EMISSION CHARACTERISTIC OF SMALL DIESEL ENGINE FUELLED BY PREHEAT BIODIESEL

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ABSTRACT

The viscosity of fuels has important effects on fuel droplet formation, atomization, vaporization and fuel–air mixing process, thus influencing the exhaust emissions and performance parameters of the engine. The higher viscosity has effect on combustion and proper mixing of fuel with air in the combustion chamber. The aim of this present research was to investigate the effects of preheated biodiesel derived from Waste Cooking Oil and Jatropha (B5, B10 and B15) at 40^{o}C, 50^{o}C and 60^{o}C on emissions of small diesel engine at three different duration of time, which are 40minutes, 80 minutes and 120 minutes. HATZ-DIESEL 1B30 small diesel engine was used in this research. The result show all biodiesel with preheat temperature show increased in exhaust temperature. However the increase of exhaust temperature still lower compare to standard diesel fuel. For gas emission analysis, it found NOx, smoke opacity was decrease compare to diesel fuel as preheat temperature rise at 60^{o}C. There are increase in CO2 emission level as biodiesel blending ratio increase due to oxygen content in biodiesel and its blend.

ABSTRAK

Kelikatan bahan api mempunyai kesan penting ke atas pembentukan saiz titisan sumburan bahan api, pengabusan, pengewapan dan proses pencampuran bahan api-udara, sekali gus mempengaruhi pelepasan ekzos dan parameter prestasi enjin. Kelikatan yang lebih tinggi mempunyai kesan ke atas pembakaran dan percampuran yang sepatutnya bagi bahan api dengan udara di kebuk pembakaran. Kajian ini dilakukan untuk menkaji kesan minyak biodiesel telah dipanaskan pada suhu yang ditetapkan b berasaskan dari sisa minyak masak dan jatropha (B5, B10 dan B15) pada suhu 40^{o}C, 50^{o}C and 60^{o}C ke atas enjin diesel pada tiga tempoh masa yang berbeza iaitu 40 minit , 80 minit dan 120 minit. Sebuah engine model HATZ-DIESEL 1B30 telah digunakan di dalam ujikaji ini Hasilnya daripada kajian, menunjukkan semua biodiesel mencatatkan peningkatan suhu ekzos berkadar terus terhadap suhu pra pemanas . Walau bagaimanapun peningkatan suhu ekzos masih rendah berbanding dengan suhu diesel. Untuk analisis pencemaran gas, ia mendapati NOx,HC, asap kelegapan mencatatkan penurunan berbanding dengan bahan api diesel. Selain itu terdapat peningkatan pencemaran CO2 berkadar terus dengan nisbah biodiesel kerana kandungan biodiesel mengandungi oxygen yang lebih dari bahan api diesel.

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LIST OF SYMBOLS AND ABBREVIATIONS

B	-	Palm oil biodiesel
B5	-	5% blending ratio
B10	-	10% blending ratio
B15	-	15% blending ratio
^{o}C	-	Degree celsius
cc	-	Cubic centimeter
CI	-	Compress ignition
cm	-	Centimeter
CO	-	Carbon monoxide
CO_2	-	Carbon dioxide
cP	-	Centipoise
CPKO	-	Crude palm kernel oil
CPO	-	Crude palm oil
STD	-	Diesel
MPOB	-	Malaysian Palm Oil Board
DI	-	Direct injection
FAME	-	Fatty acid methyl ester
g	-	gram
h	-	hour
HC	-	Hydrocarbon

HP	-	Horsepower
kg	-	kilogram
kJ	-	kilo Joule
kPa	-	kilo Pascal
kW	-	kilowatt
MPa	-	Megapascal
N	-	Ambient temperature condition
Nm	-	Newton meter
NO_x	-	Nitrogen oxides
O_2	-	Oxygen
P	-	Preheat temperature
P40	-	40°C of preheat temperature
P50	-	50°C of preheat temperature
P60	-	60°C of preheat temperature
PKO	-	Palm kernel oil
ppm	-	Parts per million
rpm	-	Revolution per minute
RTD	-	resistance temperature detectors
s	-	Second
SFC	-	Specific fuel consumption
SO_2	-	Sulfur dioxide
THC	-	Total hydrocarbons

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Biodiesel is an alternative diesel fuel as green and renewable energy derived from vegetable oils or animal fats. There has been considerable interest in developing biodiesel as an alternative fuel, due to its environmental benefits, including the fact that it can be manufactured from renewable resources such as vegetable oils and animal fats [1]. Limited supply of crude oil resources in last year 2013 and increment on the petroleum's price made the situation more critical nowadays [2]. Thus, demand on the biodiesel fuels and its blends as alternative energy sources is urgently required to overcome the problem in Malaysia.

Waste Cooking Oil (WCO) easily found in the food industry and big restaurant. Companies collecting used cooking oil must first obtain a license from the Malaysian Palm Oil Board (MPOB). If they have a letter of support from the local government, they can then obtain the license. Nowadays, waste cooking oil can be identifying alternative sources of raw material due to the lower price compared with other fuel sources. Waste cooking oil offers significant potential as an alternative low cost biodiesel because it does need production cost compare to other type of biodiesel. By using of WCO as biodiesel, it can solve the environment pollution problems especially to avoid WCO dumped in the river or drain.

