Effect of Brake Power on Specific Fuel Consumption and Speed, on Performance Characteristics of Waste Cooking Oil as an Alternative Source of Fuel for Diesel Engine.

[a]Prof A. O. Odukwe
[a] Department of Mechanical Engineering,
University of Nigeria, Nsukka,
Nigeria

[b] T. Onah
[b] Department of Mechanical Engineering,
Enugu State University of Science and Technology
(ESUT) Enugu, Enugu State, Nigeria

[c] Festus L. Tor
[c] Department of Mechanical Engineering,
Ken-Saro Wiwa Polytechnic, Bori, Rivers State,
Nigeria

Abstract:- This thesis discussed the important of used waste cooking oil as an alternative feedstock for diesel engines. It involved the fuel production and analysis phase as well as the engine performance and analysis phase. In the first phase, biodiesel was produced from used waste cooking oil. The used waste cooking oil was collected from big restaurants and transesterified by heating the oil with large excess anhydrous methanol using potassium hydroxide (KOH) as a catalyst to speed up the reaction. The fuel properties such as kinematic viscosity, oxidation stability, carbon contents, cetane number, density, flash and cloud points and calorific value of the biodiesel were determined. The obtained values were compared with those of petroleum-based diesel and the ASTM recommendation values for biodiesel. The analysis enabled the chemical formula of the biodiesel to be given which helped to determine its stoichemetric combustion equation. In addition, emission/pollution problems associated with the production and consumption of biodiesel and the techno-economic analysis of biodiesel production from used waste cooking oil where also discussed. In the second phase, the biodiesel was introduced to one diesel engine test-bed in the mechanical Laboratory, Innoson Nigeria Limited Nnewi, Anambra State, Nigeria, where the engine performance criteria such as brakes power, specific fuel consumption and performance engine speed were analyzed. These performance criteria were also determined using petroleum-based diesel as feedstock and the result were compared, it was observed that: as the speed increases the brake power decreases and as break power decreases the specific fuel consumption decreases.

Keynote: Engine test-bed, fuel gauge, air flow meter, speedometer, brake power, specific fuel consumption and engine performance speed.

1.1 INTRODUCTION

The use of bio-fuel as an alternative fuel in diesel engine originated from the demonstration of the first diesel engine by the inventor of diesel engine "Rudolf Diesel" at the World Exhibition in Paris in 1900 by using peanut oil as a fuel for the engine [23]. In the recent years, serious efforts have been made by several researchers to use different sources of energy as fuel in existing diesel engines especially with constantly increase in petroleum prices and uncertainties concerning petroleum availability.

Generally, compression-ignition engines play a greater role than spark-ignition, particularly in the field of heavy-duty vehicles and agricultural applications, on account of their higher thermal efficiency and durability [18,]. However, diesel engines are the major contributors to various types of harmful compound in the air. Since the global energy crises in the 1970s, research on alternative and renewable fuels has become a very intensive area. Hence, more stringent regulations are imposed on exhaust emissions to protect the environment. Many research works are in progress to develop newer technologies and alternative fuels to improve the combustion characteristics and reduce emissions. Among the various alternative fuels, bio-fuels are gaining importance owing to the renewable nature. Extensive research and demonstration projects have shown that it can be used pure of blends with conventional diesel fuel in unmodified diesel engine [12].

1.2 Aims and Objective

The aim of this project is to study the potentials of used Waste Cooking Oil Methyl Ester (WACOME) as an alternative fuel for CI Engine. In order to achieve this aim, the following objectives were outlined:

i. To review literature of bio-fuels and compression-ignition (CI) engines.
ii. To produce biodiesel from used waste cooking oil.
iii. To analyze the techno-economic implications of the biodiesel production and literatures on its environmental impacts.
iv. To determine the biodiesel properties and compare them with the ASTM recommended value.
v. To analyze the performance of the diesel engine test-bed in the Mechanical Engineering Laboratory, Innoson Nigeria Limited Nnewi,

Anambra when operated on the biodiesel as well as conventional diesel and then compare the results.

1.3 Statement of the Problem

The world-wide proven fossil fuel is predicted to last for the next 40 years. The above fossil fuel reserves in Nigeria (22-25 billion barrels) will exhausted in the next 29 years [15]. Viable alternatives to this conventional energy source must be sort before it becomes too late.

The production and consumption of fossil fuel release tremendous amounts of greenhouse gases such as carbon monoxide (CO), carbon dioxide (CO_2), oxides of Nitrogen (NOx), particulate matters (PM), hydrocarbons (HC) and sulfur dioxide (SO_2) into atmosphere which cause disastrous global warming because of the seemingly irreparable depletion of the ozone layer. Consequently, the polar ice blocks melt and sea levels rise world-wide causing flooding and unprecedented inundation of entire cities. For instance, nitrous oxide, N_2O, a gas emission associated with the exhaust of petro-engines has an alarming Global Warming Potentials (GWP) value 310 with atmospheric lifetime of 120 years [26].

According to Manufacturers Association of Nigeria, the cost of conventional diesel production in Nigeria per week is N1.8b and the daily national consumption is 12-13 million liters [30].

Biodiesel is much more affordable, environmental friendly and highly oxygenated. However, high viscosity and poor volatility are the major limitations of waste cooking oil for utilization as fuel in diesel engines. But these limitations are overcome if the oil is transesterified in the presence of a catalyst to form methyl esters. It is therefore pertinent to embark on the research and production of this alternative diesel early enough to be able to cope with the expected huge daily demands when fossil diesel has become extinct.

1.4 Significance of the Research

This study stands to benefit commercial palm oil producers and consumers such as big eateries as it seeks to educate the masses on the potentials of used waste cooking oil as an alternative fuel for compression-ignition engines. The outcome of this work will help to reduce Nigerian dependency on fossil fuels.

The depletion and environmental degradation resulting from the consumption of fossil fuels have led to a significant reduction of underground crude oil reserve and a lot of environmental problems such as pollution and flooding. Hence the search for biodiesel fuel which problems such as pollution and flooding. Hence search for biodiesel fuel which promises a harmonious relationship with sustainable development, energy conservation and efficiency, and efficiency, and environmental preservation is justifiable [15].

The engagement of Nigeria communities in the production and use of biodiesel shall also be a great source of employment. Her economic growth shall be spurred favourably, obviously displacing poverty to the joy and comfort of the people. In the US, the use of bio-fuels supported 39,027 jobs across the country and earned more than $2.1 billion in household income in 2011 alone. According to the latest Environmental Protection Agency (EPA) statistics [12], the use of these new oils can do the same for Nigeria.

