PERFORMANCE AND EMISSIONS OF COMPRESSION IGNITION ENGINE FUELED WITH PREHEATED BLEND OF VEGETABLE OIL

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ABSTRACT

Now days fossil fuel has been a problem that can been use in a compression ignition engine. Straight vegetable oil is one of the most reliable fuel that suitable for diesel engine. The scope of study of this study is focused on performance and emission of the straight vegetable oil from the grocery store to compare with crude palm oil from UTHM pilot plan. S5, S10 and S15 straight vegetable oil fuel is used for this experiment. This straight vegetable oil is also compared with an natural diesel in a combustion-ignition engine. The test is conducted with UTHM dynomometer which is located at automotive lab. The properties of the vegetable oil is tested for density, kinematic viscosity, water content, acids value and flash points. Brake power, flywheel torque, (in term of hydrocarbon, carbon monoxide, carbon dioxide, oxygen content and smoke opacity) and tested for performance and emission. Results obtained show that flywheel torque that has been produced from the biodiesel fuels are less than the natural diesel (ND). Biodiesel emission results shown a better emission compared to the ND fuels. The CO_2, CO, HC and O_2 content that released from the biodiesel fuels are clearly lower than the ND fuels. At low engine speed, biodiesel smoke opacity contents are quite high produces compared to the OD and other type of biodiesel fuel.

ABSTRAK

Bahan api fosil kini telah menjadi satu masalah yang boleh menjadi digunakan dalam enjin pencucuhan mampatan. Minyak sayuran adalah salah satu bahan api yang paling boleh dipercayai yang sesuai untuk enjin diesel. Skop kajian Kajian ini memberi tumpuan kepada prestasi dan pelepasan minyak sayuran lurus dari kedai runcit untuk di bandingkan dengan minyak sawit mentah daripada pelan perintis UTHM. S5, S10 dan S15 lurus bahan api minyak sayuran digunakan untuk eksperimen ini. Minyak sayuran ini juga di banding dengan diesel semula jadi dalam enjin pembakaran pencucuhan. Ujian ini dijalankan dengan UTHM dynomometer yang terletak di makmal automotif. Sifat-sifat minyak sayuran diuji untuk ketumpatan, kelikatan kinematik , kandungan air, nilai asid dan mata kilat. Kuasa brek , tork roda tenaga, (dari segi hidrokarbon , karbon monoksida , karbon dioksida, kandungan oksigen dan asap opacity) dan diuji untuk prestasi dan pelepasan. Keputusan yang diperolehi menunjukkan bahawa roda tenaga tork yang dihasilkan daripada bahan api biodiesel adalah kurang daripada diesel asli (ND). Keputusan pelepasan Biodiesel ditunjukkan pelepasan yang lebih baik berbanding dengan bahan api ND. CO2 , CO , HC dan kandungan O2 yang dibebaskan dari bahan api biodiesel adalah jelas lebih rendah daripada bahan api ND. Pada kelajuan enjin rendah, biodiesel kandungan asap kelegapan agak tinggi menghasilkan berbanding dengan OD dan lain-lain jenis bahan api biodiesel

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols	Description
%	Percentages
FFA	Free fatty acid
CPO	Coconut palm oil
SVO	Straight Vegetable Oil
OD	Ordinary diesel
HC	Hydrocarbon
O2	Oxygen
CO2,	Carbon dioxide
NOx	Nitrogen oxides
CO	Carbon monoxide
HHV	Higher heating value
EMA	*Engine Manufacturers Association*
PM	Particulate matter
FCR	Fuel consumption rate
BP	Brake power
CI	Compression ignition
kW	Kilowatt
POD	Palm oil diesel
DI	Direct engine
RPM	Revolution per minute
BMEP	Brake mean effective pressure

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the modern era of the world now days, fuel has become the most important thing that countries would invade others just to gain access of the world fuel reserved. This is why alternative fuel is introduced to fill the demand of fossil fuel. There are several aspect that are considered in developed the biodiesel fuel to reduce the engine emission and many more. Straight Vegetable oil is an alternative diesel fuel that is produced from renewable resources. Vegetable oils have become more attractive recently because of their environmental benefits. It is biodegrable and nontoxic, has low emission profiles. However, it is not competitive with petroleum fuel now because of its high viscosity and prices. The advantages of the biodiesel are can reducing dependence on natural resource on diesel, can leveraging limited supplies of fossil fuels, can reduce greenhouse gas emissions and it can help reduce air pollution and related public health risks.

In general, straight vegetable oil is characterized by a higher viscosity and lower heating value compared to petro-diesel. To improve these physical properties, petro-

diesel or additives can be added to biodiesel fuel. Biodiesel also can be blended at any level with petroleum diesel. It can be used in diesel engines with little or no modifications.

Straight vegetable oil can be used in the unmodified diesel engine because it operates on the principle of compression ignition whereby air is compressed by raising its temperature above the igniting-point of the fuel, and then the fuel is sprayed into the combustion chamber. This simple process allows the diesel engine to run on thick fuels. Since straight vegetable oil is chemically similar to petro-diesel fuel, it can be pour right into the fuel tank of any diesel vehicles. Biodiesel also can be sold at any fuel station, same as the other fuel in the market today.