Other biodiesel that has potential as alternative is Jatropha biodiesel (JPO). It found as one of the cheapest biodiesel feedstock among of vegetable oil. Being non edible oil seed feed stocks it will not affect food price compare to palm oil that use in food industry. In Malaysia, it can be produced in most parts because optimum temperatures for growing Jatropha are between 20°C and 28°C [3] which is similar to the average temperature of Malaysia environmental.

However direct use of biodiesel to engine has poor fuel atomization and operational problem are report due to their higher viscosity and low volatility compare to diesel fuel [4]. In this experimental, emission characteristic of small diesel engine operating on preheat WCO and JPO are evaluated and compare to standard diesel.

1.2 Problems statement

Recently, the consumption of crude palm oil in Malaysia was higher than the production in last year 2008. Figure 1.1 show the consumption of crude palm oil in Malaysia was increased start from 2008 to 2011 and it will continue. This is because crude palm oil has been used as biodiesel B5 in our country. To overcome the problem, biodiesel derived by Jatropha oil (JPO) and Waste Cooking Oil (WCO) have potential as alternative source of biodiesel. Both of them have potential in term of the cost of production and their availability in Malaysia. However, direct use of biodiesel on diesel engine generally considered to be unsatisfactory and impractical. This is due to biodiesel's properties that have high viscosity, density that may results poor fuel atomization in injection process. It was reported that these problem may cause engine failures such as piston ring sticking, injector chocking, formation of carbon deposits and deterioration of lubricating oil after the use of biodiesel for long period's time [5]. To overcome these problems caused by the high viscosity of biodiesel, preheat is the one of solution to reduce viscosity of biodiesel. The purpose of this research to investigate the emission characteristic of small diesel engine fuelled with preheat fuelled WCO and JPO at different blending ratio. The WCO and JPO with blending ratio B5, B10 and B15 will be tested and compared with those of baseline diesel fuel.

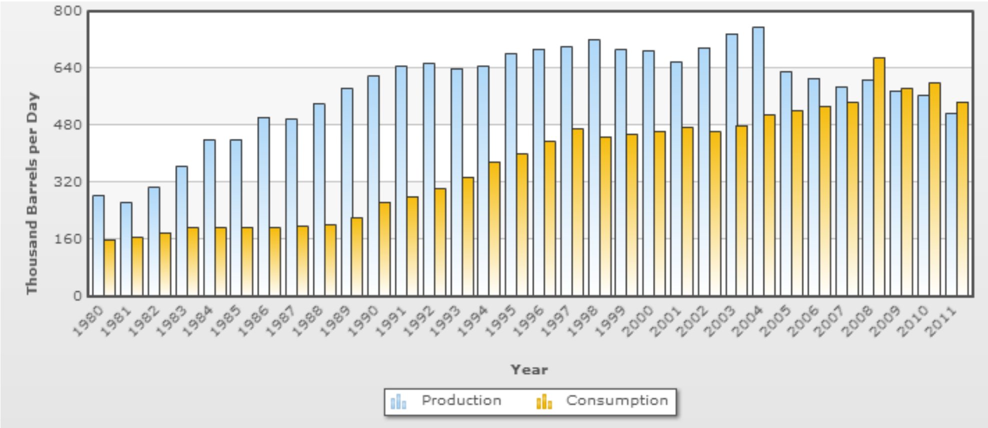

Figure 1.1: Malaysia Crude Palm oil production and consumption by year [6].

1.3 Objectives

The objectives of this research are;

i. To investigate the effect of various biodiesel blending ratio and temperature on emissions characteristic and exhaust temperature of small diesel engine.
ii. To make recommendation the biodiesel fuel with different blending ratio and preheat temperature that strongly effects on exhaust gas emissions under different the engine speed condition.

1.4 Scopes

The scopes of study are:

i. The Waste Cooking Oil (WCO) and Jatropha (JPO) biodiesel which blended from UTHM's automotive lab.

ii. The small diesel engine used is HATZ series B, 1B30 engine.

iii. Set up and conduct the experiment of emissions of small diesel engine at various rpm (1500 rpm, 2000 rpm, 2500 rpm and 3000 rpm)

iv. Preheat fuel temperature are varied at 40°C, 50°C and 60°C.

v. Study the gas emission and exhaust temperature operating by preheated biodiesel fuel and standard diesel fuel.

vi. Emissions tests will be considered in terms of oxygen (O_2), hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO_2) and nitrogen oxides (NOx), and smoke opacity

1.5 Significant of study

Even though biodiesel have some similar physical fuel properties with diesel fuel in terms of energy density, cetane number, heat of vaporization and stoichiometric air/fuel ratio the use of neat vegetable oils or its blends as fuel in diesel engines leads to some problems such as poor fuel atomization and low volatility mainly originated from their high viscosity, high molecular weight and density. It was reported that these problems may cause important engine failures such as piston ring sticking, injector coking, formation of carbon deposits and rapid deterioration of lubricating oil after the use of vegetable oils for a long period of time [7].

The viscosity of fuels has important effects on fuel droplet formation, atomization, vaporization and fuel–air mixing process, thus influencing the exhaust emissions and performance parameters of the engine. It has been also revealed that the use of biodiesel leads to a slight reduction in the engine break power and torque, and a slight increase in the fuel consumption and brake specific fuel consumption compared to diesel fuel. The higher viscosity has effect on combustion and proper mixing of fuel with air in the combustion chamber.