2.1 Overview of Biodiesel

The American Society for Testing and Materials (ASTM) defined biodiesel as monoalkyl ester of long chain fatty acids derived from a renewable lipid feedstock, such as vegetable oil or animal fat. It is renewable, biodegradable and oxygenated. Biodiesel fuel typically comprises lower alkyl fatty acid (chain length C_{14}-C_{22}) esters of short-chain alcohols, primary, methanol or ethanol.
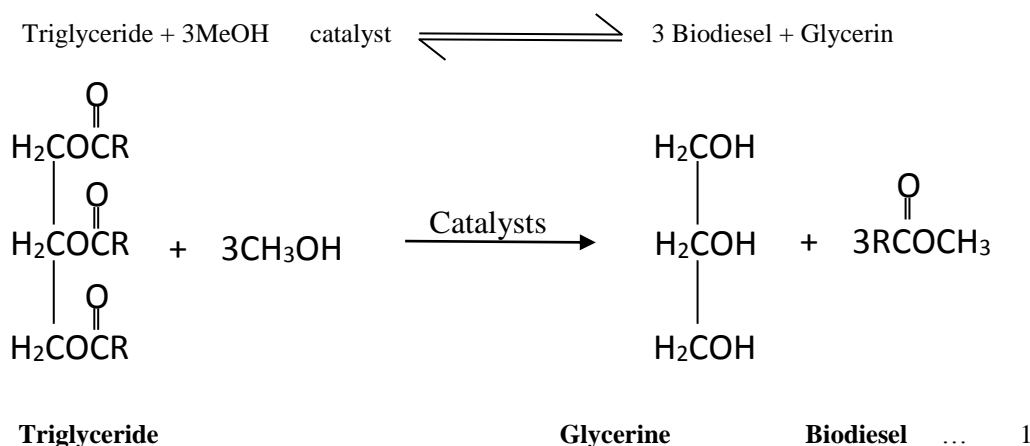
Commercial production of biodiesel began in the late 1990s when the US National Biodiesel Board (NBB) reported production 500,000 gallons (32.6 barrels per day) in 2000. This US biodiesel industry reached a milestone by producing more 1 billion gallons of this fuel in 2011 alone; supporting 39,027 jobs across the country and more that $2.1 billion in household income. According to the latest Environmental Protection Agency (EPA) statistics [12]. More importantly, some recent estimates 92011) off world-wide proven petroleum reserves of 1.35 trillion barrels with 80 million barrel as daily production rate predict them to last for the next 40 years [17].

Various methods have been reported from the production of biodiesel from vegetable oil, such as direct use and blending, microemulsification, pyrolysis and transesterification. Among these, transesterification is an attractive and widely accepted technique. The purpose of the transesterification process is to lower the viscosity of the oil.

Today, biodiesel production is being carried out world-wide with an aim of eventually doing away with the exhaustible conventional fossil diesel. The following oil industries all over the world have been able to develop biodiesel production technology and biodiesel production plants both for local and commercial uses. These include Qwest Biofuels and Riceland mills in the United States. Masa Global in the UK, Dhoomketu, Shiri international, Krishi oils limited and Amrut Eng. Works in India, Dataec Edible oils of Malaysia, PT Bumi Idawa Niaga of Indonesia, Gulf oil and Gas inc. in Nigeria and Nigerian's Premier Processing Plants in Abuja, established o April 29, 2008 by D-8 secretariat.

2.2 Production Technology of Biodiesel by Transesterification

Transesterification can be defined as a reaction between a triglyceride (oil) and an alcohol (e.g., ,ethanol or ethanol) in the presence of a catalyst, such a sodium hydroxide or potassium hydroxide, to chemically break the molecule of the oil into methyl or ethyl ester (biodiesel). Glycerin, also known as glycerol, is the by product of this reaction. The process is similar to hydrolysis except that alcohol is used instead of water [61]. This reaction is given below

Triglyceride + 3MeOH   catalyst ⇌ 3 Biodiesel + Glycerin

$$H_2COCR$$ (with O double bond)
$$H_2COCR \quad + \quad 3CH_3OH \xrightarrow{\text{Catalysts}} H_2COH \quad + \quad 3RCOCH_3$$
$$H_2COCR \qquad\qquad\qquad\qquad\qquad H_2COH$$

Triglyceride   **Glycerine**   **Biodiesel** …   1

2.3 Rate of reaction

Transesterification reaction can occur at ambient/70 degrees f, but it needs 4-8 hours for completion. The reaction is shortened to 2-4 hours at 105 degrees F. Even shorter time of 1-2 hours at 140 degree F is possible.

The higher the temperature, the faster the rate of reaction but at temperature above 65 degree C (148 degree F), the boiling point of methanol, the methanol evaporates.

2.4 Chemistry of Biodiesel

Fully saturated fats and oils have four hydrogen bonded to every carbon atom. This is important because level of saturation determines the characteristic of the fat or oil. For example, soy oil becomes a solid at lower temperatures.

The molecular formula of biodiesel has been given by many authorities in the literature as $CH_3(CH_2)nCOOCH_3$[3,8,12] where n has values ranging from 10 to 18 depending on the class of alcohol used in the transesterification process. The above formula is acceptable since fat and oil are saturated hydrocarbons. The table below shows the two common classes of alcohol usually used in the production of biodiesel, the value of n and that name of the biodiesel produced with their corresponding molecular and chemical formulae.

Class of alcohol	Value of n	Name of biodiesel	Molecular formula	Chemical formula
Methanol	16	Methyl linoleate	$CH_3(CH_2)_{16}COOCH_3$	$C_{19}H_{40}O_2$
Ethanol	17	Ethyl stearate	$CH_3(CH_2)_{17}COOCH_3$	$C_{20}H_{40}O_2$

Table 1: Chemical Formula of Biodiesel

Methanol is preferred to ethanol because methanol gives higher yield of biodiesel due to the simultaneous transesteriffication of triglycerides and methyl esterification of fatty acids. Secondly, ethanol forms an azeotrope with water. So it is expensive to purify ethanol during recovery. Methanol recycles easier since it does not form an azeotrope.

2.5 Compression – ignition Engines

Compression-Ignition (CI) engines are a class of reciprocating internal combustion (IC) engine in which combustion is initiated spontaneously by virtue of the rise in temperature during the compression process. They are also called diesel engines or oil engines.

A diesel engine has the highest thermal efficiency of any regular internal or external combustion engines due to its very high compression ratio [17].

Diesel engines are manufactured in two-stroke and four-stroke versions. They originally used as more efficient replacement for stationary steam engines. Since 1910s, they have been used in submarines and ships, in locomotives, trucks, heavy equipment, automobiles, electric generating plants etc.

