The International Journal Of Engineering And Science (IJES)
||Volume||2 ||Issue|| 9 ||Pages|| 19-25||2013||
ISSN(e): 2319 – 1813 ISSN(p): 2319 – 1805

Engine Performance Evaluation Using Biodiesel Blends From Waste Palm Kernel Oil, Mixed WVOs And Diesel Fuel

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ABSTRACT

This paper evaluates the engine performance using biodiesel from waste palm kernel oil (WPKO) and mixed waste vegetable oils (WVOs), which were compared with diesel fuel. A four stroke single cylinder air cooled diesel engine was used. The engine performance was determined by measuring brake power, brake specific fuel consumption, thermal efficiency and exhaust temperature. The properties of the biodiesel blends were also determined in the laboratory. Among the properties determined, sulphur content and cetane index showed some significant differences in values between the biodiesel blends and diesel fuel. The results indicated that B_M10 (90% diesel + 10% mixed WVO biodiesel) and B_M5 (95% diesel + 5% mixed WVO biodiesel) blends showed the least sulphur content of 113.6 ppm and 1290 ppm respectively compared to 1348 ppm for diesel fuel. For cetane index, both biodiesel blends of WPKO and mixed WVOs gave higher values than diesel fuel. In terms of engine performance, $B_{PK}10$ (90% diesel+10% waste palm kernel oil) and $B_{PK}20$ (80% diesel+20% waste palm kernel oil) indicated higher brake power, higher thermal efficiency but lower exhaust temperatures at all engine loading conditions. Brake specific fuel consumption was lower in most cases for $B_{PK}10$ and $B_{PK}20$ blends than the rest of the other blends. Therefore, it can be concluded that 10% and 20% blends of waste palm kernel oils ($B_{PK}10$ and $B_{PK}20$) can be used as an alternative fuel in diesel engine without any significant modification of the engine and that the viscosity of $B_{PK}20$ was similar to that of diesel fuel.

KEYWORDS: Alternative fuels, blends, fuel properties, performance test, waste vegetable oils.

Date of Submission: 27 July, 2013 Date of Acceptance:10, September 2013

I. INTRODUCTION

In recent years, the search for alternative fuels for power generation and transport has intensified due to rising cost of fuel, insecurity of fossil fuel supply and negative environmental impacts associated with the burning of fossil fuels. Nonetheless, biodiesels produced from waste vegetable oils (WVOs) have been identified as alternative fuels because they are biodegradable, renewable, less toxic and reduce dependency on imported petroleum oils.

Among the potential feedstock for biodiesel production is waste palm kernel oil (WPKO). In Ghana, palm kernel oil is less utilised for food because of its high fat content, high percentage of lauric acid and sometimes unpleasant odour. These make both fresh and WPKO more suitable for soap, shampoos and biodiesel production. In Ghana and several African countries, WVOs are not properly managed and hence end up in open drains, streams and rivers raising environmental concerns. Further, the use of WVOs in animal feed preparation has been banned in several countries owing to their carcinogenic effects (Macrae, 2006; Simon, 2009). Since WVOs are considered a waste product, they are less expensive; often freely given out and hence their use as feedstock for biodiesel production could reduce production cost.

Several studies have shown that WVOs can be successfully converted to biodiesel, which has properties comparable to diesel fuel (Forson et al, 2003; Pramanik, 2003; Agarwal, 2006). Currently, vegetable oils are being used as fuel in diesel engines. However, high viscosity is one of the problems associated with the use of vegetable oils in compression ignition engines (Honary, 2001; Pramanik, 2003). High viscosity of vegetable oils may contribute to the formation of carbon deposits in the engines, incomplete fuel combustion, which results in reduction of engine life. The problem of high viscosity of vegetable oils, however, has been approached in several ways including preheating the oils, blending with other fuels, transesterification and thermal cracking/pyrolysis (Pramanik, 2003; Hanumantha et al, 2009).