However the properties of higher viscosity of biodiesel and its blends can be reduced by adopting suitable techniques like preheating. By conduct of the heating process, the viscosity and density of biodiesel decreases and improves volatility thus leading to a favorable effect on fuel atomization and combustion characteristics.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter was written to review some information regarding to the biodiesel derived based by waste cooking oil and jatropha oil. It also included some previous study by researcher through journals and books which can be used as guidance to conduct the research on gas emission characteristic of WCO and JPO. Topic that highlighted here is the properties of biodiesel fuels include cetane number, density, viscosity, flash points and its advantages and disadvantages. This chapter also discuss about the engine emissions characteristic which are included of hydrocarbon (HC), oxygen (O2), carbon dioxide (CO2), carbon monoxide (CO) and smoke opacity. Effect of preheated biodiesel on gas emission also discuss in this chapter from previous researcher.

2.2 Waste Cooking Oil as biodiesel

Waste cooking oil based on palm oil usually collected in the food industry or big restaurant before transesterification process to biodiesel. Methanol and ethanol generally used in transesterification process but methanol was preferred for the biodiesel production due to its low cost and higher reactivity compare to ethanol [8, 9]. Compare to other type biodiesel, by using waste cooking oil as biodiesel is an effective way to reduce the raw preparation cost and helps to solve the problem of waste disposal. WCO produced after repeated frying of a variety of food in vegetable oil and no longer suitable for human consumption and thus can be considered a by waste product.

WCO refers to oil that has been hydrogenated after cooking. It might be the most practical alternative of all sources due to its availability. Conversion of used cooking not only provides alternate fuel but also recycle the waste product into useful energy.

2.3 Practicability of Jatropha curcas as a biodiesel in Malaysia

Malaysia is one of the largest biodiesel producing countries [10] but biodiesel produced from Jatropha is still in its incipient state in Malaysia with comparing to palm oil biodiesel industry, even though great interest has been shown lately by both the private sectors and government sectors. Much attention has been drawn to the potential of using Jatropha as feedstock of biodiesel worldwide. In 2007 Goldman Sachs cited Jatropha curcas as one of the best candidates for future biodiesel production and biodiesel from Jatropha will be the cheapest biodiesel among the potential feedstock to produce biodiesel as shown in Table 2.1.

Jatropha curcas has many vernacular names including: physic nut or purging nut it is also familiar as Ratan-jayot [12,-15] and different name in different countries such as in Malaysia it is called as *Jarak Pagar*. In Malaysia, it can be produced in most parts because optimum temperatures for growing Jatropha are between 20˚C and 28˚C [16] which are similar to the average temperature of Malaysian environment. Jatropha curcas can be grown under a wider range of rain fall from 250 mm to1500 mm per annum [17, 18] but optimum rainfall between 1000 mm and 1500 mm which correspond to sub humid region [19]. The plant Jatropha also can be adapted to prolific soil, good drainage and pH ranges from 6.0 to 8.5 [20, 21].

Table 2.1: Price comparison of biodiesel from different feedstock [11]

Feedstock	Price of crude vegetable oil(USD/ tones)	Price of B100 Biodiesel (USD/ tones)
Rapeseed[a]	815–829 (Ex-Dutch Mill)	940–965 (FOB NWE)
Soybean[a]	735 (FOB Rosario)	800–805 (FOB Rosario)
Palm oil[a]	610 (Del. Malaysia)	720–750 (FOB SE Asia)
Waste cooking oil[b]	360	600 (estimated)
Animal Tallow[b]	245	500 (estimated)
Jatropha[c]	N/A	400–500 (estimated)

* FOB-Fresh Off the Boat

[a] Source: Kingsman.

[b] Source: Rice.

[c] Source: Goldman Sachs.

2.4 Biodiesel policies, standard and implementation

Every country around the world have their own biodiesel policies and standard which have been fixed recently. National biofuels policy of Malaysia has been set on 21 March 2006 which has shown in figure 2.1 envisions:

i. Use of environmentally friendly, sustainable and viable sources of energy to reduce the dependency on depleting fossil fuels.
ii. Enhanced prosperity and well-being of all the stake holders in the agriculture and commodity based industries through stable and remunerative prices.
iii. The policy is primarily aimed at reducing the country's dependence on depleting fossil fuels, promoting the demand for palm oil and stabilizing its prices.

National Biofuel Policy

1. Biofuel for transport
2. Biofuel for industry
3. Biofuel technologies
4. Biofuel for export
5. Biofuel for cleaner environment

Short term

- ✓ Establish Malaysian standard specification for B5 diesel
- ✓ Participation in B5 diesel trials by selected government departments with their fleets of diesel vehicles
- ✓ Establish B5 diesel pumps for the public at selected stations
- ✓ Voluntary trials on B5 diesel by the Malaysian Palm Oil Board (MPOB) for selected users in the industrial sector
- ✓ Promotional awareness program to educate the public on the use of B5 diesel

Medium term

- ✓ Establish Malaysian standard specifications for palm oil-based methyl ester biofuels for domestic use and export
- ✓ Engine manufacturers to extend their warranties to the use of B5 diesel. Extensive B5 diesel testing shall be carried out to facilitate the granting of such engine warranties
- ✓ Pass and enforce legislation to mandate the use of B5 diesel
- ✓ Encourage establishment of commercial methyl ester plants. The MPOB will act as a catalyst by pioneering the establishment of palm biodiesel plants in Malaysia in collaboration with the private sector

Long term

- ✓ Gradual increase in proportion of processed palm oil in the diesel blend
- ✓ Greater uptake of biofuels technology by Malaysia companies and foreign companies abroad

Figure 2.1: Malaysia national biofuel policy and implementation [22].