2.6 Performance Criteria for CI Engines
2.6.1 Indicated Power.

The indicated power (ip) can be defined as the rate of work done by the working fluid on the piston [62]. To determine the indicated power, it is imperative to know the conditions inside the cylinder as well as the geometry of the cylinder. Mathematically

$$Ip = p_b LANn \;…\;…\;…\;…\;…\;… \quad 2 \text{ for two strokes cycle)}$$

$$Ip = PbLANn \;…\;…\;…\;…\;…\;… \quad 3 \text{ for four-stroke cycle)}$$
$$2$$

2.6.2 Brake Power (Bp)

Some of the power developed in the piston as indicated power is taken by cylinder and bearing function as well as the auxiliaries. The balance is what is available as brake power which becomes the engine net output Bp is given in KW on the hydraulic dynamometer discussed in chapter four as

$$Bo = \frac{T*N}{9549.303} \quad \dots \dots \dots \dots \dots \dots \quad 4;$$

2.6.3 Brake Mean Effective Pressure, Bmep:

This can be used in comparing the performance of two engines. This is because it gives an idea of the amount of work the engine can do per unit cylinder size.

$$\textbf{Bmep} = \frac{brake\ power}{swept\ volume} = \frac{2bp}{LANn} = \dots \dots \dots \dots \dots \dots 5$$

2.6.4 Brake Thermal Efficiency (η_{BT})

The brake thermal efficiency of an engine is very important because it determines how efficiently the fuel is being used in the engine. This efficiency shows the portion of the energy consumed by the engine that is converted into useful work. It is calculated as follows:

$$\eta_{BT} = \frac{Energy\ equivalent\ of\ the\ Brake\ Power\ per\ second}{Energy\ supplied\ by\ FUel\ per\ second} \dots 7; \ \eta_{BT} = \frac{2bp}{LANn} \dots 6$$

2.6.5 Specific Fuel Consumption, SFC

The specific fuel consumption is defined as the rate of fuel consumption per unit brake power. It gives required to deliver one kilowatt for one hour at the load considered. Its unit is kg/KWh

$$SFC = \frac{fuel\ used\ in\ kg/h}{brake\ power\ in\ KW} = \frac{m_f}{bp} \ (kg/Kwh) \dots \dots \dots \quad 7$$

3.0 METHODOLOGY

3.1   Procurement of Materials

About 30 liters of used waste cooking oil were collected from big restaurants out of which one liter was first used for demonstrations. Thereafter, more 28 liters of biodiesel were produced which were used both for the fuel property determination and engine performance analysis.

3.2   Materials
- 1 liter of used waste cooking oil
- 200ml of methyl alcohol also known as methanol
- 3.5 grams of 0.1% pure potassium hydroxide (KOH)
- 200ml capacity graduated cylinder
- Large mason jar (big enough to hold at least 2 liters)
- Small mason jar (big enough to hold at least 1 liter)
- 1 liter of distilled water with 1 liter capacity measuring cup.
- pH indicator (10ml of phenolphthalein solution)

- Heating element such as stove. Thermometer and digital scale.
- Chemical gloves and 200ml capacity glass jar with tight-fitting lid for mixing of chemicals.
- 1500ml and 20ml capacity beakers and a funnel.

Step 1: Titration Process: Determination of how much catalyst needed to neutralize the fatty acids in the used cooking oil.

1. I gram of potassium hydroxide (KOH) was measured onto a petri-dish on a digital scale.
2. 1 liter of distilled water was measured into a 1500 beaker
3. The 1 gram of KOH was poured into the 1 liter of distilled water
4. The beaker was warmed gently by standing it on some hot water between 50oC and 60oC. The beaker labeled with a piece of masking tape and a marker "KOH water Solution, Do Not Drink" and was stirred until all the water turned clear.
5. 10 ml of alcohol was measured into 20 ml beaker.
6. 1 ml of used cooking oil was dissolved into alcohol and the 20ml beaker was labeled "oil/alcohol solution"
7. 2 drops of PH indicator (phenolphthalein solution) was added to the oil/alcohol solution.
8. A burette was used to drip the 0.1% pure KOH/water solution into the oil/alcohol-phenolphthalein solution about 1 millimeter at a time.
9. The oil-alcohol-phenolphthalein solution was stirred steadily as the KOH/water solution was added and watched carefully for a color change. The change occurred suddenly.
10. The quantity of KOH/water solution added was being recorded until the color of oil-alcohol-phenolphthalein solution changed and held for at least 10 seconds. (This represented a pH of about 8.5).

NOTE: Phenolphthalein has a broad pH range where it changes color and as such it is great indicator for titrating biodiesel. It is colourless until at a pH of 8.3, then it turns pink (magenta) and red at its maximum pH of 10.4

Step 2: Titration Equation
The base equation as cited by many authors [15,23,25] is given by:
7.0g KOH + L = X … …. …. …. …. …. …. …. 8

Where L is the number of grams of KOH necessary to neutralize one liter of used cooking oil and X is the number of millimeter of KOH/water solution dropped into the oil alcohol mixture.
7.0g is a conversion factor.
The modified equation to account for impurity of KOH is given by;
(7.0 KOH/& purity) + L = X … …. …. ….. …. …. 9

Note: the above equations are for 1-liter batches. Adjustments for other volumes as necessary are done by simple arithmetic.

Using equation 11, 3.5 grams by volume of KOH needed per liter of oil obtained.

Step 3: Preparation of 1 liter of biodiesel
- 1 liter of filtered used cooking oil was poured into a large mason jar
- 100 ml of methanol was poured into a small mason jar
- 3.5 grams (as determined by titration) of KOH was put onto a petri-dish on a scale.
- The KOH was carefully poured into the methanol filled jar.
- The mixture was kept stirring and shaking until the KOH was completely dissolved in the methanol thereby creating a solution called potassium methoxide, a strong caustic.
- The potassium methoxide was carefully poured on top of the cooking oil in the large Mason jar.

- The lid on the large Mason jar was secured while the solution was agitated vigorously for 10 minutes.
- The solution in the large Mason jar was heated between 50ºC and 60ºC.
- The mixture was stirred for about 15 minutes while the temperature was kept constant.
- 75% of the separation took place within the first one hour after the reaction.
- Within 8 hours, the glycerin fell to the bottom of the large mason jar.
- The top layer was methyl esters or biodiesel.
- The Mason jar was labeled "Biodiesel Reaction in Progress. Do Not Drink"
- Complete separation of biodiesel & glycerin occurred within 24 hours after which the biodiesel was siphoned and the glycerin collected. The glycerin was used as soap.
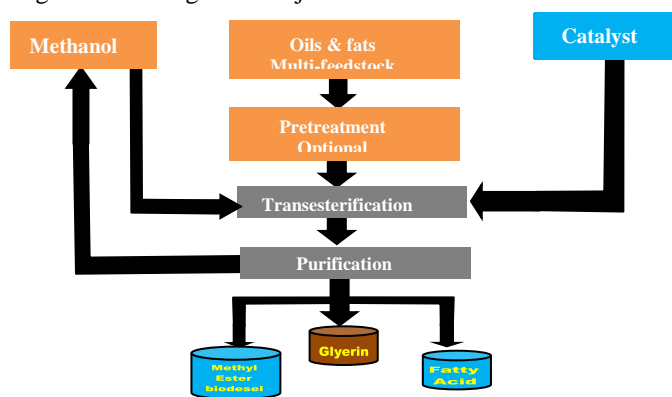- The flowchart is shown below.