1.2 Problem Statement

Recently, Crude Palm oil been tested here in UTHM. The Crude Palm Oil came from University Tun Hussein Onn Malaysia (UTHM) biodiesel pilot plant that is for research and academic purposes. To continue of the research Straight Vegetable Oil(SV) from grocery store used for testing and compare with the CPO from UTHM pilot plan. Performance of this straight vegetable oil that were tested for performance and emission to compare with CPO. This research is done to investigate the performance of the biodiesel that produced from SVO at the ratio of S5, S10 and S15. Experiment on pre-heated SVO is also done to compare the performance of the fuel. All fuel is blend with the same method so we can have a better comparison result for natural diesel, crude palm oil and straight vegetable oil.

1.3 Objective

The objective of this study is to investigate the effect of Straight Vegetable Oil in normal and Preheated condition on compression ignition engine and to compare with crude palm oil.

1.4 Scope of Study

The scopes of this study are as follows:

i. The biodiesel that was used is SVO biodiesel taken from grocery store.
ii. The properties tests that were considered included density, kinematic viscosity, water content and flash points.
iii. The testing used several types of fuels which are Ordinary Diesel (ND), S5, S10 and S15.
iv. 2500 cc engine of Mitsubishi Pajero is used for experiment
v. The performance test that was considered are in terms of flywheel torque, brake power and engine emission (in term of hydrocarbon (HC), oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO) and smoke opacity).

1.5 Importance of Study

Important of this study is to compare the performance and emission of SVO in normal temperature and pre-heated temperature compare to CPO. This is important because the properties of the biodiesel are needed to know in order to increases its qualities and performance when used in diesel engine in the future. The data that have taken during the test may be very useful for the other studies especially in biodiesel development.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the previous study of Biodiesel. Topic that highlighted here is the properties of biodiesel fuels, its advantages and disadvantages and the performance of engine which are included the flywheel torque, and brake power. This chapter also discuss about the engine emissions which are included of hydrocarbon (HC), oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO) and smoke opacity. Preheated for performance and emission also discuss in this chapter from previous study.

2.2 Compression Ignition Engine

In conventional diesel diffusion combustion, as the speed of the chemical reaction is incomparably faster than the speed of the mixing of the fuel and air, the combustion reaction starts near stoichiometric air-fuel ratio and proceeds across a wide-ranging region from lean to rich. NO_X and soot are accordingly generated, and it is difficult to reduce these simultaneously [1].

Ignition dwell is defined as the interval between end of fuel injection and start of combustion in early injection diesel combustion. The ignition delay in a diesel engine is generally seen as consisting of two different consecutive although overlapping phases: the physical and the chemical ignition delay [2]. As is commonly accepted, the physical ignition delay corresponds to the mixture formation, and the chemical delay to the time necessary to get an exponential increase in the chemical reaction rate.

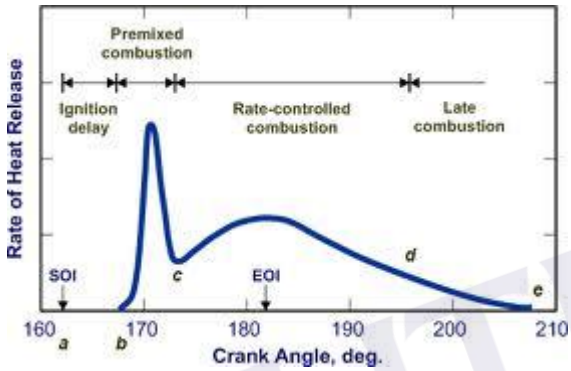

Figure 2.1: Graph of ignition delay [2]

2.3 Fuel and Air Mixing

In theory a stoichiometric mixture has just enough air to completely burn the available fuel. In practice this is never quite achieved, due primarily to the very short time available in an internal combustion engine for each combustion cycle. Most of the combustion process completes in approximately 4–5 milliseconds at an engine speed of 6000 rpm [3]. Physical intake, engine thermodynamic, and combustion models predict air mass and residual gas fraction at the beginning of compression in the cylinder. The air and fuel mixture ratio has to be balance to start the combustion. Previous work has indicated that extremely low emissions and high efficiencies are possible if ignition of homogeneous fuel-air mixtures is accomplished. The limitations of this approach were reported to be misfiring and knock [4]

2.4 Alternative fuel

In this new era of the world fuel has become limited and new type of fuel is needed to overcome the limited of fossil duel. One of the alternative fuel now days is bio fuels. Bio fuels based on vegetable oils offer the advantage being a sustainable, annually renewable source of automobile fuel. Despite years of improvement attempts, the key issue in using vegetable oil-based fuels is oxidation stability, stoichiometric point, bio fuel composition, antioxidants on the degradation and much oxygen with comparing to diesel gas oil. Thus, the improvement of emissions exhausted from diesel engines fueled by biodiesel derived from vegetable oil is urgently required to meet the future stringent emission regulations [4]. The key issue in using vegetable oil-based fuels is oxidation stability, stoichiometric point, bio-fuel composition, antioxidants on the degradation and much oxygen with comparing to diesel gas oil.

2.4.1 Biodiesel

Biodiesel remains an alternative fuel of interest for use in diesel engines. A common characteristic of biodiesel, relative to petroleum diesel, is a lowered heating value (or energy content of the fuel) [5]. The effect of the biodiesel on the engine performance and emissions is expected to become increasingly important as the emissions regulations become more stringent (Euro 5). This work aims to study the effect of the degree of unsaturation of a biodiesel fuel (which is a characteristic of the original oil), this being quantified by the iodine number, on the pollutant emissions and combustion timing [5].