2.5 Properties of waste cooking oil and jatropha oil compare to different vegetable oil

From the Table 2.2, WCO-ME has the lowest heating value that are 38650 kJ/kg compare to other type of vegetable oil and diesel but state the highest value for flash point. It also states that WCME has the lowest kinematic viscosity among them.

The edible oils like sunflower, soybean and palm are more expensive and have a direct impact on food industry. The cost of non-edible oils such as jatropha is low and hence they offer an attractive option. WCO provide viable alternative to diesel, as they are abundantly available. It has been reported that the cetane number of used frying oil methyl ester was 49 and it demonstrates its potential to replace diesel [23].

Table 2.2: Properties of Biodiesels from Different Vegetable Oil [24].

Property	Sun flower Oil **SUME**	Rice Bran oil **RBCE**	Jatropa Oil **JTME**	Pungam oil **PUME**	Waste Cooking Oil **WCME**	Palm oil **PAME**	Diesel fuel
Density (kg/m^3)	882	881.2	881.9	892	885	870	830
Kinematic viscosity (cSt)	6.74	5.37	5.12	5.41	4.73	5.43	3.52
Flash Point(^{o}c)	178	165	168	184	200	174	49
Heating Value (kJ/kg)	39700	39798	41600	39149	38650	192	44136

2.5.1 Fuel Density

Density can define mass over per unit volume. Fuel density is important parameter in diesel engine performance since it effects pump efficiency and pipeline design. Despite of that, the most importantly significant effect on atomization quality of the spray injectors, with subsequent impacts on the efficiency of the combustion and emission.

2.5.2 Kinematic viscosity

Viscosity is measure of internal fluid friction of fuel to flow, which tends to oppose any dynamic change in the fluid motion. Fuel viscosity will affect injector lubricants and atomization. However, fuel with low viscosity may not provide sufficient lubricants for the precision fit of fuel injector pumps, resulting in leakage or increased wear. Instead fuel with high viscosity cause the injection pump will unable to supply sufficient fuel to fill the pumping chamber, and again this effect will be a loss in engine power.it also tend to form larger droplets on injection which can cause poor combustion and increase exhaust smoke and gas emission.

2.5.3 Flash point

Flash point can be defined as the minimum temperature at which the fuel will gives off enough vapors to produce an inflammable mixture (fuel vapors and air) above the fuel surface, when heated under standard test conditions. Higher flash point value give advantage for storage which that mean has safety for period time.

2.5.5 Calorific Value

Calorific value of a fuel is the thermal energy released per unit quantity of the fuel when the fuel is burned completely and the products of combustion are cooled back to the initial temperature of the combustion are cooled back to the initial temperature of the combustion mixture. Other terms used for calorific value are heating value and heat combustion.

2.6 General Information of Biodiesel Fuel

Professor Ikegami described the promising prospect in biodiesel fuel for future as [25]:

Biodiesel fuel has a high potential to spread wider in the future because it may reduce some organic wastes and use of fossil fuel. Furthermore, it also may reduce pollutants from diesel. Wider spreading of biodiesel fuel may achieved only if it is accepted at social level and if there is a clever administration management. In the case of a fuel aiming at ordinary internal combustion engine, evaluation should be made by comparing the emissions from the proposed fuel with those from ordinary fuels. The advantages and disadvantages of biodiesel are shown in table below:

Table 2.3: Advantages and Disadvantages Using Biodiesel as replacement fossil oil [26]

The advantages	The disadvantages
• It is renewable with energy efficient and also displaces petroleum derived diesel fuel,	• Higher NOx emission that diesel duel
• It can be used in most diesel equipment with no or only minor modifications,	• Biodiesel causes excessive carbon deposition and gum formation (polymerization) in engine and oils get contaminate and suffer from flow problem.
• It can reduce greenhouse gases emissions	• Transesterification process is expensive (cost of fuel increases), these oil require expensive fatty acid separation or use of less effective (or expensive acid catalyst).
• It is domestically production from either agricultural (crude palm oil or jatropha) or recycled resources WCO.	• Use of biodiesel in internal combustion engine may lead to engine durability problems including injector cocking, filter plugging and piston ring sticking,
• Biodiesel has superior better lubricity properties. This improves lubrication in fuel pumps and injector units, which decreases engine wear, tear and increases engine efficiency.	
• Biodiesel has higher cetane number (about 60-65 depending on the vegetable oil) than petroleum diesel (53) which reduces ignition delay.	

2.7 Problem in using biodiesel and its blends as engine fuel

Extensive literature survey reveals that most of the engine problems can be attributed to poor quality biodiesel. Some of the problems (primarily cold-weather problems) are not due to poor fuel quality but are related to the biodiesel fuel properties. Most of these problems can be avoided or minimized. Table 2.3 reviews the possible engine problems while using biodiesel and its blends.