Figure 1: Flowchart of the transesterification Process.
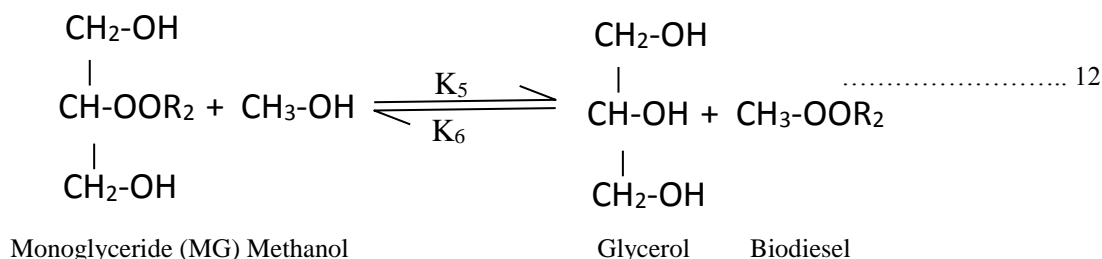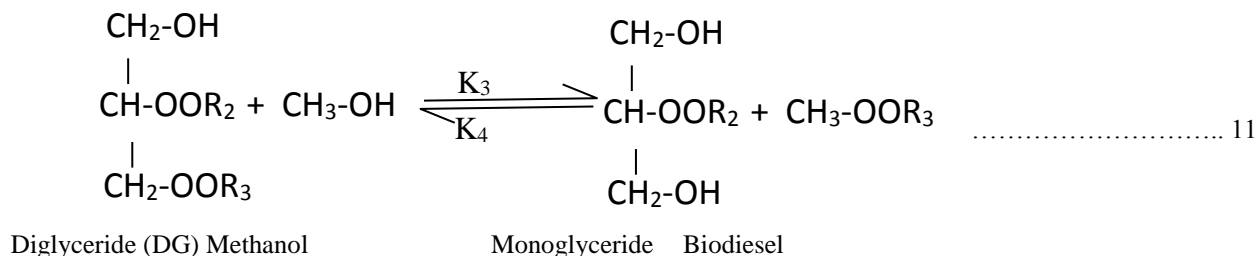
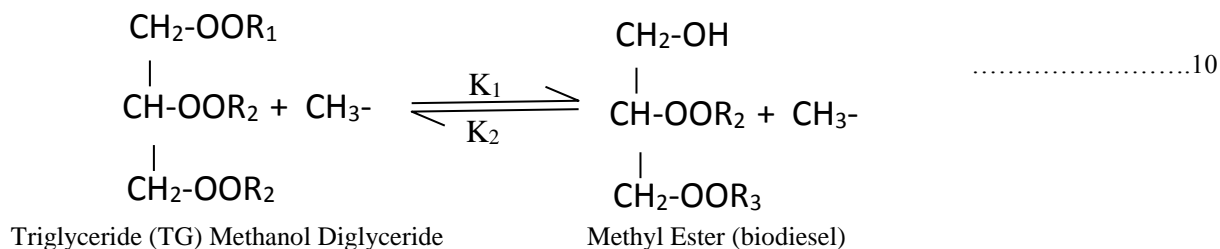## 3.4 Semi-Large Scale Production of Biodiesel

In addition to any of the applicable steps outlined above, this process involves.

i. Heating about 10 liters of oil a 20 liter-capacity drum between 50ºC and 60ºC with large excess anhydrous methanol using potassium hydroxide (KOH) as a catalyst to speed up the reaction.
ii. Stirring the mixture for about one hour while the temperature is kept constant.
iii. Allowing the mixture to settle over night.
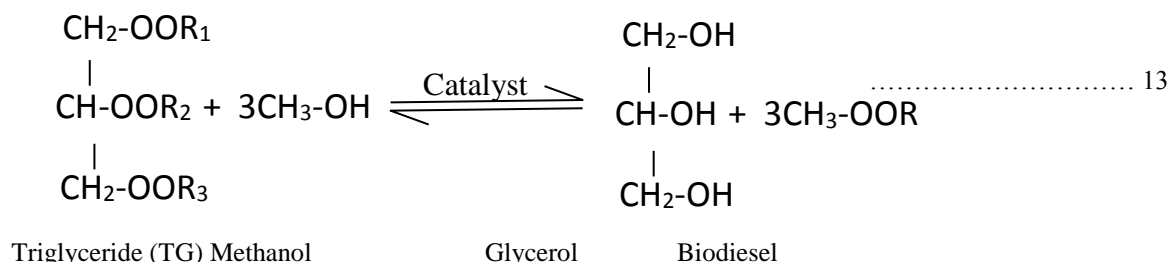iv. Siphoning about 10 liters of biodiesel leaving about 2 liters of glycerin at the bottom of the drum.

3.5 Kinetics Modeling and Governing Chemical Equations.

The overall transesterification reaction is given by equation 15. There are many reaction kinetics developed. However, in general, three consecutive and reversible reactions are believed to occur. Accordingly, these reactions are given below:

$$
\begin{array}{l}
\text{CH}_2\text{-OOR}_1 \\
| \\
\text{CH-OOR}_2 + \text{CH}_3\text{-} \quad \underset{K_2}{\overset{K_1}{\rightleftharpoons}} \quad \text{CH-OOR}_2 + \text{CH}_3\text{-} \\
| \\
\text{CH}_2\text{-OOR}_2
\end{array}
$$

........................10

Triglyceride (TG) Methanol Diglyceride   Methyl Ester (biodiesel)

$$
\begin{array}{l}
\text{CH}_2\text{-OH} \\
| \\
\text{CH-OOR}_2 + \text{CH}_3\text{-OH} \quad \underset{K_4}{\overset{K_3}{\rightleftharpoons}} \quad \text{CH-OOR}_2 + \text{CH}_3\text{-OOR}_3 \\
| \\
\text{CH}_2\text{-OOR}_3 \qquad\qquad\qquad\qquad\quad \text{CH}_2\text{-OH}
\end{array}
$$

.... 11

Diglyceride (DG) Methanol   Monoglyceride   Biodiesel

$$
\begin{array}{l}
\text{CH}_2\text{-OH} \\
| \\
\text{CH-OOR}_2 + \text{CH}_3\text{-OH} \quad \underset{K_6}{\overset{K_5}{\rightleftharpoons}} \quad \text{CH-OH} + \text{CH}_3\text{-OOR}_2 \\
| \\
\text{CH}_2\text{-OH} \qquad\qquad\qquad\qquad\quad \text{CH}_2\text{-OH}
\end{array}
$$

.... 12

Monoglyceride (MG) Methanol   Glycerol   Biodiesel

The overall reaction is:

$$
\begin{array}{l}
\text{CH}_2\text{-OOR}_1 \\
| \\
\text{CH-OOR}_2 + 3\text{CH}_3\text{-OH} \quad \overset{\text{Catalyst}}{\rightleftharpoons} \quad \text{CH-OH} + 3\text{CH}_3\text{-OOR} \\
| \\
\text{CH}_2\text{-OOR}_3 \qquad\qquad\qquad\qquad\quad \text{CH}_2\text{-OH}
\end{array}
$$

.... 13

Triglyceride (TG) Methanol   Glycerol   Biodiesel

At each of these three stages, a molecular of fatty acid methyl ester is produced so that in all, three molecules of methanol are needed to produce three molecules of ester and one molecule of glycerol of glycerin [38].