One of the indicators of fuel quality is its sulphur content. Sulphur in diesel is likely to harm new emission control devices in vehicles. Sulphur burns to sulphur dioxide and sulphur trioxide, which can combine with water to form sulphuric acid. Small droplets of sulphuric acid and other sulphates contribute to particulate emissions, which in turn contribute to environmental pollution. Of equal significance is the cetane index of diesel fuel. Cetane index influences ignition delay and fuel combustion. The higher the cetane index the shorter the period that occurs between the start of fuel injection and the start of fuel combustion (ignition delay) and the better the combustion. Engine performance test using biodiesel derived from WVOs including WPKO is relatively new as earlier studies had focused on the use of biodiesel processed from fresh vegetable oil. Therefore, the objectives of this study are to: (1) evaluate the performance of diesel engine using biodiesel blends from WPKO and mixed WVOs; and (2) analyse the effect of blending and compare the results with the properties of diesel fuel. The purpose of this study is to make some contribution to finding alternative fuels that will be suitable for powering small diesel generators for off-grid electricity supply as well as small farm vehicles for rural application.

II. MATERIALS AND METHODS

The test was carried out in the laboratory using a four stroke single cylinder unmodified victor type air cooled diesel engine. To measure the fuel consumption a two way valve fitted with a burette was attached to the engine. The fuel consumption rate was determined by recording the time taken for 5 ml of fuel to flow under gravity into the engine. The ambient and exhaust temperatures were monitored with two liquid in glass thermometers. The latter was placed on the engine as shown in Fig. 1 below and the former at a vantage point in the test room. A prony brake water cooled dynamometer fitted with load bank by means of a 100 x 0.5 spring balance was used to determine the load. The load bank was increased from 0 – 25N in increments of 5N.

