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# Performance Analysis of CI Engine Fueled with Diesel and Used Vegetable Oil Blend

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***Abstract-*** This paper investigates the performance of compression-ignition engine fueled with various proportionate blends of biodiesel. The biodiesel was gotten from the transesterification of used vegetable oil with diesel. The experiment was carried out in a single cylinder, two-stroke compression-ignition engine with variable engine speeds (1500, 1600, 1700, 1800 and 1900 rpm). Four different blends on a volume basis were used. These are B0 (0%biodiesl + 100%diesel), B4 (4%biodiesel + 96%diesel), B6 (6%biodiesel + 94%diesel), and B8 (8%biodiesel + 92%diesel). Results of the engine test with proportionate blends of the biodiesel with diesel fuel improved output torque and brake power of the engine; it was however, noted that the fuel consumption of the compression-ignition engine increased with respect to pure diesel, also the brake specific fuel consumption of biodiesel was higher than the results obtained for pure diesel.

***Keywords-*** *Transesterification, Compression-Ignition, Biodiesel*

## I. INTRODUCTION

The need to develop alternative fuels from renewable resources became necessary as a result of growing environmental concerns, depletion of petroleum resources and other socioeconomic factors. Renewable energy resources are not only cheaper, they are environmentally acceptable. The challenges we face as regards climate change and energy supply security has put energy high on the political agenda. Governments are putting strategic plans in motion to decrease the use of primary energy, to make fuels carbon-free and to facilitate modal shifts (Sebastian and Thomas, 2009). Globally, many steps and initiatives are being taken to alternate petroleum-based fuel. Researchers are developing vegetable oil-based derivatives that have properties and performance similar to those of petroleum-based diesel fuel.

Biodiesel is a liquid biofuel obtained by chemical processes from vegetable oils or animal fats and an alcohol that can be used in diesel engines, alone or blended with diesel oil (Knothe G et al, 1997, Van Gerpen J et al, 2004, Romano SD et al). ASTM International (originally known as the American Society for Testing and Materials) defines biodiesel as a mixture of long-chain monoalkylic esters from fatty acids obtained from renewable resources, to be used in diesel engines. Esters of fatty acids (biodiesel), derived from the transesterification of vegetable oils have properties similar to petroleum-based diesel fuel (Enweremadu and Rutto, 2010). The use of biodiesel has been encouraged by EU countries to partly replace petroleum diesel fuel consumption in a bid to reduce greenhouse effect and over-reliance on foreign oil.

Biodiesel helps to reduce the carbon dioxide emission to the atmosphere, it is renewable in nature and safer to handle. It has no aromatic compounds, partially no supplier content, it also reduces the emission of carbon monoxide (CO), total hydrocarbon (THC) and particulate matter (PM) due to the presence of oxygen atoms in the molecule of the fuel (Enweremadu and Rutto, 2010). However, the use of biodiesel has some disadvantages when compared to petroleum-based fuel. These are worse low-temperature properties, greater emissions of some oxygenated hydrocarbons, higher specific fuel consumption, decrease in brake thermal efficiency and higher production cost. These disadvantages can be reduced by blending biodiesel with diesel fuel. Blends with diesel fuel are indicated as ‘‘Bx’’, where ‘‘x’’ is the percentage of biodiesel in the blend. For instance, ‘‘B5’’ indicates a blend of 5% biodiesel and 95% diesel fuel; in consequence, B100 indicates pure biodiesel. The problem of production cost has been solved by the use of waste cooking or animal fats as the raw materials in the transesterification process (Ghobadian, B. et al, 2009). However, during frying, vegetable oil undergoes various physical and chemical changes. This leads to the formation of many undesirable compounds which include free fatty acid and some polymerized triglycerides. These compounds increase the molecular mass and reduce the volatility of the oil. Therefore, fatty acid esters obtained from frying oil influences the fuel characteristics (such as the viscosity and burning characteristics which reduces) leading to a greater amount of Conrad son carbon residue.