3.6   Fuel Properties

The physical properties of the biodiesel derived from used cooking oil were evaluated in the laboratory using specify gravity, kinematic viscosity, flash point, pour point, heat of combustion, oxidation stability, acid number and so forth at Peace Oil Nigeria Limited Emene, Enugu, Enugu state and SSG inspection & Oil Services Nigeria Limited at 7B, Etim Inyang Crescent, Victoria Island, Lagos.

3.6.1   Density/ Specific Gravity

Density refers to mass per volume of a substance. The relative density of fuel known as its specific gravity is the ration of the density of the fuel to the density of water at the same temperature. Density measurement was carried out using a Pycnometer at a temperature of 311.5K; the pycnometer of capacity about 25ml being calibrated with water.

3.6.2   Flash Point (Close Cup)

Flash point is the lowest temperature corrected to a standard atmospheric condition at which application of a test flame causes the specimen to ignite under the test specific conditions.

Flash point of the sample was measured by **Pensky Marten;s apparatus**.

Liquid fuel with a higher flash point can prevent auto ignition and fire hazard at high temperature during transportation and storage periods. Hence, the higher the flash point of fuel. For instance, the safer it is during handing, transportation and storage.

3.6.3   Cloud Point and Pour point.

Two important parameter for low-temperature applications of fuel are cloud point (CP) and pour points (PP). The Cloud Point is the temperature at which ax first becomes visible when the fuel is cooled. As biodiesel cools, it starts forming crystals of frozen biodiesel. This is different in appearance from wet biodiesel. When biodiesel

starts to crystallize, it will also start to cog filters, so it is important to know when it is warm enough to use the diesel. To perform the test, a thermometer was dipped in the biodiesel and checked often and then the temperature at which the crystals started forming was recorded.

The PP is the temperature at which the amount of wax from a solution is sufficient to gel the fuel, thus it is the lowest temperature wt which the fuel can flow. Biodiesel has a higher CP and PP compared to conventional diesel.

3.6.4 Kinematic Viscosity
This refers to the internal frictional force (resistance to flow) within the molecule of fluids. It is major factors of consequence in exhibiting fuel for the mass transfer and metering requirements of engine operation. High viscosity results in incomplete combustion and ultimately carbon deposits on injector nozzle and in the combustion chamber. The viscosities of oil as well as derived biodiesel were measured by red wood viscometer at 40ºC.

3.6.5 Heat of Combustion (Calorific or Heating Value of Biodiesel)
This is the thermal energy librated per unit quantity of fuel when the fuel is burnt completely in a calorimeter (under specified conditions) and the products of combustions are cooled back to the initial temperature of the combustible mixture. The water produced is assumed to remain as a vapour and the heat is not recovered. Calorific values of fuel are determined using bomb calorimeter. The stoichiometric equation of combustion for biodiesel is written as

$$C_xH_y+\left(\frac{x}{2}+\frac{y}{2}\right)O_2 \qquad xCO_2+\frac{y}{2}H_2O$$ ………………………… 14
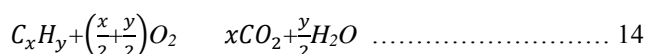
The complete combustion equation for methyl linoleate biodiesel discussed in section 2.4 is thefore .

$$2C_{19}H_{38} + 57O_2 \quad 38CO_2 \qquad + \qquad 38H_2O$$
…………………………….. 15
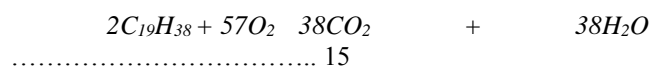
Heat of combustion measures the energy content in a fuel. It is important property of biodiesel that determines the suitability of this material as an alternative to diesel fuel. The heat of combustion (heating value) of biodiesel from palm oil is 40.01MJ/Kg. since the ester were denser, the energy content of a full tank biodiesel fuel would be less than that of mineral diesel fuel. From literature, the heating value of mineral diesel is 43.345MJ/Kg [3,12].

Hence, the percentage loss in the heating value of biodiesel becomes

$$\%HV\ loss - \frac{43.345-40.010}{40.010} *100 - 8.34\%$$

3.6.6 Acid Value or Acid Number
The acid value is defined as the milligrams of potassium hydroxide necessary to neutralize the free acids in 1 gram of the sample of a substance.

3.6.7 Water content
Water in our biodiesel will make it cloudy or turbid. If the biodiesel is clear enough to read a newspaper through a sample then conventional wisdom is that it is dry enough to use in a vehicle.

Biodiesel used as a fuel needs to be very dry, with less than 0.05% or 500rpm of water. Quantitatively, testing down to that precision calls for a precision test like the **Carbide Manometer or** the **Sandy Brae** test**.**

3.6.8 Methanol Content or the 3/27 Test
This test gives an indication of how well the used waste cooking oil was converted into biodiesel. The oil (triglycerides) will not dissolve in methanol, but biodiesel will. To form the test, 3 ml of biodiesel was added to 27 ml of methanol and swirled around a bit. All un-reacted oil quickly fell to the bottom of the methanol. Partially converted biodiesel also fell out over time in about five or longer. Temperature is important with this test. It was conducted with both the oil and the methanol at 70oF.

3.6.9 Cetane Number
An adequate cetane is required for good engine performance. Higher cetane numbers help ensure good sold start properties and minimize the formation of white smoke. This ASTM limit for biodiesel (B100) cetane number is set at 45-65, because this is the level identified for "Premium Diesel Fuel" by the National conference of Weights and Measures. Biodiesel has a higher cetane number, which means that biodiesel fuel will ignite more easily in a diesel engine while also reducing engine noise.

3.6.10 Oxidation Stability
Biodiesel can oxidize during storage and handling, leading to the formation of peroxide, acids, gums and deposits. The minimum oxidation stability requirement is intended to ensure the storage of biodiesel. The oxidation stability of biodiesel is set at 3 hours minimum.