Table 2.4: Details of engine problems and suggest remedial measures when biodiesel and its blends were used an engine fuel [27]

Engine Problems	**Remedial Measures Suggested**
Deposits on injectors affecting the fuel spray patterns.	• Injectors may be periodically cleaned. • Using specialized cleaning equipment.
Cold-weather operation of engine using partially solidified or partially transformed biodiesel.	• Use of Low-temperature properties improvers to improve the engine operation in cold conditions. To ensure complete conversion of oils to biodiesel free from contaminants.
Engine starting problems under cold weather conditions or run only a few seconds. Engine stops after operation for few seconds.	• Wait for spring time to reach. Warm the fuel filter using 12-volt jacket heaters. • Use additives to avoid gum/particles formation in biodiesel.
Fuel filter clogging due to: Poor biodiesel quality due to formation of resins or gels in the fuel supply system.	• The problem of algae build up can be removed by adding suitable algaecide. • Use of moisture free fuel is recommended.

2.8 Combustion Process in Direct Injection Diesel Engine

Refer to Figure 2.1, the graph show that there is an ignition delay between the start of injection and the start of combustion. This time is required for the fuel to atomize, vaporize and mix to give a combustible air/fuel ratio.

At the end of the delay period, a large amount of fuel has been injected into the cylinder (and injection is continuing). A very rapid rate of pressure then occurs as most of this fuel burns spontaneously. This gives rise to the characteristic diesel knock and it's also explains why the mixed cycle idealization assumes part of the fuel is burnt at constant volume.

At the end of the Premixed Combustion Phase, combustion occurs in a controlled manner as the fuel is injected. After injection stops, combustion continues as the mixing process controls the local air/fuel ratio. This process is known as the mixing controlled combustion phase. This is essentially the constant pressure part of the mixed cycle idealization.

Further, low rate of heat release combustion occurs. During expansion as pockets of rich mixtures disperse into fuel lean mixtures. This is the late combustion phase, which occurs due to imperfect mixing and dissociation.

Some important points to note about the compression ignition combustion process are:

i. Since injection occurs just before combustion starts, there is no knock limit as in the spark ignition engine. Hence, a higher compression ratio can be used giving higher thermal efficiency
ii. It is essential that the ignition period be kept short and reproducible: A long delay period results in increased noise, increased smoke and increased mechanical loading. The cetane number is the measure of the fuel ignition quality. A fuel with a low cetane number (bad for compression ignition) will have a high octane number. Therefore, petrol is a bad duel for a compression ignition engine.
iii. Since the charge is heterogeneous, quality governing can be employed giving improved thermal efficiency, especially at part load. The thermal efficiency is also increased due to the lean mixture operation

iv. Due to the imperfect mixing in the short space of time available, not all of the air in the cylinder can be utilised. If the air to fuel ratio is too low, excessive amounts of soot or black carbon are produced (the smoke limit is a measure of where the smoke becomes unacceptable. The richest air to fuel ratio possible is about 20% lean of stoichiometric. Hence, the maximum mean effective pressure for a naturally aspirated diesel engine is less than that for a SI engine.

v. A major limitation on the power output of CI engines is that the combustion process is slow compared to the SI engine due to the mixing process. This severely limits the maximum speed and hence power output

vi. Due to the last two points, CI engines are often turbocharged to increase their specific power output.

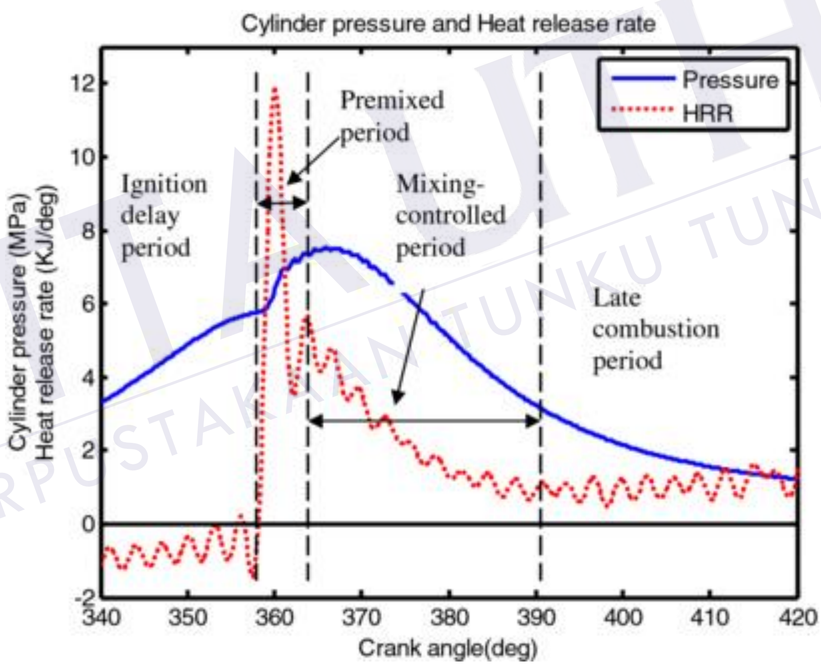

Figure 2.1: The heat release diagram and the pressure-crank angle diagram [28]

2.9 Critical Review

Table 2.5: Study of various fuels and various blends ratio of biodiesel compare to diesel fuel