## II. LITERATURE REVIEW

F.K Forson et al investigated the performance of Jatropha oil blends in a diesel engine. The test was done on a single-cylinder direct-injection engine operating on diesel fuel, jatropha oil, and blends of diesel and jatropha oil in proportions of 97.4%/2.6%; 80%/20%; and 50%/50% by volume. It was observed that Carbon dioxide emissions were similar for all fuels, the 97.4% diesel/2.6% jatropha fuel blend was observed

to be the lower net contributor to the atmospheric level. The trend of carbon monoxide emissions was similar to the fuels but diesel fuel showed slightly lower emissions to the atmosphere. The test showed that jatropha oil could be conveniently used as a diesel substitute in a diesel engine. The test further showed increases in brake thermal efficiency, brake power and reduction of specific fuel consumption for jatropha oil and its blends with diesel generally, but the most significant conclusion from the study is that the 97.4% diesel/2.6% jatropha fuel blend produced maximum values of the brake power and brake thermal efficiency as well as minimum values of the specific fuel consumption. The 97.4%/2.6% fuel blend yielded the highest cetane number and even better engine performance than the diesel fuel suggesting that jatropha oil can be used as an ignition-accelerator additive for diesel fuel

V. Chalaton M.M. Roy experimented on the use of Jatropha oil as an alternative fuel in a CI diesel engine. A Direct Injection (DI) diesel engine was tested using diesel, Jatropha oil, and blends of Jatropha oil and diesel in different proportions. A wide range of engine loads and Jatropha oil/diesel ratios of 5/95% (J5), 10/90% (J10), 20/80% (J20), 50/50% (J50), and 80/20% (J80) by volume were considered. Parameters such as brake thermal efficiency, brake specific fuel consumption and CO and CO2 emissions were measured. It was observed that there was no significant change in the brake thermal efficiency and brake specific fuel consumption up to J20 ratios. But there was 10 to 25% deterioration in efficiency and fuel consumption in higher blends. It was also observed that $CO_2$ emission with blends was lower than that of diesel at low load operations but at high loads, $CO_2$ emission became higher with a higher percentage of Jatropha oil in the blends. Also, the higher the percentage of Jatropha oil in the blend, the higher the CO emission.

Abu-Jrai, A. & Yamin, J. (2011), investigated the combustion characteristics and engine emissions of a diesel engine fueled with diesel and treated waste cooking oil blends. Results indicated an increase in brake specific fuel consumption with a simultaneous reduction in the engine thermal efficiency compared to conventional diesel.

Muralidharan, K., Vasudevan, D. (2011) observed the performance, emission and combustion characteristics of a variable compression ratio engine using methyl esters of waste cooking oil and diesel blends. They concluded that 40% blending with the compression ratio of 21 produced higher efficiency.

Lapuerta, M., *et al*, (2008), studied the effect of the alcohol type used in the production of waste cooking oil biodiesel on diesel performance and emission. The results indicated a longer ignition delay, maximum rate of pressure rise, lower heat release rate and higher mass fraction burnt at higher compression ratios for waste cooking oil when compared to that of diesel.

K. Nantha Gopal *et.al*, (2008), carried out an in-depth research and comparative study of blends of biodiesel made from WCO and diesel. The research was carried out to bring out the benefits of its extensive usage in CI engines. The study revealed that the WCO biodiesel has similar characteristics to that of diesel.

Mohammed EL_Kassaby *et al* (2004) collected samples of waste cooking oil from restaurants and used them to produce neat (pure) biodiesel through transesterification. Blends of biodiesel/diesel were then prepared. The effect of blending ratio and compression ratio on the diesel engine performance were investigated. Emission and combustion characteristics were studied when the engine operated using the different blends.

## III. Materials and Methodology

Waste cooking oil was used to produce biodiesel. The waste cooking oil that was used as a sample for this present study was obtained from hostels and cafeteria. Solid impurities such as food residues present in the used cooking oil (WCO) were sieved out twice. The biodiesel was then produced by transesterification process. The diesel fuel used during the experiments was obtained from a filling station in Akure, Ondo state, Nigeria.

