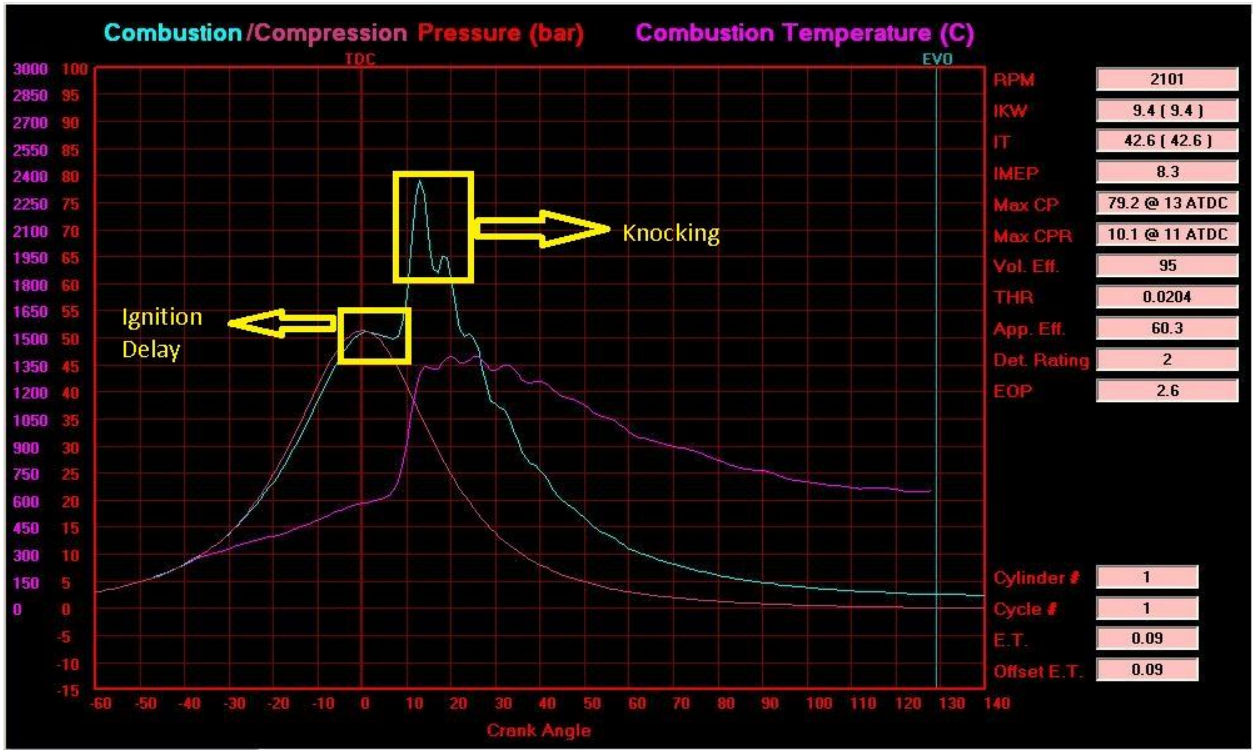

Figure 4.2.1(h): Tire Pyrolysis Oil (TPO) combustion at 2100 rpm engine speed

Figure 4.2.1(h) is a graph represent for Tire Pyrolysis Oil (TPO) combustion at 2100 rpm engine speed. The ignition delay occurs at 0° to 9° with have different 9°. The maximum combustion/compression pressure is about 76.0 bar@7600kPa at crank angle 12°. The indicate power and indicate torque of this experiment is 9.4hp@6.9kW and 42.6kN.m respectively. It appears knocking effect start from 18° crank angle after Top Dead Centre (TDC).

Table 4.2.1(b): Data for torque, power and maximum pressure with engine speed for Tire Pyrolysis Oil (TPO)

Engine Speed (rpm)	Indicate Torque (kN.m)	Indicate Power (kW)	Max. Pressure (kPa)
1200	31.7	2.9	7940
1500	35.9	4.1	8180
1800	40.5	5.7	7470
2100	42.6	6.9	7600

From Table 4.2.1(b), as the engine speed increasing, torque and power of the engine keep increasing too. Lower torque is 31.7 kN.m when engine speed 1200 rpm and highest is 42.6 kN.m when engine speed 2100 rpm. Lowest power is 2.9 kW with engine speed 1200 rpm and the highest power is 6.9 kW with engine speed 2100 rpm. Differently for the maximum pressure value when we use tire as fuel. It not was increasing with respect to the engine speed. It only need engine speed at 1500 rpm to gets the highest maximum pressure that is 8180 kPa. Lowest maximum pressure is 7600 kPa at engine speed 2100 rpm that is the highest engine speed in this experiment.