No	Author	Blending ratio and preheat temperature	Engine Performance	Engine Emissions
1	S.M.A.Ibrahim et el.2014 [29].	-Using B5,B20,B40,B70 AND B100 JPO -preheat temperature 50°C,70°C, and 90°	-specific fuel consumption for all fuel tested reduces with increase load due to increase in brake power -all the biodiesel blending ratio with preheat temperature are higher than standard diesel due to lower heating value. - it found that at 90°C preheat state lower fuel consumption	-CO_2 emission reduce as increase of biodiesel blending ratio, however compare to preheat biodiesel CO_2 emission are higher than diesel fuel. -higher density of preheat biodiesel oil increases the fuel flow rate as the load increase which in turn increase CO_2 emission -increasing preheating temperature leads to increase of NOx emission due to increase cylinder gas temperature. -increasing preheats temperature less HC compare to unheated biodiesel. This is

				achieve by reducing viscosity and density thus improves vaporization and fuel air mixing rates combustion become complete and results in low HC emission
2	Dhananjay Trivedi and Amit Pal.2013 [29].	-Using biodiesel derived WCO at blending B20 and B40 -preheat temperature 800°C	-Brake specific fuel consumption (BSFC) reduces with increase of brake power for all fuel tested. This is due to complete combustion as additional oxygen available from biodiesel.	
3	Dinesha P et al 2012 [31]	-Biodiesel derived by Pongamia methyl ester (PMO) at blending ratio B20 and B40 --preheat temperature 60°C,75°C, 90°C, 110°C	-Brake specific energy consumption (BSEC) reduces as load increase. All preheat biodiesel state lower BSEC than unheated B20. Higher preheating temperature results in better spray and improved atomization during injection there by improvising the combustion. -At low load condition, exhaust temperature	-unburned hydrocarbon (UHC) was decrease for all preheat biodiesel. It found the reduce of UHC at 75°C and 90°C is more compare at 110°C preheat temperature. -NOx are increasing at higher preheating temperatures and showing trend as load increase. The higher NOx emission as preheat biodiesel improve fuel spray

			is found lower, hence it could not preheat inlet fuel effectively as compared to be at higher loads.	characteristic, better combustion achieve due to oxygen content and higher temperatures in cylinder.
4	A.K. Hossain et al [32]	Neat Jatropha And Karanji preheat by jacket water 60-75°C	- Brake specific fuel consumption (BSFC) was higher than diesel fuel because the lower calorific value thus more fuel is needed for the same engine output.	- NOx emission was higher for both biodiesel. This is due to higher peak cylinder pressure observed with plant oil.
5	P.V. Roa .2011 [33]	Jatropha Oil B100 with preheat	-For the fuel consumption, unheated JPO is more than diesel fuel and preheated JDP. Therefore, due to lower value of calorific value of JPO, this behavior of more fuel consumption was expected fall al power output. Preheated JPO show decreased with preheating of JPO to the improved combustion caused increased evaporation and spray characteristic.	-It is observed that, the CO emission of JPO is less than that of diesel fuel. The decrease in CO emission for JPO is attributed to the high cetane number and the presence of oxygen in the molecular structure of the JPO. Also, the CO emission levels are further reduced for preheated JPO and the reason is attributed to its reduced viscosity, density, and increase in rate of evaporation due to preheating.

2.10 Effect on preheat temperature on kinematic viscosity biodiesel

Viscosity is a measure of the internal fluid friction of fuel to flow, which tends to oppose any dynamic change in the fluid motion. To reduce viscosity, jatropha oil was transesterified to methyl ester (or biodiesel). From the graph, it show at 25°C, the viscosity of jatropha oil is about 14 times greater compare to of diesel oil. Viscosity of the plant oils is temperature dependent and can be reduced by 80-90% through preheating up to 90°C.

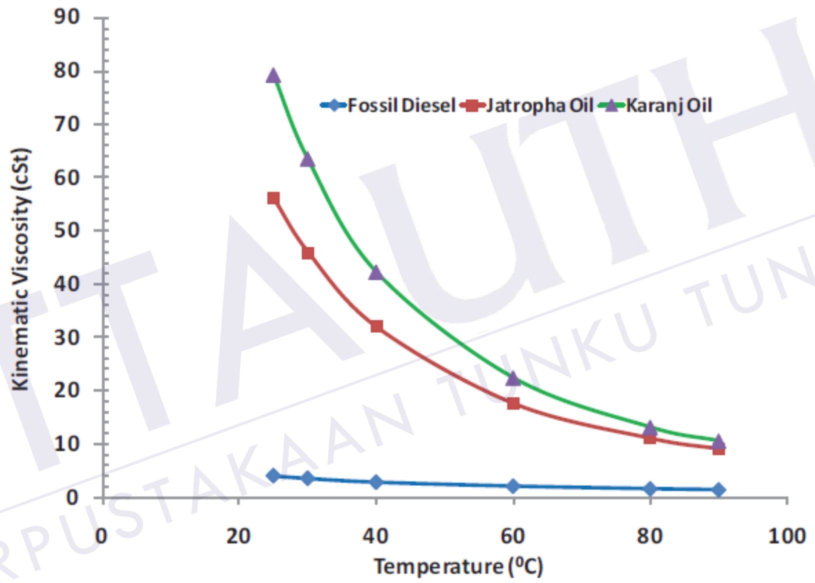

Figure 2.3: Viscosity vs. temperature of jatropha, karanj and fossil diesel [31]

2.11 Combustion characteristic

The combustion parameter are consider net heat release rate and exhaust gas temperature.

2.11.1 Net heat release rate

Net heat release rate can defined as work in and is measure of the rate which the work done plus the change of internal energy. Figure 2.3 show the net heat release rate at maximum power during combustion process. Jatropha biodiesel state the higher value of net heat release rate compare to diesel fuel and preheat jatropha. This is due to poor mixing of jatropha biodiesel with air because of high viscosity. Meanwhile preheat jatropha air state less quantity of air fuel mixture prepared for combustion. This is because faster evaporation of the preheat biodiesel thus more burning occurs in the diffusion phase rather than premixed phase. The increase of heat release at gross heat release due to improve mixing and evaporation of jatropha preheat which leads to complete burning.

