Assessment of IC Diesel Engine Performance Fuelled with Jatropha Curcas Biodiesel, Petro-Diesel 50ppm and 500ppm

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***Abstract*—**numerous studies are going on around the world searching for potential replacements of petroleum-diesel fuels for the internal combustion (IC) engine. In this regard, investigations of IC engine performance using alternative fuels such as biodiesel are worthy of exploration. In the present investigation, a comparative study was carried out to investigate the engine performance characteristics of IC diesel engine fuelled with Jatropha curcas biodiesel, petro-diesel 50ppm and petro-diesel 500ppm. The engine performance characteristics investigated include specific fuel consumption, engine torque, engine brake power and thermal efficiency. Results showed closely comparable performance for the three fuels investigated.

***Keywords*—**Engine Performance, Jatropha curcas Biodiesel, Petroleum diesel 50ppm, Petroleum diesel 500ppm

I. Introduction

FOSSIL diesel fuel has contributed significantly in vital sectors of economy such as transportation, agricultural and industrial. However, different factors such as world population increase, depletion of petroleum reserves, greenhouse gases (GHGs) emissions from the combustion of fossil fuel has forced the world to look for alternative fuel which can be used [1]. Several studies have pointed out biodiesel as one of the best alternative fuels because it has immerse potential to reduce GHGs emissions and that it can be used in most compression ignition engine [2].

Biodiesel is a renewable, biodegradable and environmental friendly fuel with similar properties as petroleum diesel [3]. Chemically, biodiesel is alkyl esters of fatty acid typically made from biological resources such as vegetable oils, animal fats and used cooking oils [4]–[6]. From these three, vegetable oils are the most promising because they can be produced in large scale. They can be obtained from edible and non-edible oil sources. Edible vegetables oils include palm oil, rapeseed oil and flower oil while non edible includes jatropha, mahua and jojoba [7]. Due to world concerns of using edible oil for fuel, many researchers are working tirelessly to find the best non edible oil crops [8],[9]. Among these studies Jatropha carcus has been pointed out as a potential energy crop for biodiesel production. Jatropha curcas is a multipurpose crop with several uses from its different parts. In tropical countries, such as India, Jatropha curcas is mainly planted as a hedge to protect cropland from grazing by domestic animals such as cattle, sheep and goats. The plant also protects against damages caused by wind, water and soil erosion [10],[11]. Its seeds contain up to 40% oil that can be converted into biodiesel through a process called trans-esterification [16],[17].

Several studies which have used biodiesel processed in the mentioned chemical process in an internal compression (IC) engine has shown not much difference in performance as petroleum diesel [14],[15]. Other studies investigated the performance of jatropha oil and its fuel blends with diesel in a direct-injection single-cylinder diesel [16]. They concluded that Jatropha biodiesel, petro-diesel fuel and blends of Jatropha to diesel fuel exhibited almost similar engine performance under comparable operating conditions. In similar study Raghuvanshi and Singh [14], used single cylinder, four-stroke, direct injection (DI), water-cooled, diesel engine with mechanical rope brake loading. The authors reported that the engine performance results powered with Jatropha biodiesel did not differ greatly from those recorded for petro-diesel. However, their results showed lower brake power of Jatropha biodiesel while specific fuel consumption was higher than petro-diesel. This may be due to the lower heating value of the ester.

The present work is an assessment of IC diesel engine performance parameters such as specific fuel consumption, engine torque, engine brake power air fuel ratio, volumetric efficiency, thermal efficiency and exhaust gas temperature using Jatropha curcas biodiesel, petro-diesel 50ppm and 500ppm.

II. Materials and Research Methods

The TD200 small engine test (TecQuipment) set was used to carry out engine performance tests. The main components of the test set are a heavy fabricated portable bed and bench-mounted instrumentation frame. The bed sits on a trolley for portability. It includes a four stroke diesel engine which is loaded by a robust hydraulic dynamometer. Hydraulic dynamometer has no electrical supplies or load resistors like

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most of other test diesel engine instead the engine power is dissipated into the water used to load the dynamometer at approximately 4 litres per minutes at 1 bar. The system was powered with single phase AC 90-240V, 50/60 Hz. The dynamometer applies load according to the flow rate and level of water in the casing. An accurate needle valve controls the flow rate. An electronic load cell measures engine torque.

The instrumentation was mounted on a sturdy frame. This frame had a single power inlet and several power outlets to supply the various display units. The instrumentation and test bed were separate in order to avoid vibration being transmitted from the engine to the measuring devices.