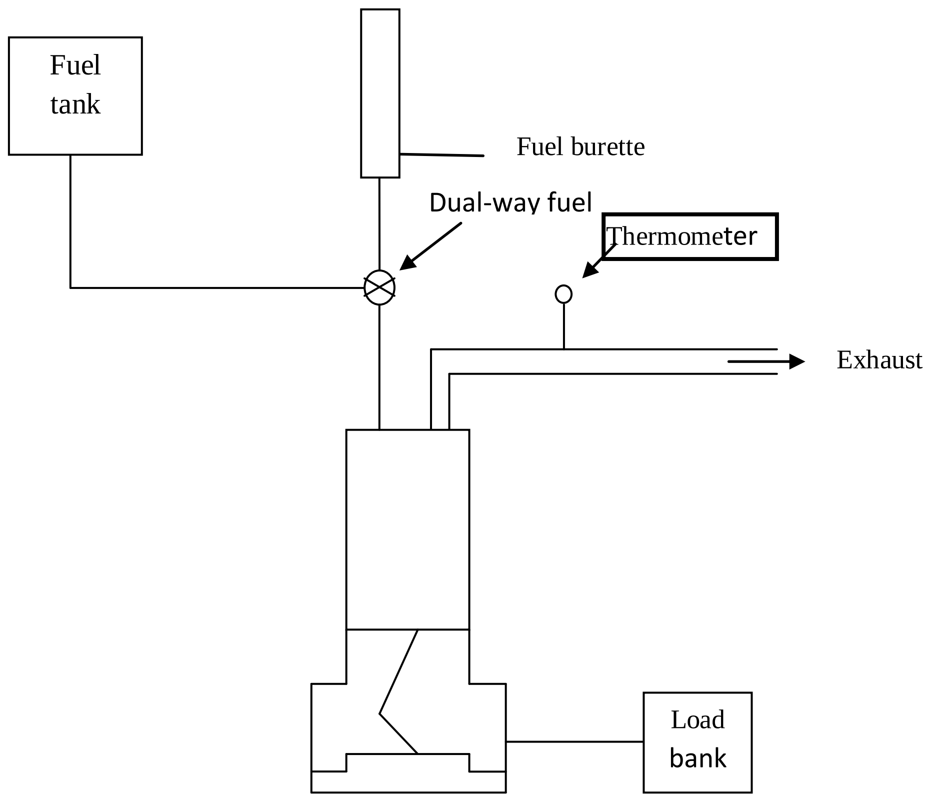

Fig. 1: Experimental setup

The engine speed was determined with a hand held digital tachometer which had an accuracy of ± 1 rpm. The engine was run on biodiesel from WPKO and WVOs as well as diesel fuel to evaluate its performance. In addition to determining the physical and chemical properties of the biodiesel blends, the following parameters were determined: brake power; brake specific fuel consumption of the fuel; thermal efficiency; and exhaust temperature. Table 1 provides the specifications of the diesel engine that was used.

Table1: Specifications of test engine

Manufacturer	Victor Diesel Engine Company Ltd
Engine	Number 42
Type	Single cylinder, 4 stroke, vertical compression, air cooled, fixed throttle
Cylinder bore	80mm
Torque arm	10mm
Stroke	100mm
Swept volume	0.5(l)
Fuel	diesel
Max. speed	1500rpm
Brake power	2.982KW at 1500rpm
Installation	1981

The biodiesel was prepared from WPKO and mixed WVOs from lele, frytol brands (palm oil parent stock), soy oil and groundnut parent stock oils in unknown proportions by transesterification with alcohol using NaOH as a catalyst. The pre-prepared biodiesels were blended on volume basis with diesel to obtain the following blends, which were compared with diesel fuel:

- 95% diesel + 5% mixed WVO biodiesel = (M5 or B_M5)
- 90% diesel + 10% mixed WVO biodiesel = (M10 or B_M10)
- 80% diesel + 20% mixed WVO biodiesel = (M20 or B_M20)
- 95% diesel + 5% waste palm kernel oil biodiesel = (pk5 or $B_{PK}5$)
- 90% diesel + 10% waste palm kernel oil biodiesel = (pk10 or $B_{PK}10$)
- 80% diesel + 20% waste palm kernel oil biodiesel = (pk20 or $B_{PK}20$)

III. RESULTS AND DISCUSSION

3.1 Physical and chemical properties of the biodiesel blends with diesel

The chemical and physical properties of the biodiesel blends were investigated. From the results shown in Table 2, all the blends had relatively low density values compared to diesel fuel, though the difference is not very significant. It was also observed that as the proportion of the biodiesel increased in the blend, density increased. In terms of the fuels ability to auto-ignite, the cetane index of all the blends was found to be higher than diesel fuel. The higher cetane index of the biodiesel blends might be due to the chemical structure of the biodiesel which improves the fuel's ability to auto ignite and burn smoothly. The sulphur content of the biodiesel blends was found to be lower than diesel fuel and generally decreased as the percentage of the biodiesel increased in the blend. Another important property which was measured was the viscosity of the fuels. In the case of the mixed WVOs, it was observed that as the proportion of biodiesel in the blends increased from B_M5 to B_M20, viscosity also increased; whereas for WPKO, the viscosity decreased from $B_{PK}5$ to $B_{PK}20$. Further, the data revealed that $B_{PK}20$ was as viscous as the diesel fuel. Overall viscosity of the blends appeared to be higher than the diesel fuel. The pour points of the blends were also enhanced considerably, recording relatively low temperatures as indicated in Table 2. The carbon residue of a fuel is the tendency of carbon deposits to form under high temperature in an inert atmosphere. This property indicates the carbonaceous deposit-forming tendencies of the fuel. It is known that the correlation between carbon residue and diesel engine performance is poor. From the data, the micro carbon residue (MCR) values of the biodiesel blends as well as the diesel fuel were all less than 0.1% (m/m) indicating low carbon residue values. Factors that can affect the combustion process and the deposit tendencies of a particular fuel in diesel engines include engine loading, engine tuning and the ignition qualities of the fuel (Kittiwake Developments, 2013).