2.5.1.1 Advantages of Biodiesel

There is a few advantaged of biodiesel. The higher cetane premium fuels tested in this study (CN > 60), gave the lowest overall fuel consumption, HC and CO emissions. Hydrogenated vegetable oil (HVO) component offered further emissions advantages when blended at B5 level into a high cetane fuel, as well as giving significant emissions benefits at B20 level over standard European EN590 diesel [3]. NOx emission of pure biodiesel is lower than baseline of diesel at about 10% EGR rate [6]. Compatibility with current fleet of diesel-powered vehicles, where any major adjustments to the engines and related hardware components are not necessary. Furthermore, the uses of biodiesel fuels has the added advantages of having minimal sulphur and aromatic contents, higher flash point and cetane number as well as improved lubricate [7]. The biodiesel impacts on exhaust emissions vary depending on the type of biodiesel and on the type of conventional diesel. The commercial biodiesel fuel significantly reduced particulate matter (PM) exhaust emissions (75–83%) compared to the petro diesel base fuel [6]. The biggest advantage of biodiesel is environmentally friendliness that it has over gasoline and petroleum diesel [6]. Biodiesel has a higher cetane number than petroleum diesel fuel, no aromatics, and contains 10–11% oxygen by weight. These characteristics of biodiesel reduce the emissions of carbon monoxide (CO), hydrocarbons (HC), and particulate matter (PM) in the exhaust gas compared with diesel fuel [7]

2.4.1.2 Disadvantages of Biodiesel

There is also a few disadvantage of biodiesel. Exhaust Gas Recirculation have little influence on the peak of heat release rate for pure biodiesel [8]. Existing industrial scale biodiesel production technologies are still unable to produce biodiesel which is cost competitive with conventional diesel fuel [8]. The major disadvantages of biodiesel are its higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxide (NOx) emissions, lower engine speed and power, injector coking, engine compatibility, and high price [9]. The effective efficiency and effective pressure values of commercial diesel fuel are greater than biodiesel [9]. NOx exhaust emissions increased slightly with commercial biodiesel compared to the base fuel [10]. The NOx

emissions of biodiesel increase because of combustion and some fuel characteristics. When a higher percentage of biodiesel is used in the diesel engine during cold weather, it thickens more than diesel fuel and special systems may be required [9]

2.4.2 Biodiesel Standard

The Table 2.1, explained that biodiesel has been produced on industrial scale in the European Union since 1992, in the United States of America since 1993. Annually they have produced almost 6900 and 7100 million liters of biodiesel. So, there is standards specification to be met for biodiesel itself [11]. The bio-fuel must meet the EN-14214 specification in Europe and American society of testing and materials (ASTM) D-6751 specifications in the USA. Meanwhile, it has been reported that biodiesel blends up to 5% should not cause engine and fuel system problems [12]

Table 2.1: American Society for Testing and Material (ASTM) and Euro standard [12]

Property	Units	EN-14214	ASTM-D6751
Density at 15 °C	g/cm^3	0.86– 0.90	–
Viscosity at 40 °C	mm^2/s	3.50– 5.00	1.9– 6.0
Flash point	°C	120 min	130 min
Cetane number	–	51 min	47 min
Sulfur	mg/kg	10.0 max	15.0 max
Phosphorus content	mg/kg	10.0 max	10.0 max
Water content	mg/kg	500 max	500 max
Acid number	mg KOH/g	0.50 max	0.80 max
Free glycerin	% mass	0.02 max	0.02 max
Total glycerin	% mass	0.25 max	0.24 max
Sulfated ash content	% mass	0.020 max	0.020 max
Methanol content	% mass	0.20 max	–
Monoglycerides	% mass	0.80 max	–
Diglycerides	% mass	0.20 max	–
Triglycerides	% mass	0.20 max	–
Ester content	% mass	96.5 min	–
Linolenic acid methyl ester	% mass	12.0 max	–
Carbon residue[a]	% mass	–	0.050 max
Iodine value	–	120 max	–
Oxidation stability, at 110 °C	h	6 min	–
Copper corrosion (3 h, at 50 °C)	Degree of corrosion	No. 1	No. 3
Distillation 90% recovered	°C	–	360 max

2.4.3 Straight Vegetable Oil (SVO)

SVO has been a recurring subject of study as a fuel for compression ignition engines. The process of producing SVO is very scalable as it has low energy consumption per output ratio. With simple engine applications, SVO could be used in 3rd world domestic situations, producing electricity to help children study, refrigeration for food safety, and transportation. Farmers could reduce reliance upon fossil fuels by using SVO in farm equipment, including irrigation and tractors, thereby lowering the impact on local food prices [13].

Vegetable oils mainly contain triglycerides (90% to 98%) and small amounts of mono and di-glycerides. Triglycerides contain three fatty acid molecules and a glycerol molecule. They contain significant amounts of oxygen. Commonly found fatty acids in vegetable oils are stearic, palmitic, oleic, linoleic and linolenic acid [4]. Due to the agricultural origin, they are able to reduce net CO2 emissions [14].

