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Performance Evaluation of Waste Vegetable Cooking Oil as Biodiesel

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***Abstract*-- This work involved the production of biodiesel from waste vegetable cooking oil and testing for the engine torque, brake power and specific fuel consumption of a conventional diesel engine utilizing the produced biodiesel from the waste vegetable cooking oil. The results obtained were compared with those for petro-diesel fuel. The results showed that the value of brake power for petro-diesel was closely matched with that of biodiesel. Similarly the value for engine torque for petro-diesel was higher than that of biodiesel, due to the oxygen content in biodiesel. The average value obtained for the specific fuel consumption for biodiesel was higher than that of petro-diesel. Results obtained in this study showed that biodiesel obtained from waste vegetable oil had properties close to petrol-diesel.**

***Keywords*-- Waste vegetable cooking oil; biodiesel; transesterification; glycerol.**

I. Introduction

There is a growing interest in renewable energy sources where biodiesel production obtained from waste vegetable cooking oil (WVO) is proposed as an alternative to petroleum based fuel to reduce greenhouse gas emission, pollution and dependence on fossil fuel. While Straight Vegetable Oils (SVO) can be used directly as diesel engine fuels, they require engine modification because some of their properties are less advantageous for this application including their very high viscosity and poor thermal and hydrolytic stability. They also have less favourable ignition qualities. Biodiesel is made by chemically reacting vegetable oil or animal fat or a combination of oils and fats with alcohol, such as pure ethanol or methanol [1,2]. The mixture is then combined with a catalyst such as potassium hydroxide or sodium hydroxide. This chemical reaction called transesterification, breaks the fat molecules in the oils into an ester, which is the biodiesel fuel, and glycerol [3,4].

II. Materials And Methods

2.1 Materials and Equipment

The materials used for the experiment were waste vegetable cooking oil, potassium hydroxide, methanol, water, petro-diesel and sulphuric acid.

The following equipment was used in the study: (i) volumetric flask, (ii) beakers, (iii) thermometer, with range 0-100°C graduated in 1°C, (iv) magnetic stirrer hotplate, (v) funnels, (vi) conical flask, (vii) test tubes, (viii) separating funnels, (ix) distillation apparatus, (x) measuring cylinders, (xi) graduated cylinder.

2.2 Methods

2.2.1 Acid – Catalyzed Transesterification

Collected waste cooking oil was heated to about 100^{o}C for about thirty minutes to reduce water content in the oil. The oil was then passed through a sieve while still hot to filter off solid particles and debris. To determine the amount of KOH required for titration of free fatty acids, 1 gram of KOH was dissolved in one litre of distilled water in the high density container to make a 0.1 % lye solution. 1 ml of dewatered waste vegetable oil was mixed with 10ml of isopropyl alcohol in a 50 ml flask. The mixture was then warmed by standing it in hot water while stirring until the oil completely dissolved in alcohol. Two drops of phenolphthalein indicator were added to the oil using a dropper. 0.1% KOH solution was added drop wise to the resulting mixture while stirring in a swirling action until the solution turned and stayed pink for about 15 seconds. The number of millilitres of 0.1 % KOH solution used for titration plus 3.5 (amount required for fresh oil) is the number of grams of KOH required per litre of oil [5].

Potassium methoxide was prepared by dissolving the predetermined amount of KOH (8.25 grams) in 200 ml of methanol (in a high density polythene container) for every litre of clean waste vegetable oil to be processed. The oil was heated to 60^{o}C then mixed with potassium methoxide at a ratio of 5:1 respectively. The mixture was vigorously stirred in a 10 litre capacity blender for about 45 minutes then transferred to a settling container to allow glycerol to separate from biodiesel. Since glycerol has a higher density than biodiesel, it settled at the bottom of the container. After 24-hours of separation, the tap beneath the container was opened and glycerol was drained off.

2.2.2 Experimental Procedures for the Determination of Brake Power

The brake power (b.p.) of an engine is measured by running the engine against some absorption brake i.e. dynamometer. The output shaft of the dynamometer will be locked to a suitable load capacity of load cell. The engine torque will be applied to the dynamometer through the coupling and the engine brake power will be determined as follows;

$$\text{Brake Power}\left(\text{b.p.}\right) = \frac{2\pi NWR}{60}\ \text{kW}$$

Where, W = Effective Load on Torque arm (N), N = Engine running speed (rpm), R= Length of torque arm (m). The brake power developed by the engine at various speeds was then determined.