Table 2: Properties of the biodiesel blends compared with diesel fuel

Fuel type	Density at STP (Kg/m^3)	Cetane index	Sulphur content (ppm)	Pour point (°C)	Micro Carbon Residue (MCR) (%, wt)	Viscosity mm^2/s (cSt)	Calorific value (kJ/kg)
Diesel fuel (measured)	860	47.13	1348	-6	0.0065	4.09	45316
B_M5	853	51.49	1294	-6	0.0065	3.938	45460
B_M10	854	49.81	113.6	-9	0.0133	3.98	45450
B_M20	858	48.62	1051	-6	0.0567	4.39	45397
$B_{PK}5$	856	50.44	1150	-9	0.0198	4.28	45424
$B_{PK}10$	857	50.44	1157	-12	0.0199	4.17	45408
$B_{PK}20$	859	49.91	1037	-6	0.0133	4.09	45386

Note: B_M - mixed biodiesel from waste vegetable oils; B_{PK} – biodiesel from waste palm kernel oil; M-mixed WVOs; PK- palm kernel.

3.2 Brake power of engine

As indicated in Fig. 2, the brake power of the engine generally increased with load, peaked at 18N and started decreasing with increased load. The brake power of the engine was higher for all the blends than diesel between 6N and 20N. This is consistent with what was revealed in a study of fossil diesel blend with Jatropha oil (Forson et al, 2004). Of particular interest are the biodiesel blends B_M5, B_M10, $B_{PK}5$, $B_{PK}10$, B_M20 and $B_{PK}20$, all of which indicated higher brake power than diesel fuel as shown in Fig. 2. It is well known that the heating value of fuel affects the power of an engine. As the fuel temperature is decreased, the energy level also decreased. Some reduction will occur in the engine power if lower calorific value of biodiesel is used in diesel engine without modification (Can, et al, 2004).

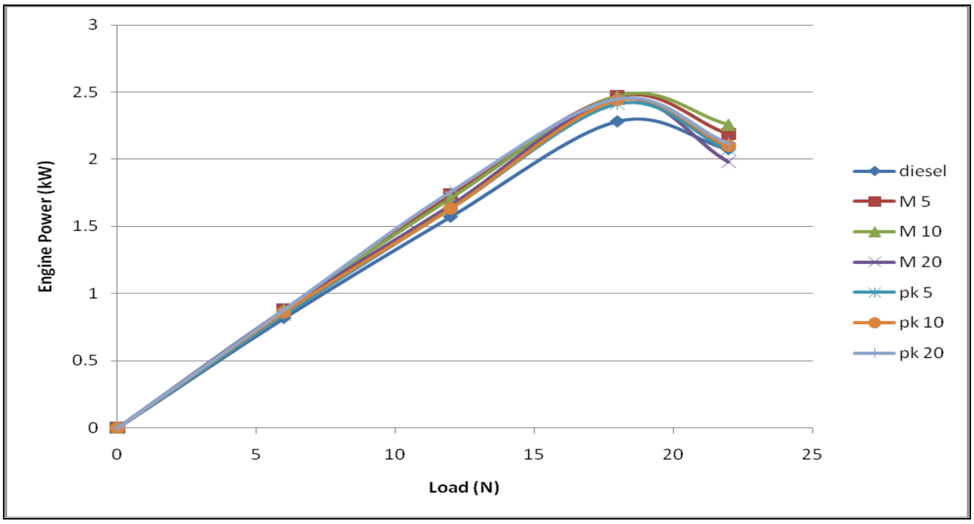

Fig. 2: Brake power against load

3.3 Brake specific fuel consumption of the engine

In Fig.3 brake specific fuel consumption (BSFC) of the engine generally decreased with increasing load and this trend is consistent with the results of the study by Jaichanda and Annamalai (2011). Relative to diesel fuel and the other biodiesel blends, $B_{PK}20$ appeared to have the lowest BSFC up to a load of 20N. Low BSFC indicates low fuel consumption and high thermal efficiency.