### *A. Physicochemical Result*

#### *1) Volatile matter content determination*

This was done by the gravimetric method according to AOAC (1990). The weight of a previously washed and dried empty evaporating dish was determined using a mettle balance as (W1). 10g of the sample was weighed into the evaporating dish (W2). The dish and sample were then placed in the oven and dried for 8hrs at 70°*c* after drying the dish and sample were then placed in the desiccator to cool to room temperatures and was weighed. This process was continued until a constant weight was obtained, (W3), (i.e., drying, cooling and weighing were done repeatedly at 30mins interval until a constant weight was obtained). The volatile matter was calculated and expressed as a percentage of weight of the sample analyzed. This was given by the expression below:

$$\% \text{ volatile matter content} = \frac{W2-W3}{W2-W1} \times \frac{100}{1} \quad (1)$$

where:

$w_1$= weight of empty evaporating dish

$w_2$= weight of sample + evaporating dish

$w_3$= weight of sample + evaporating dish after drying at 70°*c*

#### *2) Ash content determination*

The determination of ash content was done by the gravimetric method according to AOAC (1990). The weight of a previously washed and dried empty crucible was determined using a mettle balance as (W1). 5g of the sample was weighed into the crucible (W2). The crucible and sample were then placed in a muffle furnace set at 550°C and was ashed for 4hrs. After ashing, the crucible and sample were then placed in the desiccator to cool to room temperatures after which it was weighed (W3). The percentage ash content was calculated thus:

$$\% \text{ Ash} = \frac{W3-W1}{W2-W1} \times \frac{100}{1} \quad (2)$$

*3) Specific gravity*

The specific gravity of the sample was determined using a 2ml density bottle. The bottle was washed thoroughly with a detergent solution and rinsed with tap water thoroughly and finally with distilled water. It was dried at $105°C$ in an oven for 30 minutes. This was cooled in a desiccator and weighed, and the weight was noted. The bottle was filled with distilled water and weighed on a mettle balance. It was then filled with sample. This was then weighed and the weight was noted. The specific gravity of the sample solution was calculated from the equation below:

$$\text{S.G} = \frac{weight\ of\ sample}{equal\ weight\ of\ water} \quad (3)$$

*4) Refractive index*

The refractive index of the sample was determined at 25°C using the Abbe refractometer equipment.

*5) Cloud point*

The cloud point was determined using a high precision cloud point meter having a waveguide sensor and an incidence channel and a detection surface. The incidence channel and emergency channel intersecting along the detection surface and an optical fibre.

*6) Pour point*

The sample was homogenized and poured into the test jar to the level. The jar was closed tightly with cork carrying the pour point thermometer placed 3min below the surface of the oil sample. The disc was placed in the bottom of the jacket and the ring gasket was around the jar at the 25mm from the bottom. The test jar was then placed in the jacket. The test jar was then removed carefully and tilted to ascertain whether there is a movement of the oil.

*7) Experimental Set Up*

The performance analysis test was carried out on a compression ignition test bed engine.

The engine was coupled to a hydraulic dynamometer which is equipped with an instrument cabinet fitted with a torque gauge, electric tachometer and switches for the load remote control. Fuel consumption was measured by using a calibrated burette and a stopwatch with an accuracy of 0.2 seconds.

## IV. THE PHYSICOCHEMICAL RESULT

The laboratory experiment was carried at the Federal University of Technology, Akure, Ondo State. The following are the properties of the samples:

A (92% Diesel+8% used Vegetable Oil Biodiesel)

B (94%Diesel+6% used Vegetable Oil Biodiesel)

C (96%Diesel+4% used Vegetable Oil Biodiesel)

D (100% used Vegetable Oil Biodiesel)

The engine performance is evaluated by a lump of many factors such as power, torque, and fuel consumption. In this study, the brake power, fuel consumption, torque, brake specific fuel consumption, exhaust gas temperature and P-V diagram were measured at a reasonable speed, e.g., 1500, 1600, 1700, 1800 and 1900 rpm.