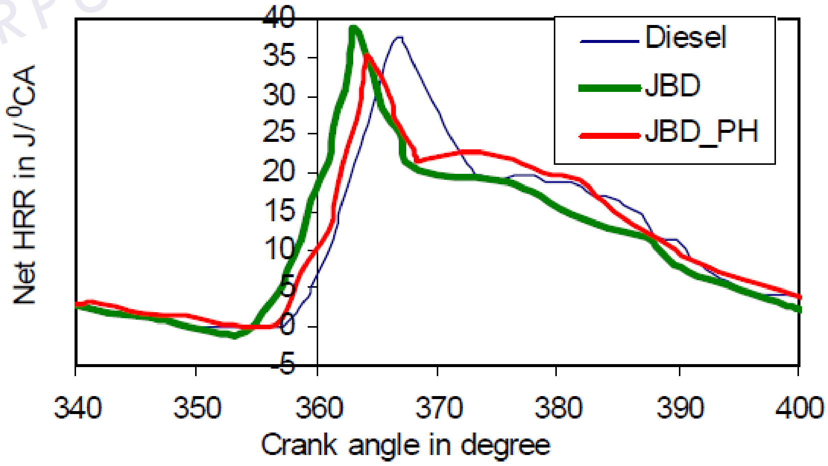

Figure 2.3: Net Heat Release Rate [33].

2.11.2 Exhaust gas temperature

The variation of exhaust gas temperature for different fuel inlet temperature with respect to the load is indicated in Figure 2.4. The exhaust gas temperature for the fuels tested increases with increase in the load. The amount of fuel injected increased with the engine load in order to maintain the power output and hence the heat release and the exhaust gas temperature rose with increase in load. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber [34]. At all loads, diesel was found to have the higher temperature and the temperatures for the neat jatropha oil and its methyl ester showed a downward trend. The exact reason for lower exhaust temperatures compared to diesel could not be identified. However, it may be due to lesser calorific value of Jatropha oil. As can be seen from the figure, the variation in exhaust temperature is more at higher load with respect to the lower loading condition of the engine. However, it shows a decreasing trend up to 90°C preheated condition; after that increasing trend up to 110°C, this variation is more after 40% of engine loading condition was up to full load.

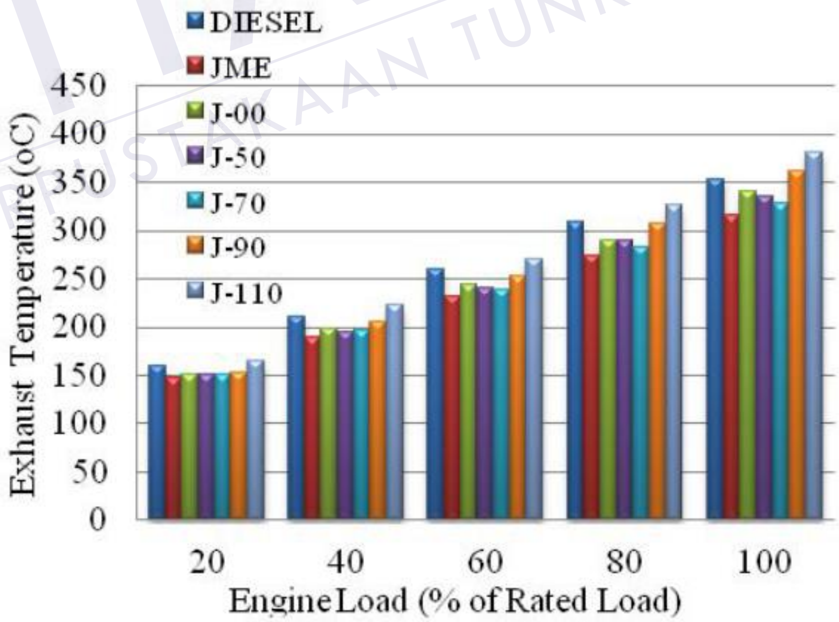

Figure 2.5. Variation of Exhaust gas temperature with load at elevated fuel inlet temperatures [35].

2.12 Emissions Characteristic

The engine emissions are considered in terms of nitrogen oxides, carbon monoxide, hydrocarbon and smoke opacity.

2.12.1 Emissions of Nitrogen Oxides

NOx emissions are extremely undesirable. NO_x emissions refer to stable oxides of nitrogen formed at high temperatures in the combustion chamber. NO_x emissions are characteristics of engines as they operate with high air to fuel ratio. The formation of NOx is highly dependent on the temperature in the combustion chamber and oxygen concentration for the reaction to take place.

From Figure 2.5, it is observed that NOx emissions Cashew nut shell liquid (CNSLME) are increased at preheating temperature 80°C and showing increasing trend as brake power increases.. The higher NOx emission at higher temperature can be attributed to various reasons, such as improved fuel spray characteristics, better combustion of biodiesel due to its oxygen content and higher temperature in the cylinder as a result of preheating [36].