A few disadvantage of SVO is that SVO will lead to reduced engine life. This reduced engine life is caused by the build-up of carbon deposits inside the engine, as well as negative impacts of SVO on the engine lubricant. Both carbon deposits and excessive build-up of SVO in the lubricant are caused by the very high boiling point and viscosity of SVO relative to the required boiling range for diesel fuel [14]. The carbon build up doesn't necessarily happen quickly but instead over a longer period. Some investigators have explored modifying the vehicle to preheat the SVO prior to injection into the engine. Others have examined blends of vegetable oil with conventional diesel. These techniques may mitigate the problems to some degree, but do not eliminate them entirely. Studies show that carbon build up continues over time, resulting in higher engine maintenance costs and/or shorter engine life. Another issue that is particularly critical for use of SVO is fuel viscosity [15].

2.5 Performance

Performance will be determined in this chapter from the previous study for preheated Straight Vegetable Oil (SVO). Performance that is considered is in term of brake thermal efficiency, brake power and torque. The use of higher percentage biodiesel blends requires engine recalibration, as it affects engine performance, combustion patterns and emissions. Previous work has shown that the combustion of 50:50 blends of biodiesel fuels (first generation RME and next generation synthetic fuel) can give diesel fuel-like performance (i.e. incylinder pressure, fuel injection and heat release patterns). This means engine recalibration can be avoided, plus a reduction in all the regulated emissions. Using a 30% biodiesel blend (with different first and next generation proportions) mixed with Diesel may be a more realistic future fuel.

2.5.1 Brake Power

According to the literature, brake power output is not affected by oxygen enrichment, unless the fuel quantity injected is also increased, keeping constant oxygen to fuel ratio or by using high fuel flow rates. The studies in the Yanmar L70EE-DE, where fuel flow rate remained constant, confirmed this observation [16]. Usually, the brake power of the engine with standard diesel was higher than for any biodiesel. This is because the biodiesels have lower calorific values than that of standard diesel. However, difference in brake power and brake torque between standard diesel and the biodiesels were very small in most cases [16]. It is clear from the figure that as the load increases, the BSFC decreases for all fuel blends. The figure indicates marginally higher BSFC with biodiesel and it blends on account of lower calorific value.

Figure 2.2 shows the BSEC versus BMEP for all selected diesel – biodiesel fuel blends and neat diesel. It is clear from the figure that as the load increases, the BSEC decreases for all fuel blends.

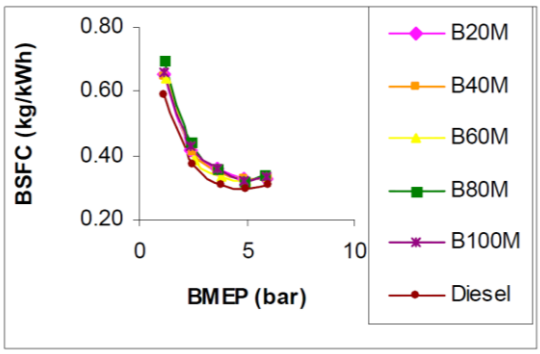

Figure 2.2: Brake specific fuel consumption for different fuel blends [16]

2.5.2 Brake Thermal Efficiency

The brake thermal efficiency of CI engine is lower than that of the corresponding diesel fuel at all the engine speed. Thermal efficiency of preheated biodiesel oil was found slightly lower than diesel. The possible reason may be higher fuel viscosity. Higher fuel viscosity results in poor atomization and larger fuel droplets followed by inadequate mixing of vegetable oil droplets and heated air. Fig 2.3 gives the percentage change of brake thermal efficiency with the engine speed [17].

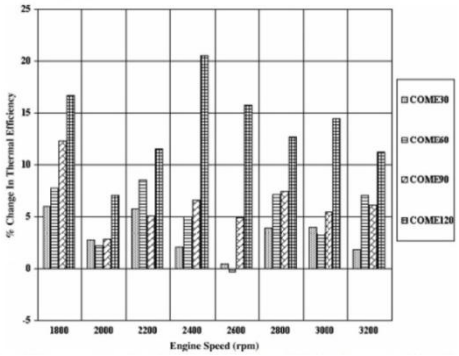

Fig 2.3: Changes in the Brake Thermal Efficiency with Engine Speed [17]

2.5.3 Flywheel Torque

An experimental study on preheating raw rapeseed oil shows that the torque was almost not affected with preheating. As expected there is slight increase in torque with the increase in temperature. The average torque differences with preheating were 1.2%, 0.8% and 0.14% for DF, O20 and O50, respectively [18]. The performance of engine is greatly influenced by sources of biodiesel, for example engine fuelled with palm oil bio-diesel is more efficient than biodiesel produced from tallow and canola oil. Blends of biodiesel with petroleum fuel are widely used in diesel engine although the high viscosity of the fuels causes fuel flow and ignition problems in unmodified CI (compression ignition) engines and also decreases in power output. The decrease in output torque at these two modes also affects the power output of the engine, since torque and power are directly proportional when the engine speed is fixed. As a result, the power output also decreases by 4 to 5%. Decrease in power and torque is due to their lower energy content of biodiesel. Lower energy content shows lower energy characteristics [18]

2.6 Engine Emission

In this study, the engine emissions that are considered included smoke opacity, carbon monoxide (CO), carbon dioxide (CO2), oxygen (O) Nitrogen oxide (NOx) and hydrocarbon (HC).Ideally a compression ignition (CI) fuel would produce low emissions, be renewable, produce useable power to current diesel standards, run in both existing and newly manufactured engines and require no engine modifications.