3.6.11   Element Composition (%) of Biodiesel fuel

Carbon © -	79.6;	Hydrogen (H)	-	10.5
Oxygen (O)	- 8.6;	Nitrogen (N)	-	13

Table 2 summarizes the results of the evaluated biodiesel properties. It also gives the values of the corresponding.

S/N	Property	Determined Value	ASTM Recommended Value	Corresponding Value for petro-Diesel[3,12]	Unit
1	Density @ 15oC	0.886	0.86 – 0.90	0.835	Kg/m3
2	Specific Gravity	0.86	0.85 – 0.88	0.85	-
3	Flash Point (Closed Cup)	130	93 minimum	65	oC
4	Cloud Point	10	-3 – 12	5	oC
5	Kinematic Viscosity @ 40oC	4.1	1.9 – 6.0	3.4	Mm2/s
6	Pour Point	4	-15 – 10	-35 – 15	oC
7	Heat of Combustion (Calorific value	40.01	37 – 45	45.345	MJ/Kg
8	Acid Value/ Acid Number	0.27	0.5 maximum	0.12	mgKOH/g
9	Water content	330	500 maximum	500 maximum	Mg/Kg
10	Methanol Content or the 3/27 Test	0.15	0.2 maximum	-	%mass
11	Cetane Number	52	45-65	46	-
12	Boiling Point	330	315 – 350	180 – 340	oC

Properties for Petroleum basic diesel

4.0 DATA SHEET FOR THE COOLING WATER SYSTEM

EQUIPMENT: ENGINE COOLING WATER RECIRCULATING SYSTEM.
CAPACITY: 0.5HP; SPEED 280REV/MIIN; ELCTRICAL SUPPLY: 220/240V/1PH/50HZ
RATING CONTINUOUS; FLOWMETER: ROTAMETER LTD; 0 TO 50L/MIN INLET AND OUTLET THERMOMETER:-10 TO 110OC

4.1 Test Procedures
A short trial run was done in order to make certain that all essential accessories were in working order before the actual test. The testing itself involves the recording of a considerable number of different readings simultaneously, as far as possible.

4.1.1 Engine test at varying speed (Constant load)
To carry out this test, after observing the general testing procedure and noting the ambient conditions. The engine was started and kept at a relatively low speed of 1000rpm and then the value of the torque was taken and recorded. The time taken for a given volume (100cm3) of the fuel to be consumed at this speed was noted. The manometer reading was taken, as well as the readings of exhaust temperature, oil temperature and oil pressure. The readings on the two water systems for both engine and dynamometer were taken namely: The water inlet temperature, the water outlet temperature and the water flow rate/head.

The above procedure was repeated for higher speed values of 1200rpm, 1400rpm, 1600rtpm, 1800rpm, 2000rpm, 2200 rpm, 2400 rpm, 2600 rpm, 2800 rpm.

4.1.2 Engine Test at constant Speed (varying Load)
For the test, the engine was started and kept at a constant speed of 200rpm, and loaded. At a specified speed, the load on the engine was varied using the dynamometer loading wheel while the speed was kept constant. The test can also be performed at any arbitrary chosen speed but the test-bed performs better within the range of 1800 to 2400rpm (see section 4.9)

As a result, the torque developed by the engine for this constant speed changed as was observed on the spring circular scale. For this new value of the torque, the readings were taken again. This procedure repeated for varying values of the torque at this constant speed.

4.2 Theoretical Analysis
Under this section, the parameter that would constitute our calculations on the different columns of our sheets in section 4.9 are defined. These include:

4.2.1 Brake means effective pressure, Mmep of pb
This is given $B_{mep} = \frac{2bp}{LANn}$ ………………16

Hence, substituting the values for L,A and n as given in section 4.3, we have

$$Bmep = \frac{bp*10^3 \left(\frac{Nm}{s}\right)*2*10^{-5}\left(\frac{bar}{N/m^2}\right)}{N\left(\frac{rev}{60s}\right)*88.10^{-3}(m)*\pi*(79.735*10^{-3})^2/4(m^2/rev)*4}(bar) \ ....17$$

» Bmep = 675.82 $\frac{bp}{N}$ (bar) ………………………..18

4.2.2 Swept volume
This is given in section 4.3 as Vs = 1.76 (litres/cycle0

V_s = 1./7(litres/cycle) *10^{-3} $\left(\frac{m^3}{litre}\right)$ (m^3/cycle) …….. 19

V_s = 0.00176 $\left(\frac{m^3}{rev}\right)$ * $\left(\frac{rev}{60s}\right)$ = 0.00002933N (m^3/s) …20

Gas constant for air, Ra = 287 J/Kg K

Other calculations depend on data gotten in the laboratory

4.3 Data measured in the Laboratory
Ambient air temperature, Ta = 28oC = 301K; Barometric Pressure, Pa=0.95bar = 95N/m^2

Calorific value of petro-diesel fuel used, $Q_{net.v}$ = 43345KJ/Kg
Calorific value biodiesel fuel used $Q_{net.vb}$ = 40010KJ/Kg
Density of petrol-diesel fuel used, ρ_f = 0.835Kg/m^3
Density of biodiesel fuel used ρ_{fb} = 0.886Kg/m^3

Published by :

http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 07, July-2016

4.4 Calculations Based on the Measured Data

4.4.1 Mass flow Rate of Fuel, m_f

Recall that $m_f = \rho_f\, V_f$ hence

$m_f = 0.835 V_f$;   (for petrol-diesel) and $m_{fb} = 0.886 V_{fb}$ (for biodiesel)

4.4.2 Volume flow rate of air , V_a

The pressure difference, P as stated, the measured in millimeters of water is 1mm H_2O = 9.8N/m^3 , P = $9.8h_w$

Where h_w = head across orifice, mm H_2O

And assuming air to be a perfect gas, the density of air, ρ_a is given by

$Pa = \frac{Pa}{R_a T_a}$ ……………………….………..21

Where: pa = Barometric (atmospheric) pressure of air,

Ta = Temperature of air, Ra = Gas constant for air.