Figure 1. Pictures of the engine

TABLE I. ENGINE PERFORMANCE RESULTS

| s/n | Parameter | Sample A | Sample B | Sample C | Sample D | Diesel Oil (100%) |
|---|---|---|---|---|---|---|
| 1. | Refractive Index (@30°C) | 1.4710 | 1.4725 | 1.4729 | 1.4440 | 1.460 |
| 2. | Specific Gravity (g/cm$^3$) | 0.8226 | 0.8225 | 0.8220 | 0.8364 | 0.8820 |
| 3. | Kinematic Viscosity (pas/sec) | $4.671\times10^{-3}$ | $5.173\times10^{-3}$ | $5.297\times10^{-3}$ | $5.023\times10^{-3}$ | $5.890\times10^{-3}$ |
| 4. | Ash Content (%) | 0.610 | 0.538 | 0.417 | 1.023 | 0.101 |
| 5. | Flash Point (°C) | 100.000 | 92.000 | 86.000 | 160.000 | 105.000 |
| 6. | Volatile Matter (%) | 3.641 | 3.263 | 3.074 | 0.421 | 22.404 |
| 7. | Cloud Point (°C) | 2.000 | -2.000 | -4.000 | 8.000 | -4.000 |
| 8. | Pour Point (°C) | 11.000 | 6.000 | 2.000 | 14.000 | 14.000 |
| 9. | Fire Point (°C) | 136.000 | 122.000 | 116.000 | 232.000 | 118.000 |
| 10. | Moisture Content (%) | 2.230 | 1.802 | 1.203 | 4.210 | 0.560 |
| 11. | Heating Value (KJ) | 33326.249 | 33501.073 | 34779.463 | 28145.563 | 33917.225 |
| 12. | Fixed Carbon (%) | 93.519 | 94.397 | 95.306 | 94.346 | 76.935 |

## *A. Results*

TABLE II. 8% BIODIESEL

| Speed | Brake Power | Brake Specific Fuel Consumption | Fuel Consumption | Torque |
|---|---|---|---|---|
| 1500 | 0.44 | 0.730 | 1.854 | 2.80 |
| 1600 | 0.38 | 0.821 | 1.843 | 2.27 |
| 1700 | 0.37 | 0.938 | 1.775 | 2.08 |
| 1800 | 0.32 | 1.001 | 1.461 | 1.70 |
| 1900 | 0.19 | 1,143 | 1.253 | 0.96 |

TABLE III. 6% BIODIESEL

| Speed | Brake Power | Brake Specific Fuel Consumption | Fuel Consumption | Torque |
|---|---|---|---|---|
| 1500 | 0.31 | 0.683 | 1.770 | 1.97 |
| 1600 | 0.35 | 0.775 | 1.736 | 2.09 |
| 1700 | 0.37 | 0.901 | 1.745 | 2.08 |
| 1800 | 0.26 | 0.963 | 1.454 | 1.38 |
| 1900 | 0.21 | 1.122 | 1.248 | 1.06 |

TABLE IV. 4% BIODIESEL

| Speed | Brake Power | Brake Specific Fuel Consumption | Fuel Consumption | Torque |
|---|---|---|---|---|
| 1900 | 0.36 | 1.103 | 1.243 | 2.10 |
| 1800 | 0.29 | 0.941 | 1.447 | 2.21 |
| 1700 | 0.38 | 0.863 | 1.718 | 2.13 |
| 1600 | 0.37 | 0.715 | 1.639 | 1.54 |
| 1500 | 0.33 | 0.643 | 1.691 | 1.81 |

TABLE V. 100% DIESEL

| Speed | Brake Power | Brake Specific Fuel Consumption | Fuel Consumption | Torque |
|---|---|---|---|---|
| 1500 | 0.30 | 0.714 | 1.768 | 1.01 |
| 1600 | 0.27 | 0.775 | 1.733 | 1.33 |
| 1700 | 0.25 | 0.884 | 1.767 | 1.40 |
| 1800 | 0.25 | 0.881 | 1.419 | 1.61 |
| 1900 | 0.30 | 0.883 | 1.231 | 1.91 |

*B. Analysis of Results*

Figure 2 presents the brake power developed by the engine at different speed conditions (900rev/min to 1500rev/min). It was observed that as the speed decreased (which signifies an increase in load) the brake power developed by the engine increased for all blends of diesel and biodiesel. At minimum speed (maximum load), the engine produced the highest brake power with 8% biodiesel.

Figure 3 shows the variation of brake specific fuel consumption with speed. For all blends tested, the brake specific fuel consumption was found to decrease in speed (increase in load). This is due to the higher percentage increase in brake power with a decrease in speed. At the speed of 1600rev/min, 4% biodiesel had brake specific fuel consumption lower than that of pure diesel. With the increase in biodiesel percentage in the blends, the calorific value of fuel decreased. Hence the brake specific fuel consumption of the higher percentage of biodiesel in blends increased when compared to that of diesel.