2.6.1 Smoke Opacity

The diesel engine smoke formation generally occurs in the rich zone at high temperature, particularly within the core region of fuel spray. At all loads, smoke emissions for the blend decreased significantly when compared with those of standard diesel. The significant reduction in smoke emission may be due to the presence of oxygen in biodiesel blend. Smoke is mainly produced in the diffusive combustion phase [14].Besides that, the smoke emission of biodiesel at all loads was lower than that of diesel. This is due to the higher oxygen content and absence of sulphur content in biodiesel. The oxygen content of biodiesel ensures post flame oxidation and increase in flame speed during the air fuel interactions which results in complete hydrocarbon oxidation. The reduction of smoke level of biodiesel is usually due to its oxygen content and small particle diameter of the injected fuel at high injection pressure [19].

2.6.2 Carbon Monoxide (CO)

CO emission is toxic and must be controlled. It is an intermediate product in the combustion of a hydrocarbon fuel, so its emission results from incomplete combustion. Emission of CO is therefore greatly dependent on the air fuel ratio relative to the stoichiometric proportions. From rich combustion invariably produces CO, and emissions increase nearly linearly with the deviation from the stoichiometric [16].Besides that, stated in his journal which at the maximum operating condition, the CO concentration produced by the diesel engine was much higher compared with the dual-fuel system. The reduction of the CO in the exhaust gas means a more complete combustion is achieved; the lower CO concentration in the exhaust gas, the better and complete combustion is achieved. The air to fuel ratio was very rich for the diesel operation at higher torque and power, and this resulted in the increased in CO concentration [17].

2.6.3 Carbon Dioxide (CO_2)

CO_2 occurs naturally in the atmosphere and is a normal product of combustion. Ideally, combustion of a hydrocarbon fuel should produce only carbon dioxide and water (H2O). When the ethanol amount increased in the fuel mixture, the CO and unburned HC concentration in the exhaust decreased. The CO_2 concentrations have an opposite behavior when compared with the CO concentrations, and this is due to improving the combustion process as a result of the oxygen content in the ethanol [16].

2.6.4 Oxygen (O_2)

The oxygen content in the biodiesel results in better combustion and increases the combustion chamber temperature, which leads to higher NOx emissions, especially at high engine loads. The significant improvement in reduction of NOx and a minor increase in CO were identified use of selective catalytic reduction [15].

2.6.5 Hydrocarbon (HC)

The concentration of HC emissions is closely related to many designs and operating variables. Combustion chamber and induction system design are two important design variables while air–fuel ratio, speed and load are main operating variables [20]. Displacement, combustion chamber shape, bore diameter, stroke and compression ratio affect the surface to volume ratio and HC emission. The higher the compression ratio and higher surface to volume ratio caused to the higher the HC emissions. This results from the lower cylinder temperature at the end of the expansion stroke. The lower cylinder temperature resulted an incomplete combustion of the remaining fuel [21].

Besides that the HC emissions of biodiesel and its blends have little difference from diesel fuel. It is also observed that there is a significant reduction in CO and smoke emissions at high engine loads [21].

2.6.6 Nitrogen Oxide (NO_X)

The NOx emissions of diesel engine fueled with diesel biodiesel blends and diesel fuel at selected operating conditions are shown in Figure 2.4 [22]. In a DI natural aspirated 4- stroke diesel engine, NOx emissions are sensitive to oxygen content, adiabatic flame temperature and spray characteristics. The fuel spray properties depend on droplet size, droplet momentum and degree of mixing with air and penetration rate, evaporation rate and radiant heat transfer rate. A change in any of those properties may change the NOx production [23]. Furthermore, fuel chemistry effects in the flame region could account for a change in NOx production. The emissions of the blends increases up to 21.88 percent with increasing biodiesel content at the same load but rate of Nox emissions decreases with increasing brake load for all diesel- biodiesel fuel blends.

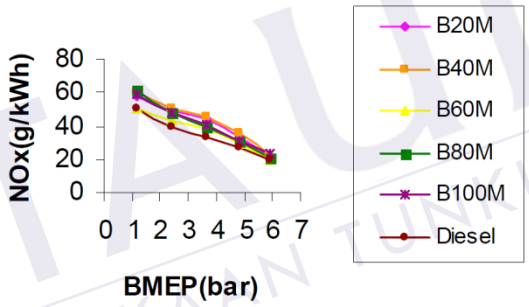

Figure 2.3: NOx emission for different fuels [22]

2.7 Case study

Literature reviews are usually done according to the previous study from the researches. All the data and results from the previous study are very important as the references during done this study.

2.7.1 Study on Isuzu 4FB1 Engine

The test is done to know the performance and engine emission when use the additive. Table 2.2 and Table 2.3 show the specification of diesel engine being used and the test sequence and the fuels composition [18].

Table 2.2: Test sequence and fuels composition [18]

Test sequence	Fuel	Compositions	Lube oil
Test 1	OD[a]	100% ordinary diesel	SAE 40[a]
Test 2	A	50 ppm (corrosion inhibitor) additive + 7.5% POD+92.5% OD	SAE 40 + 0.1% (corrosion inhibitor) additive
Test 3	B	50 ppm (corrosion inhibitor) additive +15% POD+85% OD	SAE 40 + 0.1% (corrosion inhibitor) additive
	POD	100% palm oil methyl ester	

[a]No additive is added.