But velocity u is given by $U = \sqrt{\frac{2*9.81 h_w R_a T_a}{P_a}}$ ………22

The volumetric flow rate of air is given by

V_a = Area of orifice * Orifice coefficient of discharge * velocity

$V_a = \frac{\pi D^2}{4} * K_D * \sqrt{\frac{2*9.81 h_w R_a T_a}{P_a}}$ …………………….23

Where: D = orifice diameter (m)

KD = orifice coefficient of discharge

Substituting the values for D and KD from section 4.3 and for Ra, Ta and Pa from section 4.6m, we have

$V_a = 0.00621\sqrt{h_w}$ …………………….24a; and for biodiesel , we have

$V_{ab} = 0.00621\sqrt{h_w}$ …………………………………………24b

4.3.3 Mass flow rate of air, m_a

The mass flow rate of air, ma is given by

$m_a = \rho_a * V_a$ …………………………………………25

$m_a = \frac{P_a}{R_a T_a} * \frac{\pi D^2}{4} * K_D \sqrt{\frac{2*9.81 h_w R_a T_a}{P_a}}$ ……………..……26

Substituting the values for D and KD and for Ra, Ta and Pa, we have

$m_a = 0.00683\sqrt{h_w}$ …………………………………27a

and for biodiesel, $M_{ab} = 0.00683\sqrt{h_w}$ ………………..27b

4.3.4 Break Thermal efficiency, η_{BT}

$\eta_{BT} = \frac{bp}{m_f Q_{net,V}}$ ……..28Putting the values of $Q_{net.v}$ given in section 4.3, we have

$\eta_{BT} = \frac{bp}{m_f 43345}$ -………………29a, and for biodiesel,

$\eta_{BT} = \frac{bp}{m_{fb} 400010}$ …………………………………………29b

Table 3: Table of Values for Varying Speed (constant Load) Test for Petro-Diesel

S/N	Toque T (nm)	Speed N(rpm)	Fuel consumption Time, t(s)	Fuel consumption Vol, V (cm^3)	Fuel volume flow rate, $v_f = \frac{V}{t}$ (m^3/s) [*10^{-6}]	Manometer Reading h_w (mmH$_2$O)	Oil press. (N/m^2)	Oil Temp (ºC)	Exht Temp (ºC)	Dynamometer Water Inlet Temp (ºC)	Dynamometer Water Exit Temp (ºC)	Dynamometer Water Head (cm	Engine cooling water Inlet Temp (ºC)	Engine cooling water Exit Temp (ºC)	Engine cooling water Head (cm
1	75	1000	130.00	100	0.769	4.20	425	37	250	35	39	18.50	36	45	14.60
2	70	1200	120.00	100	0.833	7.00	420	39	298	37	41	18.20	38	57	14.50
3	65	1400	109.50	100	0.914	7.50	417	40	347	39	42	18.00	41	50	14.50
4	60	1600	98.50	100	1.015	8.00	415	43	397	42	45	17.90	43	52	14.40
5	55	1800	91.10	100	1.095	8.50	410	45	448	45	49	17.70	47	53	14.20
6	50	2000	83.70	100	1.194	9.10	407	47	484	47	50	17.60	50	55	14.10
7	45	2200	77.30	100	1.294	9.70	405	50	520	50	53	17.40	52	58	14.00
8	40	2400	70.90	100	1.410	10.20	400	53	579	51	55	17.20	55	62	13.80
9	35	2600	65.70	100	1.522	10.50	396	55	638	53	57	17.10	58	66	13.60
10	30	2800	60.50	100	1.653	11.00	391	57	697	54	59	17.00	61	68	13.60

Table 4: Table of values Ii for varying speed (constant load) Test for Petro-Diesel

S/N	Speed N (rpm)	Toque T (nm)	Fuel volume flow rate of fuel v_f (m^3/s) [*10^{-6}]	Mass flow rate of fuel, m_f(kg/s) = 835V_f [*10^{-3}]	Manometer Reading h_w (mmH$_2$O)	Air volume flow rate Va = 0.0062 $1\sqrt{h_w}$ (m^3/s)	Air mass flow rate ma = 0.0068 $3\sqrt{h_w}$ (Kg/s)	Brake power bp = $\frac{T*N}{9549.305}$ (Kw)	B_{mep} = 675.82 $\frac{bp}{N}$ (bar)	Swept volume Vs = 0.00029 33N (m^3/s)	Volumetric efficiency η=$\frac{V_a}{V_s}$ (5)	Brake thermal efficiency , ηBT = $\frac{bp}{m_f\,45345}$	SFC = $\frac{3600m_f}{bp}$ (Kg/kWh)	Air/fuel ratio = $\frac{m_a}{m_f}$
1	1000	75	0.77	0.64	4.20	0.013	0.014	7.853	5.307	0.029	43.39	26.97	0.294	21.79
2	1200	70	0.89	0.70	7.00	0.016	0.018	8.796	4.954	0.035	46.68	27.88	0.285	25.97
3	1400	65	0.91	0.76	7.50	0.017	0.019	9.529	4.600	0.041	41.42	27.51	0.289	24.48
4	1600	60	1.02	0.85	8.00	0.018	0.019	10.053	4.246	0.046	37.43	26.15	0.304	22.79
5	1800	55	1.09	0.92	8.50	0.018	0.019	10.367	3.892	0.052	34.30	24.94	0.318	21.73
6	2000	50	1.19	1.00	9.10	0.019	0.021	10.471	3.538	0.059	31.94	23.15	0.343	20.65
7	2200	45	1.29	1.08	9.70	0.019	0.021	10.367	3.185	0.065	29.97	21.17	0.375	19.69
8	2400	40	1.41	1.18	10.20	0.020	0.022	10.053	2.831	0.070	28.18	18.83	0.422	18.52
9	2600	35	1.52	1.27	10.50	0.020	0.022	9.529	2.477	0.076	26.39	16.54	0.480	17.41
10	2800	30	1.65	1.38	11.00	0.021	0.023	8.796	2.123	0.082	25.08	14.06	0.565	16.41

5.0   DISCUSSIONS OF RESULTS

5.1   Brake Power versus Speed

Figure 2 shows the brake power as a function of speed. From the figure 2, it is shown that biodiesel requires a higher amount of break power. The brake power reached the maximum values for speed ranging from 1800rpm to 2400 rpm. This indicates that the engine operates more effectively within the above range. It is therefore a waste of economy to run the engine below 1800rpm and /or above 2400rpm.

As the speed increases above the efficient range, the lesser time available for combustion produces improper combustion and hence the brake power decreases. As the break power decreases for the same load, the brake thermal efficiency decreases. Consequently the specific, full consumption (SFC) increases.
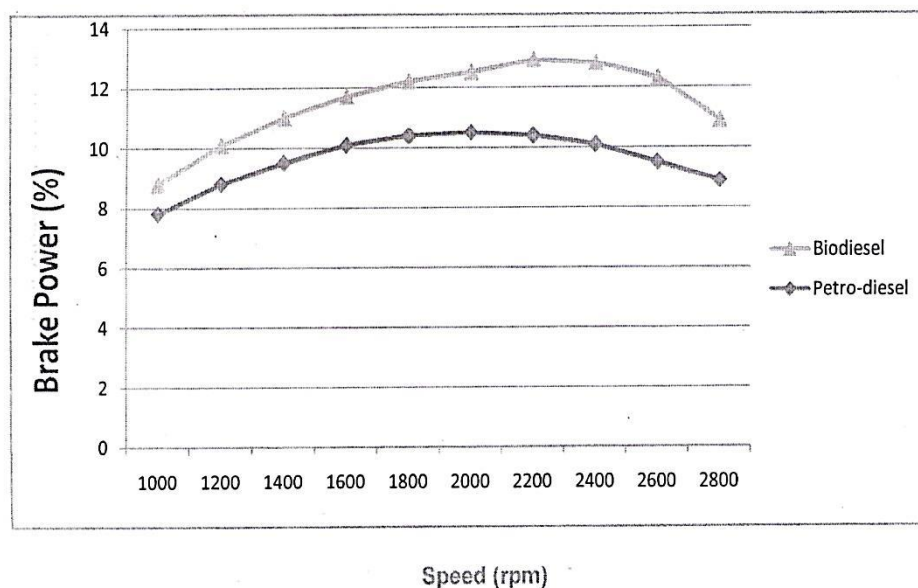