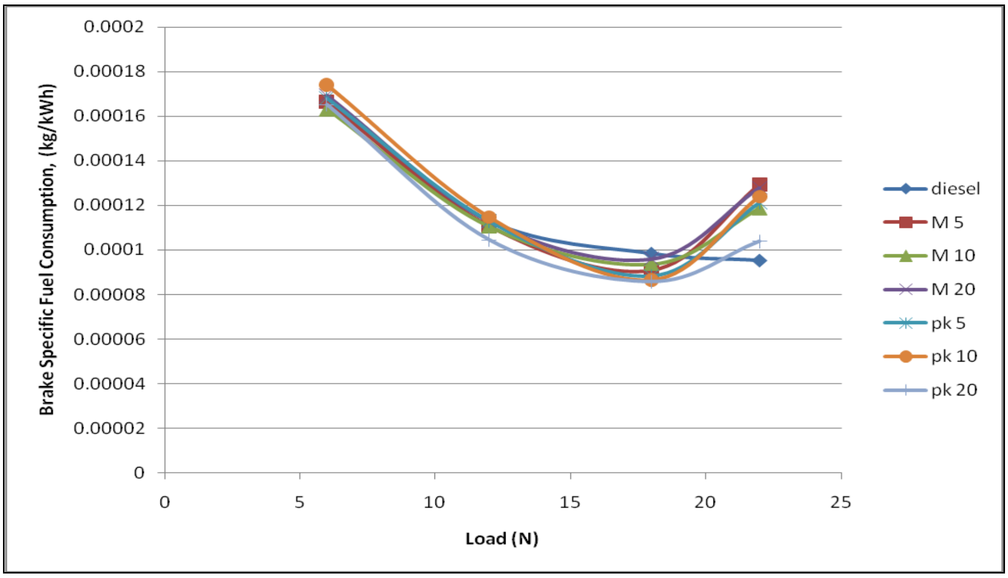

Fig. 3: Brake specific fuel consumption against load

3.4 Thermal efficiency

Thermal efficiency is the true indication of the efficiency with which the chemical energy input in the form of fuel is converted into useful work (Jaichanda and Annamalai, 2011). Fig. 4 showed that in general thermal efficiency increased with increasing load. However, it was observed that at loads of 6N – 18N (low loads) the thermal efficiencies of the biodiesel blends were higher than that of diesel fuel. This result corroborates the study carried out by Agarwal and Das (2001). The study also indicated a peak thermal efficiency ranging between about 23% (for diesel fuel) and about 26% (for $B_{PK}20$) at peak loads of about 18N. The higher engine thermal efficiency may be due to better lubricity of the biodiesel fuels which makes almost all the energy generated from the burning fuel be transformed into useful work in addition to the high presence of oxygen in the fuel aiding in complete combustion.