Table 2.3: Specification of diesel engine being [18]

Engine	Isuzu
Model	4FB1
Type	Water-cooled, four strokes
Combustion	Indirect injection (IDI) and naturally aspirated
Number of cylinders	4
Bore × Stroke	84 × 82 mm
Displacement	1817 cc
Compression ratio	21:1
Nominal rated power	39 kW=5000 rpm
Maximum torque speed	1800–3000 rpm
Dimension (L × W × H)	700 × 560 × 635(mm)
Combustion chamber	Swirl chamber

From Figure 2.4, the brake power increases with increasing POD blend concentration over the speed range compared to OD. Fuel B produced the maximum brake power (12:4 kW) at 1600 rpm followed by fuel A (11:44 kW) and fuel OD (10:48 kW). The reason of increasing brake power with increasing POD in blends is the effect of addition of corrosion inhibitor in POD blends that influences conversion of heat energy to work or increases fuel conversion efficiency through the complete combustion. On average, fuel B produced 10–15% higher brake power than OD. This is the effect of additive that enhances POD in producing higher power.

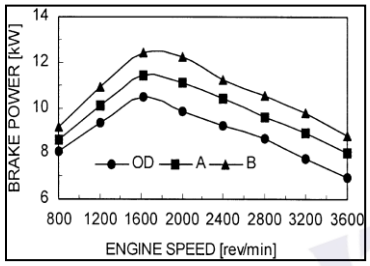

Figure 2.4: Brake power versus engine speed [18]

Figure 2.5 show the NOx and CO concentration versus engine speed graph. When raising the POD blend from 7.5% to 15%, it decreased the exhaust NOx level from 147 to 135 ppm at 1200 rpm. The difference was mainly due to the reduction in combustion temperature caused by POD blends and that can be found elsewhere. It can be attributed to the fact that POD blend produces lower heat release rate at premix combustion phase, which lowers the peak combustion temperature, hence reduces NOx emissions. The reasons for the production at lower combustion temperature by vegetable oil, as well as by POD, are their chemical bond/properties (in saturated fatty acid) together with the effect of fuel additive that limits the formulation of ions which catalyze oxidation processes.

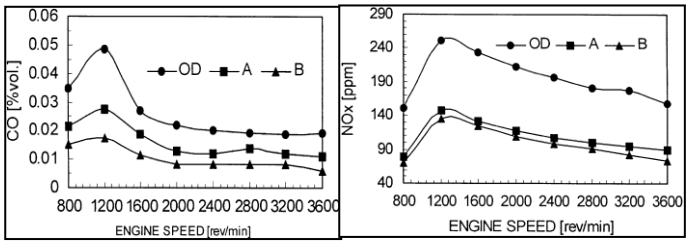

Figure 2.5: NOx and CO concentration versus engine speed [18]

2.7.2 Study on John Deere 4276T Engine

Experiments were performed on a John Deere 4276T, four-cylinder, four-stroke, turbocharged direct-injection (DI) diesel-engine. A 112 kW General Electric (Schenectady, NY) model TLC 2544 direct-current dynamometer, assembled on the engine, was used. An electronic scale and a stopwatch were used to measure the fuel flow rate, and the intake airflow rate was measured using a laminar-flow element. The fuels were tested at full load (100%) at 1400-rpm engine speed, where the engine torque was 257.7 Nm.

Table 2.4, Table 2.5 and Table 2.6 shows the specifications of test engine, the list of emission analyzers used in the tests, the statistical values of predictions and comparisons of predicted results and experimental results during done the experiment.

Table 2.4: Specifications of test engine [7].

Make and model	John Deere 4276T
Motor type	Four-stroke, turbocharged diesel engine
Number of cylinders	Four-cylinder
Compression ratio	16.8:1
Bore and stroke	106.5 mm/127.0 mm
Connecting-rod length	202.9 mm
Maximum engine power	57.1 kW@2100 rpm
Maximum torque	305.0 Nm@1300 rpm
Type of injection pump	Distributor-type
Fuel-injector holes 4	0.305 mm diameter
Fuel-injector opening pressure	207 bar

Table 2.5: List of emission analyzers used in the tests [7]

Analyzer Model	Type
Smoke meter Robert Bosch	GMBH-ETD02050
NO/NOx analyzer	Beckman Industrial Corp. 955
HC analyzer	J.U.M. Engineering, VE7
CO2 analyzer	Rosemount Analytical, Inc., 880A
CO analyzer	Rosemount Analytical, Inc., 880A
O2 monitor	Rosemount Analytical, Inc., 755R

Table 2.6: Statistical values of predictions [7]

Outputs	RMS (training)	R^2 (training)	Mean % error (training)	RMS (test)	R^2 (test)	Mean % error (test)
BSFC	0.004264	0.999954	0.573866	0.000674	0.999999	0.100623
SN	0.029216	0.996702	4.132617	0.032582	0.997051	5.430333
CO	0.008778	0.999635	1.505732	0.016838	0.998927	3.27612
CO_2	0.006779	0.999913	0.780031	0.004808	0.999964	0.59898
HC	0.003551	0.9999	0.808099	0.005782	0.999859	1.185666
T_{exh}	0.003558	0.999976	0.320963	0.000993	0.999998	0.123447
O_2	0.005497	0.999935	0.662413	0.006556	0.999925	0.866655
NO_x	0.010851	0.999659	1.589002	0.000657	0.999999	0.103291