Figure 2: Graph of Brake Power versus Speed for Varying Speed Test

5.2   Specific Fuel Consumption versus Brake Power

The brake specific fuel consumption for biodiesel compared to conventional diesel fuel is shown in Figure 3. The fuel consumption of diesel is relatively higher than that of conventional diesel fuel. This is because the biodiesel has higher specific gravity and viscosity and thus lower volume flow rate than petro-diesel. This result is comparable with the results given by Schumacher et al and PrankL et al where the rate of fuel delivery to engine speed was greatly affected by density, specific gravity and viscosity of the fuel.
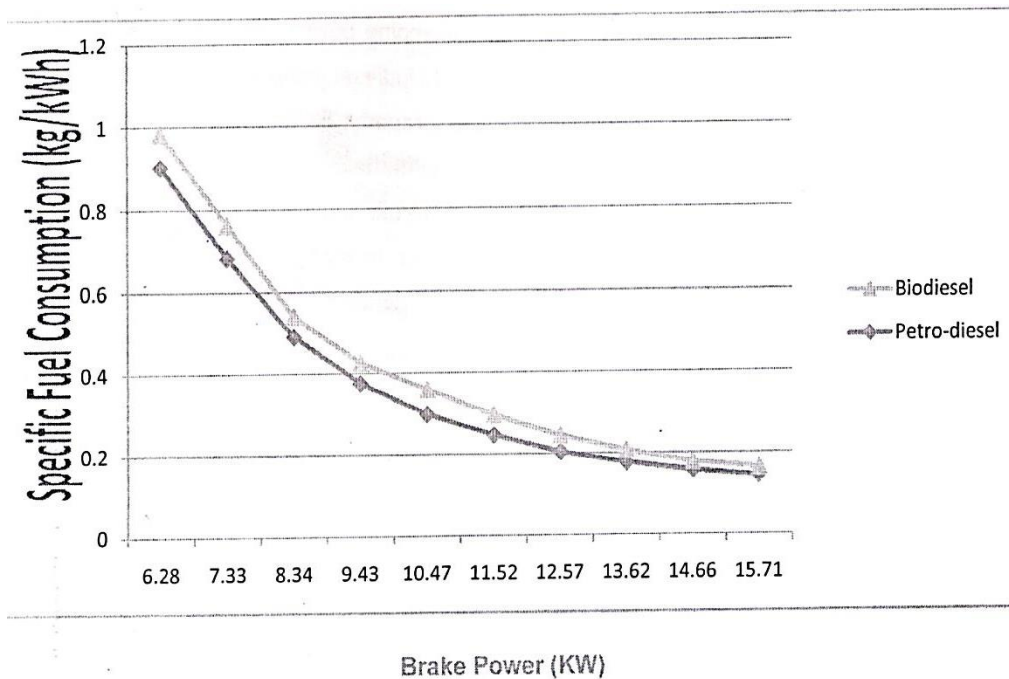
Figure 3: Graph of Specific fuel consumption versus Brake Power for a Constant Speed Test

CONCLUSION

It is deduced that as speed increases above the efficient range, the lesser time available for combustion produces improper combustion and hence the brake power decreases. As the break power decreases for the same load, the brake thermal efficiency decreases. And also increasing the brake power for a constant test leads to increase in specific fuel consumption.

REFERENCES

[1] Annual book of ASTM standards, petroleum products and lubricants (I-III), vols. 05.01-05.03.   Philadelphia. 1991.
[2] Babu AK, Devarajane G (2003). Vegetable oils and their derivatives as fuels for CI engines. An overview SAE technical Paper. 2003-01-0767. Ferson FK, Oduro EF.
[3] Baharuddin bin Ali, Addul Halim, and Fuad Bib Abas (1992) "Development in Automobile   Engine Technology" Second National conference. Thermal engineering and Sciences.
[4] Bala BK. Studies on biodiesel from transformation of vegetable oils for diesel engines. Energy Educ. Sci. Technol 2005; 15:1-43.
[5] Carl L. Alsberg and Alinzo E. Taylor "The Fats and Oils; a General View' viewed 8 March 2004,   < htpp://ww.journeytofope=rever,org/index.html>
[6] Chemical and Process Enginering research www.liste.org ISSN 2224-7467 (Paper) ISSN 2225-   0913 (Online) Vol. 2, 2012.
[7] Chol S-H, Oh Y./ The emission effects by the use of biodiesel fuel. Int. J. Mod phys B 2006,   20:4481-6.
[8] Demirbas A, Demirbas I. Importance of rural bioenergy for developing countries. Energy   conversion   Management 2007: 48:2386-98.
[9] Demirbas A. biodiesel from waste cooking oil via base-catalytic and supercritical methanol   transesterification.   Energy   convers Manage 2009; 50:923-7.
[10] Demirbas A. A biodiesel: A Realistic Fuel Alternative for diesel engines. London Spinger;' 2008:25-29.
[11] Eastop T.D and McConkey A., Applied Thermodynamic for Engineering Technologist, fifth   Edition,   India Pearson Educational limited, 2003 pp 460-461.
[12] Gerpan JV, Biodiesel Processing and Production, fuel Proc. Technol 2006, 86 – 107.
[13] Ghobadia B. Rahimi H, Nikbarht AM, Najafi G, Yusuf TF, Diesel engine performance and   exhaust emission analysis using waste cooking biodiesel fuel with an artificial neural   network. Renew Energ 2009:34:976-62.
[14] Hammond-Donkuh (2004) Performance of jatropha oil blends in a diesel engine. Renewable   energy. 29.1135-1145.
[15] IP stanars for analysis and testing of petroleum products, vol. 1 london. Inst. Pet. 1990.
[16] Kalam Ma, Masjuki HH. Testing palm biodiesel and NPAA additives to control NOx and Co   while improving efficiency I diesel engines. Biomass bioenerg 2008;32:116-22.
[17] Karabektas M. The effects of turbocharger on the performance and exhaust emission of a   diesel engine fuelled with biodiesel. Renew Energ 2009:34"989-93.