4.3 Torque Performance

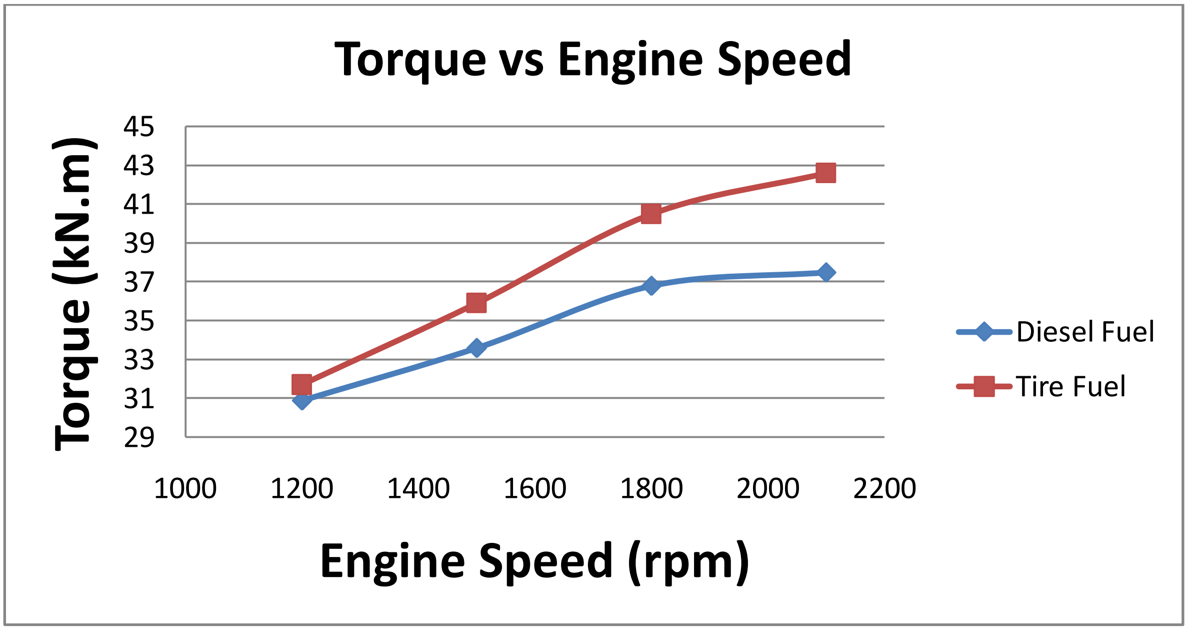

Figure 4.3: Indicate Torque vs. Engine Speed Graph for Diesel Fuel and Tire Pyrolysis Oil (TPO)

Figure 4.3 show that indicates torque is proportional to engine speed. Indicate torque of diesel fuel suddenly increases and indicate torque for Tire Pyrolysis Oil (TPO) suddenly decreases. From engine speed 1200 rpm until 1800 rpm engine speed, it increasing smoothly but after 1800 rpm engine speed, the gradient of both graphs is going to decrease. It means, up until 1800 rpm engine speed, the torque of engine is going to increase drastically and after that it start increase slowly. For overall, we could see that Tire Pyrolysis Oil (TPO) gives better indicate torque than diesel fuel.