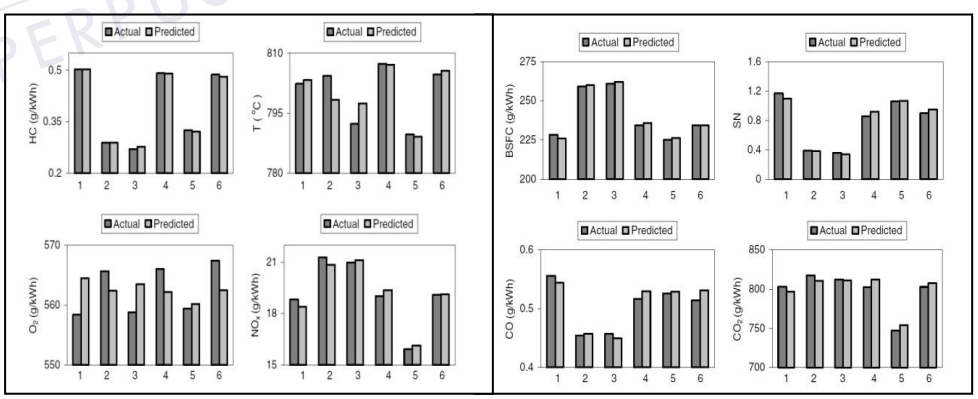

Figure 2.6: Comparisons of predicted results and experimental results [7].

The smoke level of the biodiesel blends, as seen in the figure, starts to decrease even at 1% blends for both biodiesels. For all the predicted results, almost no difference has been observed between the two biodiesel blends. The researchers have observed that the smoke levels of the biodiesels and their blends were significantly lower than that for the diesel fuel. Therefore CO emissions from the diesel engines are usually low and most engine manufacturers meet CO regulations easily. The CO emissions have decreased with increasing amounts of biodiesel in the blend. The reduction of CO emissions is significant when the blend percentage is 15 or higher [7].

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, data will be taken to determine the performance of SVO biodiesel. This project will be using compression-ignition engion at various low and high condition of load. Result of data that gained from this will be compared with the ordinary diesel, crude palm oil in normal temperature and preheated condition of 60°C and straight vegetable oil in normal temperature and preheated of 60°C.

All the equipment and materials used in this study also will be explained in this study. Discussion of the data that gained is done in chapter 4 to give reader more understanding about this project. Density, Kinematic viscosity, water content and flash point will be considered for this experiment. Brake power and flywheel torque is considered for the performance and for emission the properties that is measured is CO, CO_2, O_2, HC and smoke opacity.

3.2 Methodology flow chart

The flow chart shown on figure 3.1 is for the engine testing to determine the performance and emission. This will be the guideline for sequence from staring of material preparation until the result analysis. Figure 3.2 show the flow of preparation of the straight vegetable oil.