The equipment was connected to TecQuipment's Versatile Data Acquisition System (VDAS). The VDAS enables real time data capture, monitoring and display, calculation and charting of all relevant parameters on a computer making tests quick and reliable.

Tested Fuels

The petroleum diesels namely diesel 50ppm and diesel 500ppm were obtained from a local filling station in Gaborone, Botswana. The biodiesel was processed using Jatropha curcas crude oil obtained from Mmadinare village. Mmadinare village is one of the major village in Botswana situated in the eastern part of the country. Physicochemical properties of the tested diesel fuels and biodiesels are shown in Table 1. It can be seen that differences between these fuels mainly lies in the two of the properties: viscosity and heating value.

TABLE 1: PHYSICOCHEMICAL PROPERTIES OF BIODIESEL, DIESEL 50PPM AND DIESEL 500PPM [3]

Physicochemical Properties	Biodiesel	Diesel 50ppm	Diesel 500ppm
Heating Value (MJ/kg)	39.52	44.90	39.61
Viscosity at 40 °C (cSt)	3.09	2.57	2.40
Flashpoint (°C)	177.3	80.25	86.00
Pour point (°C)	1.00	-6.00	-14.00
Cloud point (°C)	1.00	-3.00	0.33

Experimental Procedure

Fuel tank was filled with fuel for the test engine. The starting handle of the test engine was gently pulled until it was passed its compression stroke then returned to its original place. On the instrumentation frame different parameters such as torque and differential readings were pressed to zero. In order to allow fuel to pass down the fuel feed pipe to the test engine both valves on the fuel gauge were opened. At that point, the computer connected to the equipment was turned on and the VDAS software was opened. The test engine was started and allowed to reach normal operating temperature then the throttle was set to maximum speed of approximately 2800rev/min. To adjust the speed of the test engine, the dynamometer control valve was kept on being adjusted to increase or decrease the load. With more water allowed through the dynamometer more load was exerted. Since water flow also removes heat from the dynamometer the control valve was never fully closed. The engine was allowed to run for approximately 20 minutes for the engine to reach steady-state conditions (fully stabilize).

After the engine had fully stabilised the speed was adjusted to the lowest achievable speed of approximately 1200 rev/min then readings were recorded on the computer. These readings were recorded at different speeds of 1200, 1400, 1800, 2100 and 2600 rev/min. The same procedure was repeated for all other fuels under review.

III. RESULTS AND DISCUSSIONS

As mentioned earlier, engine performance was assessed in terms of engine torque, specific fuel consumption, thermal efficiency and exhaust gas temperature. The following sections present and discuss the experimental results.

Engine Torque

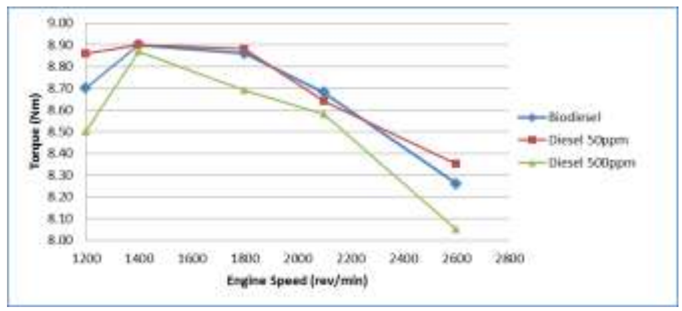

Fig 1: Engine speed against torque

Figure 1 shows engine torque of all fuel samples with respect to engine speed. It is observed that engine torque increases with a significant increase for biodiesel and diesel 500ppm between 1200 rev/min to 1400 rev/min, then a decrease in engine torque. Other authors have reported that this can be mainly due to mechanical friction loss and lower volumetric efficiency of the engine [17],[18],[19]. The maximum values of engine torque of 8.90 Nm, 8.90 Nm, 8.87 Nm for biodiesel, diesel 50ppm, diesel 500ppm respectively were attained at an engine speed of approximately 1500 rev/min. However, diesel 500ppm had the lowest engine torque for all the speed measured while diesel 50ppm and biodiesel had almost the same trend for all the engine speeds.

At engine speed of 1200 rev/min, the percentage difference between biodiesel and diesel 50ppm was 1.84% and at maximum engine speed of 2600 rev/min the percentage difference was 1.09% . As observed there is no significant difference between biodiesel and diesel 50ppm. This is consistence with results obtained by Lin at el [20] who also found insignificant variation between biodiesel and petro diesel. They reported that although biodiesel have a higher viscosity and lower heating value than diesel which may hinder its engine performance, a higher oxygen content, higher combustion rate and higher brake specific fuel consumption of biodiesel compensate for those limitations.