The relationship between speed and fuel consumption was illustrated in Figure 4. It was observed that the speed decreased with increased fuel consumption. The fuel consumption at various speeds was found lesser with the pure diesel except for 4% biodiesel (from 1700rev/min to 1500rev/min). The reduction in fuel consumption for blended fuel could be attributed to the decrease in overall calorific value of fuel which occurred as a result of the increase in the percentage of the blend.

Figure 5 shows the relationship between the engine torque and engine speed for various proportionate blends of biodiesel and pure diesel. The engine torque decreased as the engine speed increased.

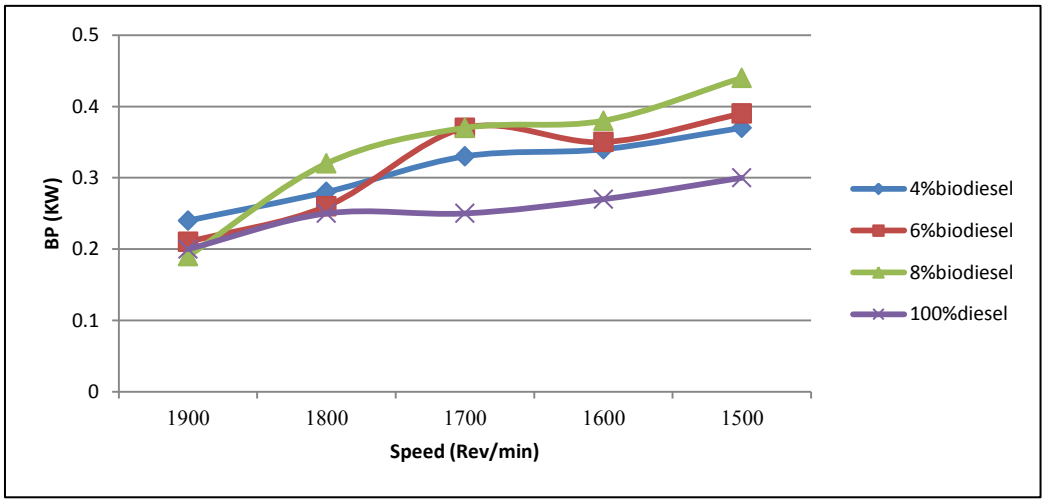


Figure 2. Speed vs Brake Power for Various Blends

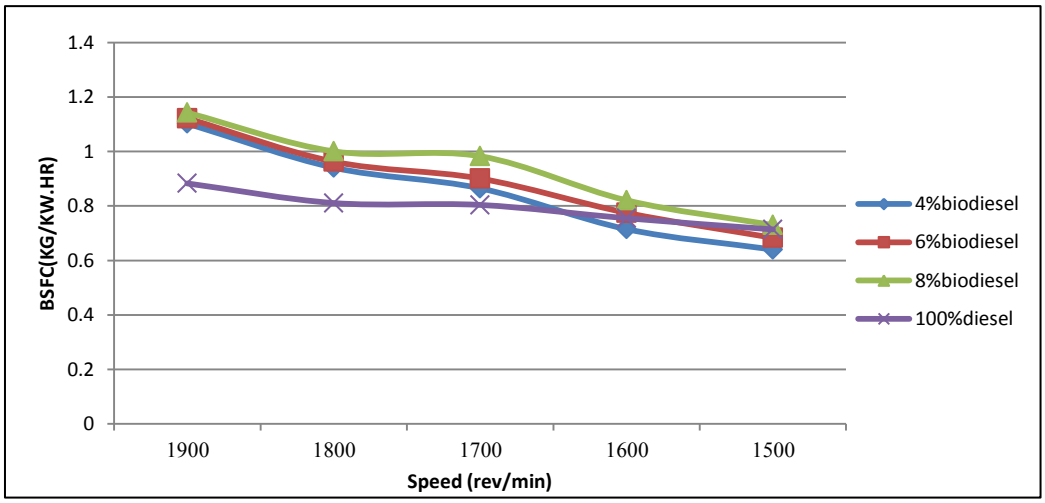