2.2.3 Experimental Procedures for the Determination of Engine Torque

The same experimental procedure for determining brake power was followed and the total loaded weight that stopped the flywheel was recorded as well as the distance from the centre of the flywheel to the centre of the total loaded weights. The recorded weights and the radius were used to calculate the torque of the engine.

Torque applied to the engine shaft = Force × Radius= F × r (N-m). The torque transmitted by engine = Effective Load (N) × Length of torque arm (m), where, W (N) = Effective load (sum of spring balance reading + effective load on torque arm). R (m). = Length of torque arm.

2.2.4 Experimental Procedures for the Determination Fuel Consumption

The amount of fuel consumed by the engine in a given period of time is referred to as the rate of fuel consumption.

$$\text{Rate of Fuel Consumption} = \frac{\text{Mass of Fuel Consumed}}{\text{Time Taken}}$$

Where,

$$\text{Mass of Fuel Consumed} = \text{Density} \times \text{Volume}$$

The amount of fuel consumed by the engine in a period of one hour for each kilowatt of power developed is referred to as specific fuel consumption.

$$\text{Brake Specific Fuel Consumption, (Kg/kWh)} = \frac{\text{Rate of Fuel Consumption}}{\text{Brake Power}}$$

III. Results And Discussions

3.1 Comparison of Engine Load

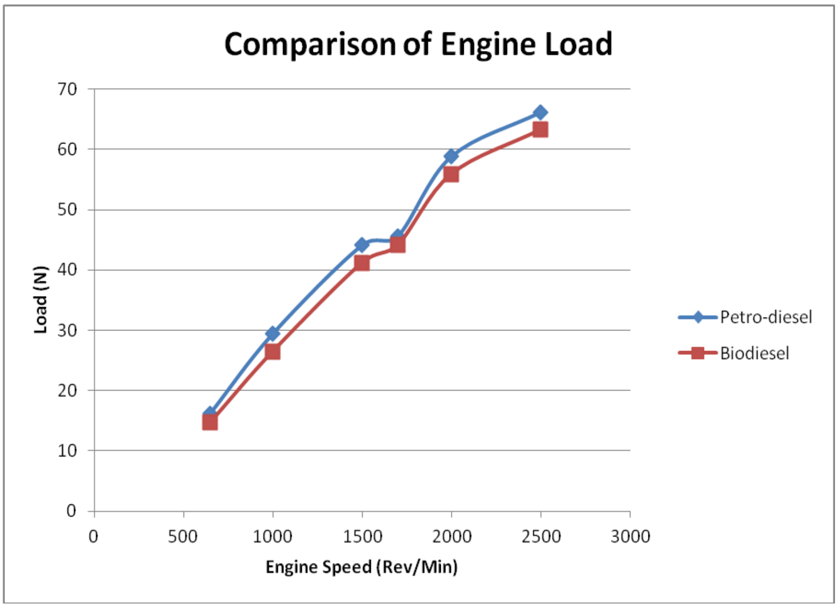

Figure 1: Comparison of Engine Load

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Figure 1 shows the comparison of engine load. The values of engine load for petro-diesel are higher than for biodiesel.

3.2 Comparison of Engine Torque

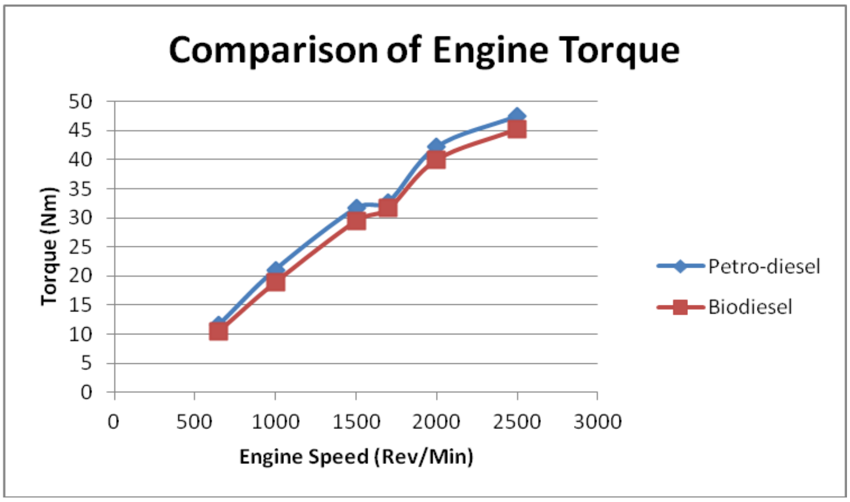

Figure 2: Comparison of Engine Torque

The reason for this stems mainly from the oxygen content of biodiesel, the ensuing better combustion process which partly compensate for the impact of the lower load content.