Specific Fuel Consumption

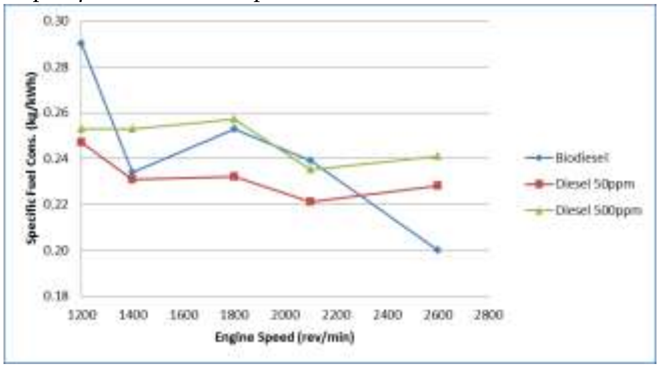

Fig 2: Engine speed against specific fuel consumption

Figure 2 shows the specific fuel consumption (SFC) at different engine speeds. It can be seen that the two petroleum diesel 50ppm and 500ppm had almost the same trend of SFC with increase in speed. Even though these petroleum diesel had the same trend, diesel 50ppm was less consumed at all different engine speeds than diesel 500ppm. At the lowest speed of approximately 1255 rev/min both petroleum diesel had equal SFC of 0.25kg/kWh while Jatropha biodiesel had the highest SFC of 0.29kg/kWh at the same speed. This is probably caused by high viscosity of biodiesel when compared with those of petroleum diesel [3]. At intermediates engine speeds of approx. 1700rev/min, 1900rev/min the value for SFC for biodiesel and diesel 500ppm were almost the same. At engine speed of approx. 1700rev/min the SFC was 0.25kg/kWh and 0.26kg/kWh for biodiesel and diesel 500ppm respectively while at approx. 1900rev/min the SFC was the same with 0.24kg/kWh for both fuels. Despite biodiesel fuel having the highest consumption at the lowest speed it had lowest SFC of 0.20kg/kWh at the highest engine speed of 2600rev/min while the SFC for diesel 50ppm and diesel 500ppm were 0.23kg/kWh and 0.24kg/kWh respectively. The maximum variation of biodiesel to these two petro-diesel at the highest engine speed of 2600 rev/min is 15% and 20% for diesel 50ppm and diesel 500ppm respectively.

Thermal Efficiency

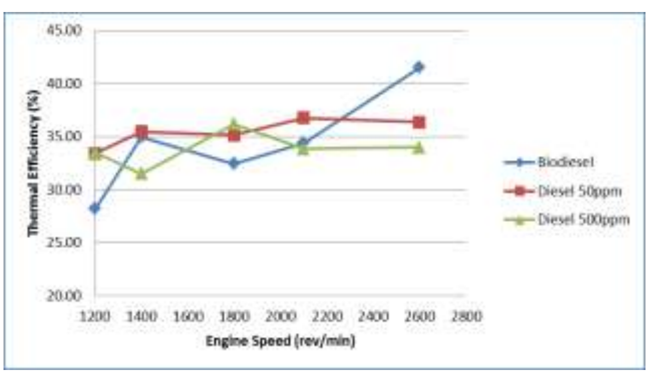

Fig 3: Engine speed against thermal efficiency

Figure 3 shows the variation of thermal efficiency with change in engine speed. At the engine speed of 1250 rev/min both petroleum diesel had the same percentage of thermal efficiency of 33% while biodiesel at lower speed had the lowest thermal efficiency of 28%. Thereafter, the thermal efficiency of biodiesel increased with increase in engine speed while both petroleum diesel were generally constant with an average thermal efficiency of 35.44% and 33.80% for diesel 50ppm and diesel 500ppm respectively. At high engine speed of approx. 2600 rev/min, the thermal efficiency of biodiesel was the highest with 41.49%. This is due to the fact that biodiesel has high oxygen content and combustion rate when compared with petro diesel. Because of these attributes it favours more combustion of biodiesel hence higher thermal efficiency[21].