4.4 Power Performance

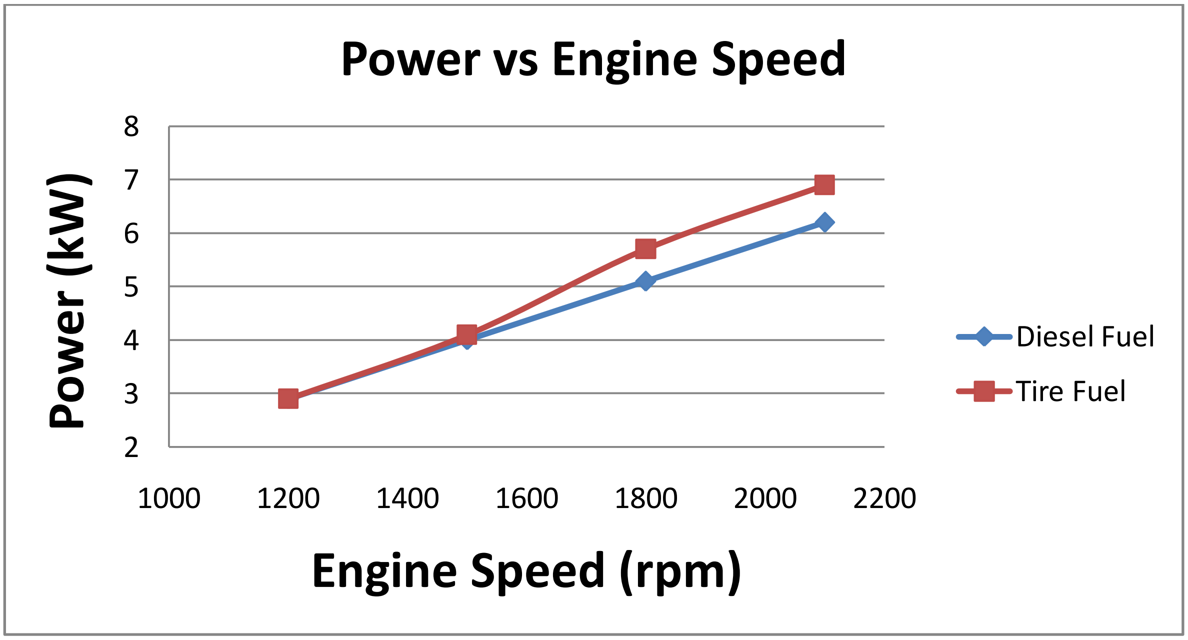

Figure 4.4: Indicate torque vs. engine speed graph for diesel fuel and Tire Pyrolysis Oil (TPO))

Figure 4.4 show that indicates power is proportional to engine speed but there a bit change at engine speed. At first, power for both fuels is quite a same but start to change at 1500 rpm engine speed where graph for Tire Pyrolysis Oil (TPO) is going to increase more than before. We could see that Tire Pyrolysis Oil (TPO) give better engine indicate power than diesel fuel.

4.5 Maximum Pressure

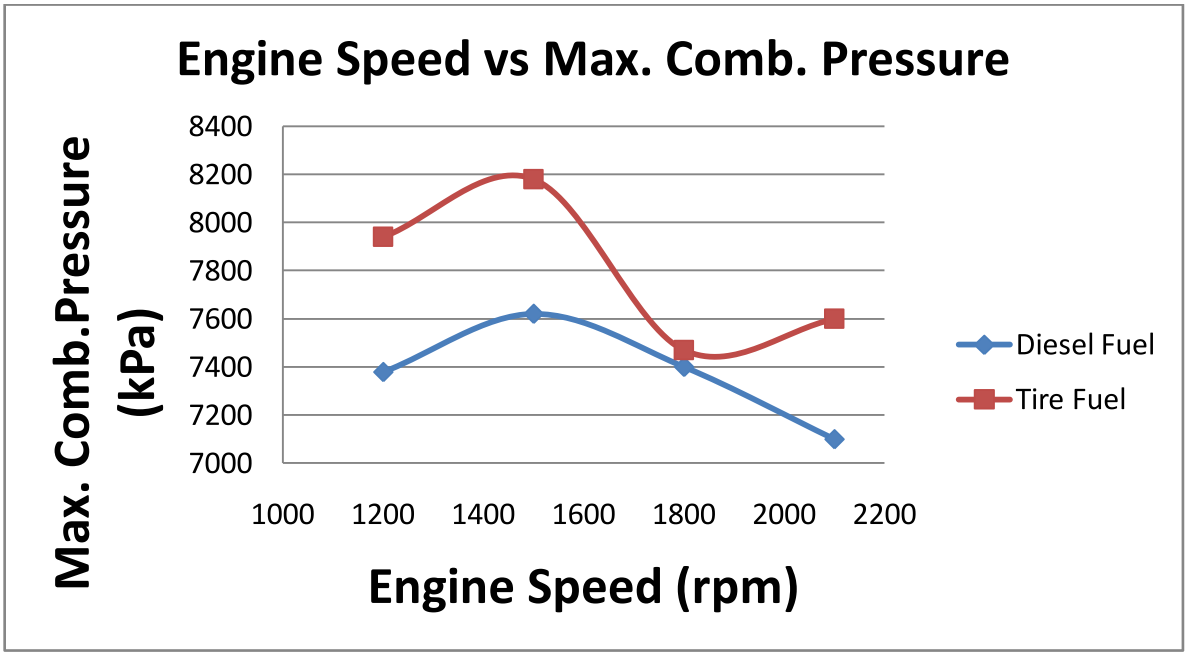

Figure 4.5: Maximum combustion pressure vs. engine speed for diesel fuel and Tire Pyrolysis Oil (TPO)

Figure 4.5 show that maximum combustion pressure of both fuels. Both fuels have the maximum combustion chamber at engine speed 1500 rpm. The maximum combustion pressure is going to decrease between 1500 rpm until 2100 rpm engine speed. It show that Tire Pyrolysis Oil (TPO) have maximum combustion pressure compare to diesel fuel