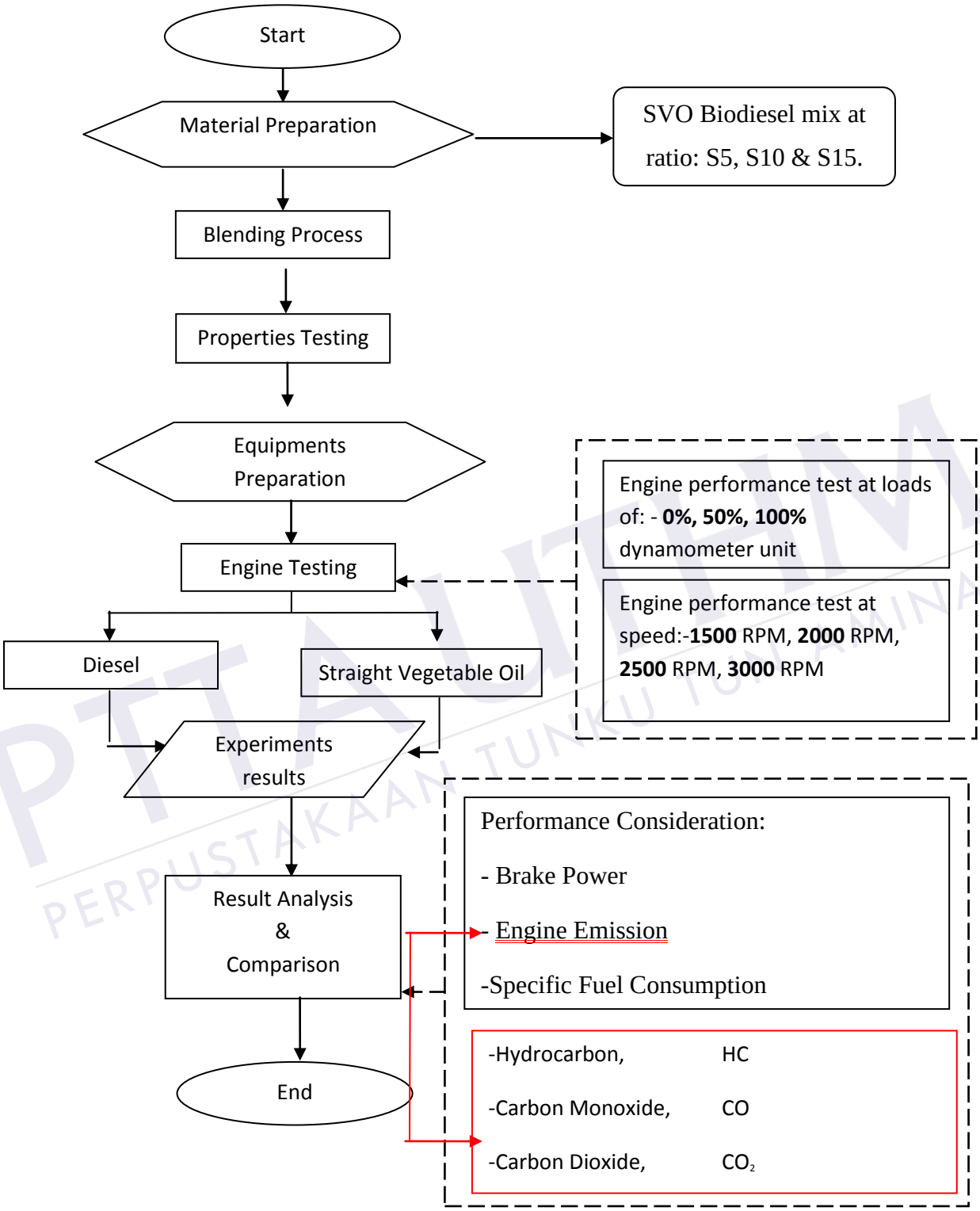

Figure 3.1: The Methodology Flowchart

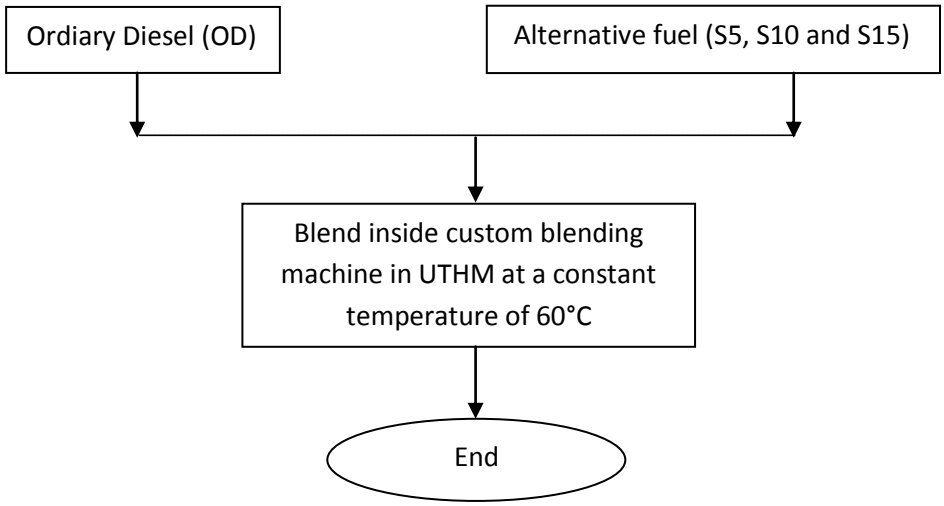

Figure 3.2 The methodology flowchart for biodiesel blending

3.3.1 Material Preparation

The blending of straight vegetable oil fuel that is being use are S5, S10 and S15. This is the fuel that we can get from ordinary grocery store. We will be also using a diesel engine to test the fuel for performance in term of brake power and engine emission. The alternative fuel will also be prepared accordingly. The straight vegetable oil that being used is a blending of vegetable oil with other fuel such as diesel and the mixture would bring the viscosity close to diesel fuel specification.

Performance curves will be developed for a diesel engine fueled by S5, S10 and S15. The engine to be tested shall be representative of the manufacturer's production units, and the fuel used shall conform to the manufacturer specifications. To define the power curve, data should be recorded for five or more evenly spaced operating speeds between the lowest stable speed and the maximum speed recommended by the manufacturer. The engine will be loaded for tests with a water cooled eddy current absorption dynamometer 0%, 5% and 100% load. Dynamometer load being controlled using a controller. The throttle will then be increased until the engine reaches full open throttle. Once full open throttle is obtained, a load will be applied to the engine. The load is increased to the highest possible load at which the engine remains at maximum

speed, which is about 3000 revolutions per minute (rpm). Once engine speed and torque measurements have been stable for two minutes, all data is collected for two minutes. The load on the engine then being increased, while full open throttle is maintained, until the engine speed decreases to a desired level. Tests are to be completed for four evenly spaced engine speed intervals (1500, 2000, 2500 and 3000 rpm).

3.3.2 Diesel

A sample of the OD is shown in Figure 3.3. This ordinary diesel is the fuel that we can from ordinary petrol station. This kind of diesel will be call ordinary diesel (OD) in this experiment. Properties for diesel that being use shown in table 3.1. This experiment used ordinary diesel (OD) for comparison and the diesel were gathered from the nearest Petron station locates at Parit Raja, Batu Pahat.

Table 3.1 : Diesel properties

Product Name	Petron Diesel
Manufacturer	Petron Corporation
Chemical Family	Petroleum Hydrocarbons
Product type	Petroleum Distillate with Performance Addative
Flash Point, PM, ˚C	72
Auto Ignition Temp, ˚C	220
Hazardous Ingredients	The product predominantly consists of aliphatic, alicyclic and aromatic hydrocarbons. In general, the product is combustible and may contain carcinogenic component.

Figure 3.3: Ordinary Diesel

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