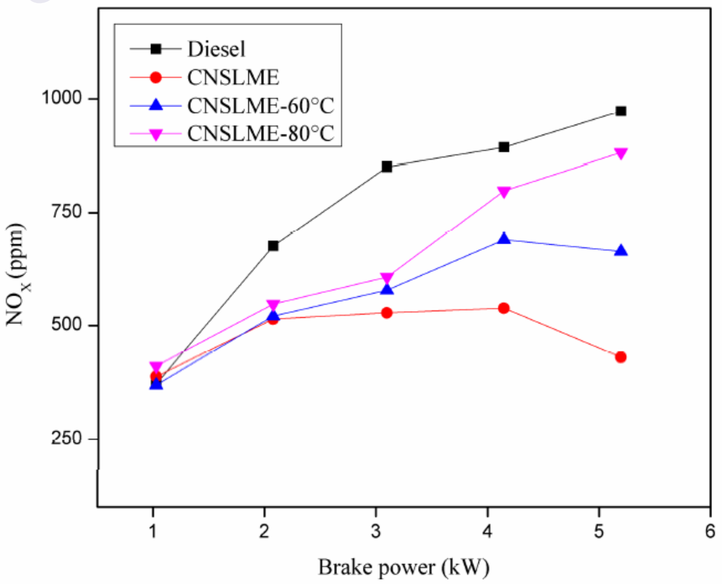

Figure 2.6: Effect of fuel preheating on NOX emission [37]

2.12.2 Emissions of Carbon Monoxide

Carbon monoxide (CO) emissions occur due to the incomplete combustion of fuel. The emissions of carbon monoxide are toxic. CO is well-known to deprive the brain, heart, and other tissue of oxygen, which can lead to death [38].

For both the fuels, the increasing trend of carbon monoxide (CO) emission levels are observed with power output as shown in figure 2.6. This increasing trend of CO emissions is due to increase in volumetric fuel consumption (due to its lower calorific value) with the engine output power. The CO emission level of (preheat biodiesel) PBD is less than that of (no preheat biodiesel) PDB fuel. The CO emission levels are further reduced for PBD_H, due to reduced viscosity, density and increase in evaporation rate.39]

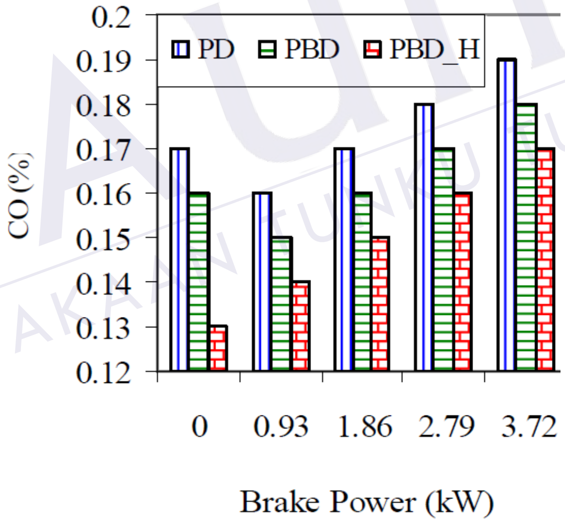

Figure 2.7: Carbon monoxide emission [39]

2.12.3 Emission of carbon dioxide

Figure 2.7 shows the comparison of CO_2 emissions of unheated and preheated jatropha oils .From the data obtained, it was observed for preheated jatropha oil state lowest CO_2 emission. In addition, it is probable that higher oxygen content in the plant oil helped to combust jatropha oil and caused higher CO2 emission than fossil oil. Since biodiesel is produced from plant oils or animal fats, it has been promoted as means for reducing emission of carbon dioxide that would otherwise be produced from combustion of petroleum based fuels.

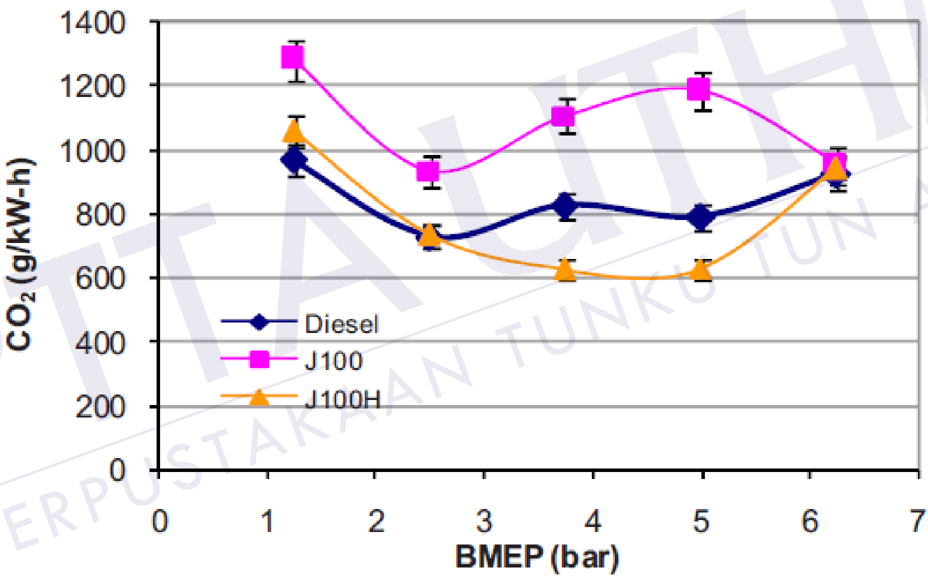

Figure 2.8: CO_2 emission of different biodiesel blends at two speeds [40]

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