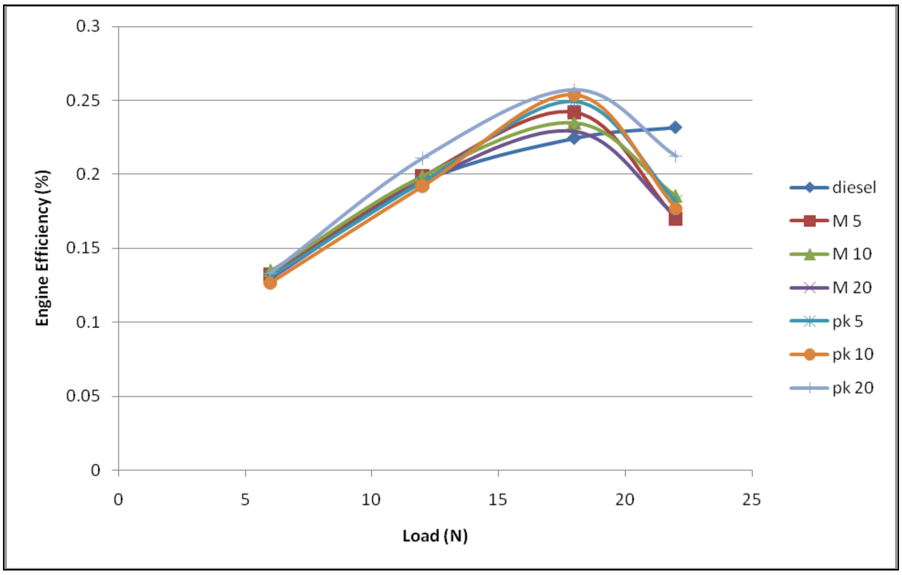

Fig. 4: Thermal efficiency against load

3.5 Exhaust Temperature

Exhaust temperature is a measure of combustion efficiency of an engine. Lower exhaust temperature is an indicator that complete combustion has taken place and converted energy from the fuel has been maximised into useful work. In Fig. 5, exhaust temperature generally increased with load. However, the exhaust temperature of $B_{PK}10$ and $B_{PK}20$ were lower than all the other blends and the diesel fuel. Thus 10% waste palm kernel oil ($B_{PK}10$) blend and 20% waste palm kernel oil blend ($B_{PK}20$) will maximise the energy input into useful work thereby giving a better thermal efficiency of the engine than diesel fuel.

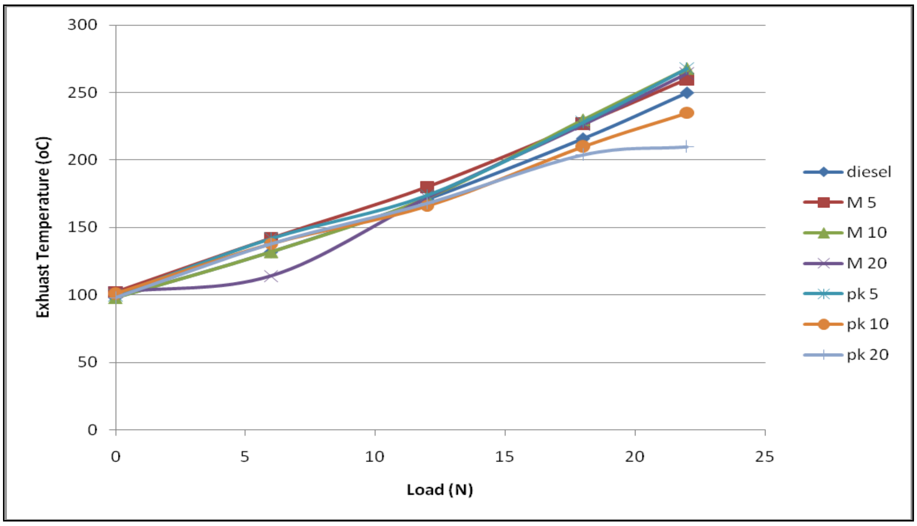

Fig. 5: Exhuast temperature against load

IV. CONCLUSION

Engine performance evaluation and standard test for some fuel properties were conducted to compare biodiesel blends from waste PKO and mixed WVOs with diesel fuel. Results obtained showed that:

- 90% diesel + 10% waste palm kernel oil ($B_{PK}10$); and 80% diesel + 20% waste palm kernel oil ($B_{PK}20$) blends of biodiesel gave higher thermal efficiencies, higher brake power and lower exhaust temperatures.
- Furthermore, brake specific fuel consumption was lower in most cases for these two blends than the rest of the other blends.

So it can be concluded from the above mentioned findings that 10% and 20% blends of waste palm kernel oils ($B_{PK}10$ and $B_{PK}20$) can be used as an alternative fuel in diesel engine without any significant modification of the engine and that the viscosity of $B_{PK}20$ was similar to that of diesel fuel.

V. ACKNOWLEDGEMENT

Special thanks must be given to the central administration of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana, for providing a grant for the fieldwork and laboratory analysis in Ghana. The authors are grateful to the Tema Oil Refinery (TOR), Departments of Mechanical and Chemical Engineering, KNUST, Kumasi for making their laboratories accessible for the biodiesel preparation, analyses of fuel properties and engine performance test. These facilities made it possible for us to generate data for this paper.

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