Figure 3. Speed vs BSFC for Various Blends

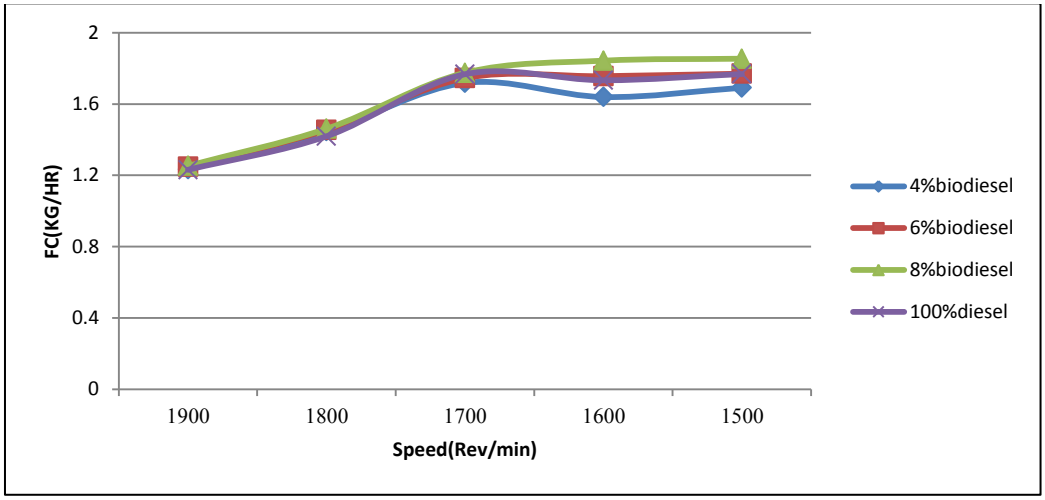


Figure 4. Speed vs FC for Various Blends

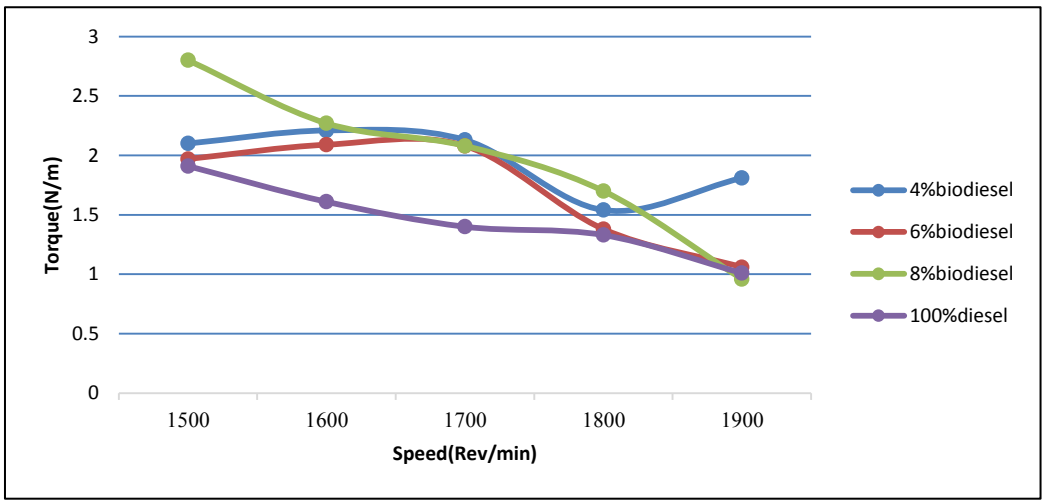


Figure 5. Speed vs Torque for Various Blends

## V. CONCLUSION

The research shows that transesterified used vegetable oil can be blended with pure diesel at various proportions to obtain an optimum performance of a compression ignition engine. The result shows that 8% biodiesel blend produced the highest brake power at 1500rev/min, 6% biodiesel blend at 1600 rev/min had the closest B.S.F.C value to pure diesel, and 6% biodiesel blend at 1600 rev/min had the closet F.C value to pure diesel. Thus the above integration suggests that 6% biodiesel is the optimum blend that can produce better performance in a compression-ignition engine.

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