4.6 Fuel Consumption

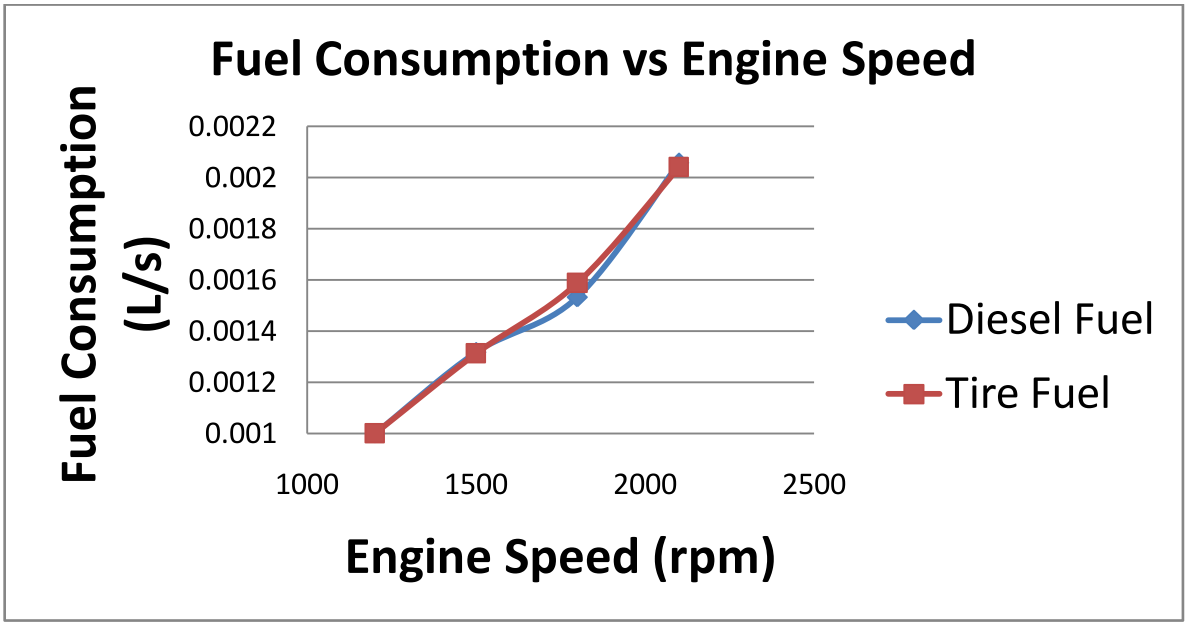

Figure 4.6: Fuel consumption vs. engine speed

We could see from the graph that the fuel consumption between both fuels can be said as similar. This make the fuel consumption of Tire Pyrolysis Oil (TPO) is not going to give any problem because it quite a same as diesel fuel. This means in term of fuel consumption, TPO can be replacing diesel fuel.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Alternative Tire Pyrolysis Oil (TPO) can be used to replace or to save the usage of diesel fuel. The power and torque of the engine using Tire Pyrolysis Oil (TPO) is more efficient compare to diesel fuel. However, lower cetane number of Tire Pyrolysis Oil (TPO) make knocking effect on Tire Pyrolysis Oil (TPO) is longer than diesel fuel. This makes more power lost using Tire Pyrolysis Oil (TPO) although the performance is better than diesel fuel.

In TPO, it appears that there is some precipitate in the liquid. This can give trouble to the engine in the long term. If we are going to make TPO as the fuel, we must find out a way to reducing the precipitate.

For the future research, we may consider to mixing both fuel to increase the cetane number of the fuel so that knocking effect can be minimize and reducing the precipitate. This can maximum the performance of the single cylinder diesel engine and then take care of engine condition. The knocking effect can also be minimizing by controlling the fuel supply at the beginning. Less fuel is injected at the beginning and then the fuel amount in the combustion chamber can be control to a certain extend. To do this, cam shape for the suitable profile can be design. Other than that to reducing the knocking effect is to make injector to inject small amount of fuel at first. This is doing by using two or more injector arranging in out of phase. Besides that, one of the ways to saving our wonderful earth, we also must have the research about the emission effect such as the condition of nitrogen oxide (NOx), carbon dioxide (CO_2) and sulphur (S).

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APPENDIC

MOHAMMAD SHAFEI BIN RAMLI MH09018

YEAR 4 SEMESTER 7

TITLE: EXPERIMENTAL STUDY OF ALTERNATIVE TIRE PYROLYSIS OIL (TPO) PERFORMANCE ON SINGLE CYLINDER DIESEL ENGINE

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Identify Problem, Objective & Scope	■	■												
Literature Review			■	■										
Design Of Experiment					■	■								
Experiment Setup							■	■						
Result Analysis									■	■				
Discussion											■	■	■	
Report Writing												■	■	■