Brake Power

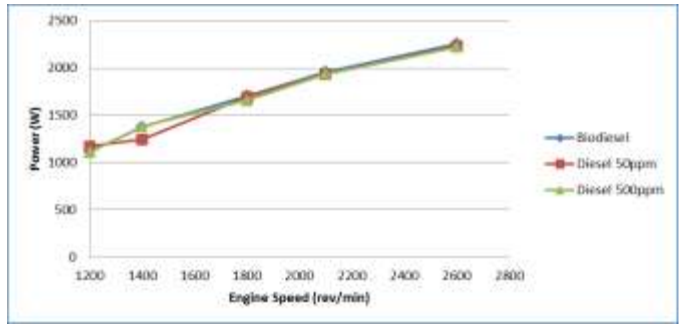

Fig 4: Engine speed against brake power

Figure 4 shows variation of brake power with increase in engine speed. Generally the brake power for all fuel samples tested is directly proportional to engine speed. As the engine speed increases the brake power also increases. There are some little variations noticed for the brake power between the fuels as the engine speed increases. At a minimum engine speed of 1200 rev/min, it was found that difference in brake power for biodiesel and diesel 50ppm was 5.31% and as for biodiesel diesel 500ppm was -0.18%. When the same observation was done at the maximum engine speed of 2600rev/min the difference in brake power for biodiesel and diesel 50ppm is -1.11% and for biodiesel and diesel 500ppm is -1.64%. From these variations, it can be observed that there is no significant difference in brake power between biodiesel and the two diesel types. Although biodiesel may have a higher viscosity and lower heating value than petro diesel the presence of high oxygen content and high combustion rate of biodiesel compesate for lower heating value hence increase in brake power

Exhaust Gas Temperature

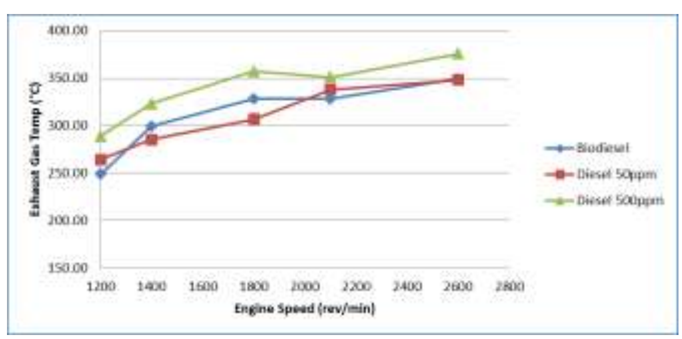

Fig 5: Engine Speed against exhaust gas temperature

Figure 7 shows the change in exhaust gas temperature with increase in engine speed. It is observed that the results in figure 7, the exhaust gas temperature for both petroleum diesel increases gradually with increase in engine speed. The exhaust gas temperatures at lowest engine speed were 288.9 °C and 264.1 °C for diesel 50ppm and diesel 500ppm respectively. Thereafter there was an increase of 30.15% and 29.04% at the maximum engine speed for diesel 50ppm and diesel 500ppm respectively. The exhaust gas temperature of biodiesel also had a similar trend by having exhaust gas temperature of 248.5 °C at lowest engine speed of 1200 rev/min and maximum temperature of 349 °C at highest engine speed of 2600 rev/min. A slight decrease of exhaust gas temperature of biodiesel from 2100 rev/min may be due to the effect of water present in the jatropha oil which when heated up subsequently evaporate than the diesel fuel [16].

IV. Conclusion

This paper's aim was to assess the IC diesel engine performance parameters namely; specific fuel consumption, engine torque, engine brake power, air fuel ratio, volumetric efficiency and thermal efficiency using Jatropha curcas biodiesel, petro-diesel 50ppm and 500ppm. Based on the experimental investigation, the follwing conclusions can be drawn:

1 Engine torque for all the fuels increased with increase in engine speed to the maximum value and then falls as the engine speed increases. Despite all the fuels having the same trend biodiesel recorded almost similar values as diesel 50ppm as compared to diesel 500ppm.

2 For SFC and thermal efficiency, biodiesel had a completely different trend than the two petrodiesel. At minimum speed, the SFC for biodiesel was high and at maximum speed the SFC was lower than for petrodiesel. For thermal efficiency, at lower speed the value was lower than petrodiesels and at high speed thermal efficiency was higher than petrodiesels.

3 Engine power for all the fuels investigated closely comparable at all different engine speeds.

4 As for exhaust gas temperature, biodiesel was more comparable to diesel 500ppm than diesel 50ppm at different engine speeds but a significant change was noticed at higher engine speeds where the exhaust gas temperature dropped significantly.

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