Figure 2 represents the data collected on engine torque. While biodiesel closely matches the petro-diesel, all the values of engine torque for petro-diesel are higher than for biodiesel. Biodiesel is an oxygenated compound. Oxygenates are just preused hydrocarbons having a structure that provides a reasonable antiknock value.

Also, as oxygenates contain oxygen, fuel combustion is more efficient, reducing hydrocarbons in exhaust gases. The only disadvantage is that oxygenated fuel has less energy content. For the same efficiency and power output, more fuel has to be burned as shown in Figures 3 and 4.

3.3 Comparison of Brake Power

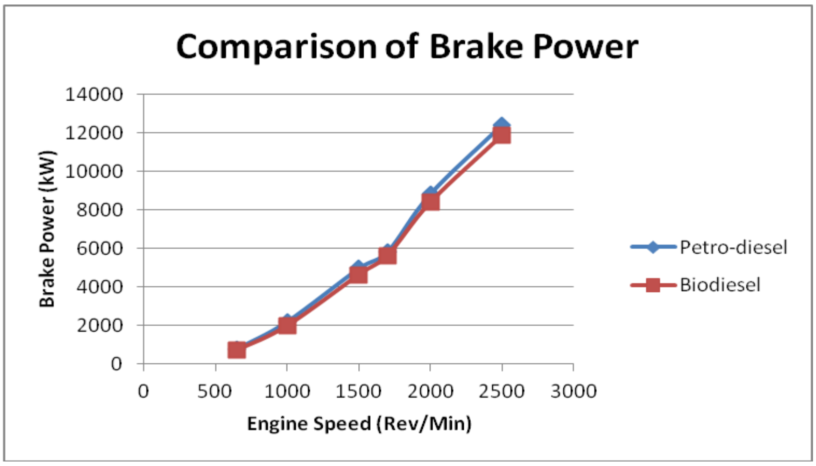

Figure 3: Comparison of Engine Brake Power

Figure 3 shows that the brake power of biodiesel was nearly the same as with petro-diesel fuel. This implies that the engine converts the chemical energy of the fuel to mechanical energy with the same efficiency for the two fuels used in the experiment.

3.4 Comparison of Brake Specific Fuel Consumption

Figure 4 shows that the average value obtained for the brake specific fuel consumption (BSFC) of biodiesel was higher than that of petro-diesel. The high viscosity of biodiesel was supposed to be the cause of the increased BSFC.

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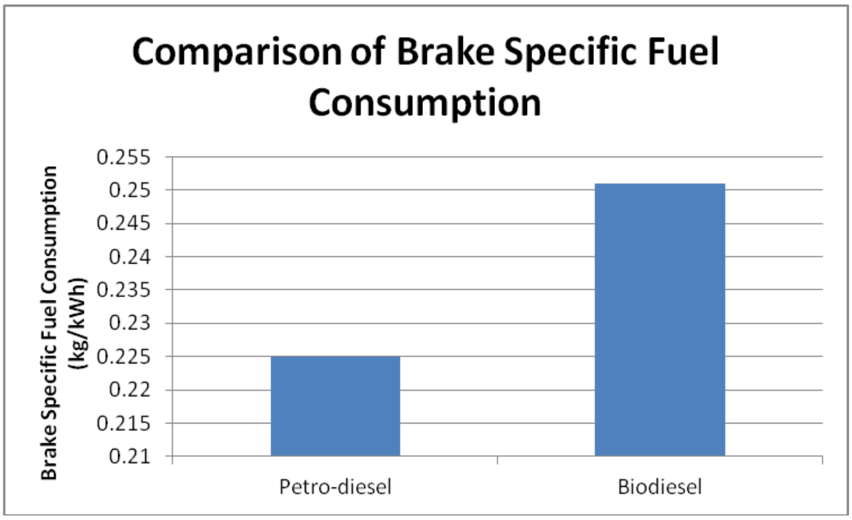

Figure 4: Comparison of Engine Brake Power

IV. CONCLUSIONS

Results obtained in this study showed that biodiesel obtained from waste vegetable oil had properties close to petrol-diesel therefore it can be used as a substitute for petrol-diesel. A study on the blending of biodiesel with diesel is expected to lower the viscosity of the mixture and increase the calorific value of the oil.

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