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Performance and emission characteristics of diesel engine fueled by biodiesel and ethanol

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Abstract:

A four strokes single cylinder directs injection water cooled, diesel engine was used to investigate the performance and emission characteristics of the engine when fueled by Diesel-Ethanol- Jatropha blend. The brake power , brake specific fuel consumption, brake thermal efficiency and concentration of exhaust gas emissions (carbon dioxide and nitrogen oxides) were conducted at speeds ranging from 1200 to -2000 rpm at zero and 80% load of the engine. A pure diesel and four blends (B20D80, B25E5D70, B30E5D65 and B40E5D55) were tested. The results showed that the brake power, brake specific fuel consumption, brake thermal efficiency and the nitrogen oxides increased with the rise of Jatropha-Ethanol percentage while the carbon monoxide decreased. This study recommends that further investigations of the blend ratios are required for the same engine by increasing ethanol percentage, which reduced the viscosity of the blend.

Key words: diesel, Biodiesel (jatropha), ethanol, performance, emissions

I - INTRODUCTION

The rapid depletion of oil reserves and environmental pollutions created an incentive to study and evaluate alternative fuels, which are renewable and cleaner than fossil fuels [1-3]. The biodiesel as an alternative renewable fuels which can be used without or with a few modifications in diesel engines will be the most interesting and attractive in the future[4]. Biodiesel can be produced through transesterification from a variety of vegetable oils including soybean, rapeseed, sunflower, peanut and palm [5, 6].

Sudan's energy demand has significantly grown through the past 30 years from 6.8 million tons of oil equivalent (MTOE) to more than 11.2 MTOE [7]. Crude oil is the main source of fossil energy and its consumption has rapidly increased in recent years owing to the increase in the country's economic and population growth[8, 9]. The amount of energy from biomass has stayed relatively constant though its percentage contribution or share has significantly dropped due to high growth in hydro and crude oil-sourced fuels[10].

After the secession of southern Sudan, the sharp drop of the share in Sudan's (North of the old Sudan) oil production (almost, 85 % of the old Sudan's production) revitalized the interest in alternative fuels[11, 12]. Although, the production is speculated to increase to 320 thousand barrels per day by the year 2030, as a result of new investments, but still the need to invest in green fuel is strongly realized. Optimal use of new and renewable sources of energy available in Sudan today is one of the strategic issues in planning for sustainable future energy alternatives. Accordingly, extracting biofuels from Jatropha curcas (biodiesel) is a vigorously growing trend. The result is not just having an alternative fuel but also, creating a sustainable, benign economic return and environmentally sound, i.e., reducing greenhouse gas emissions[13, 14].

Due to the above mentioned factors, jatropha based biodiesel mixed with ethanol as a fuel for diesel engine was used in this research to analyze the engine performance and exhaust emissions by using a single cylinder four stroke diesel engine in order to attend better performance of the engine with little fuel consumption.

The main biofuels identified, or in production, in Sudan at the present are:

1- Ethanol

Sudan is considered one of the largest producers in Africa of sugarcane and ethanol made from sugarcane molasses [15-18]. In 2009 Kenana Sugar Company (KSC), the Sudan's largest sugar producer launched an ethanol production plant based on 1st generation technology (molasses fermentation) with the capacity to produce commercial volumes of high-grade ethanol (65 million liters annually). While 90% of this ethanol is presently exported to EU, already some refueling stations in Sudan are selling an E10 blend (Nile-Ultra) and the test results for the pure ethanol are satisfactory[19]. Some trial work is being conducted into the relative advantages for producing fuel grade ethanol from sweet sorghum. One feature of the production of ethanol is that Sudan has the potential to use it as a fuel for agricultural spray planes.

2- Biodiesel

Biodiesel is an alternative fuel made from vegetable oils and animal fats. Chemically, it consists of mono alkyl esters of the long chain fatty acids present in the triglycerides of vegetable oils or animal fats. Since the feedstock is plant- or animal-derived, biodiesel is a renewable fuel. It contains very small quantities of sulphur, polycyclic aromatic hydrocarbons or metals, whereas, petroleum diesel, for example, can contain up to 20% polycyclic aromatic hydrocarbons. Biodiesel has similar properties to those of petroleum diesel. Its flash point is higher than diesel oil and so it is safer to handle. Biodiesel also has a higher cetane number and diesel index. Biodiesel lower sulphur content and ash content make it more environmentally friendly than any fossil fuels[20, 21] .

One major constraint on production of biodiesel is the simple difficulty of getting a high yield of vegetable oils per hectare or acre (so resulting in very large land areas being needed). While that has generally turned out to be not so, with the development of strains with better genetics, and with optimal management on good sites jatropha is once again being seen as having the potential to produce the next highest yields (after the oil palm) of over 1.5 tons of oil per hr. Jatropha is again being considered as the plant with high potential to sustainably produce oil as a feedstock for production of biodiesel and bio jet fuel complying with standards specifications[22, 23].

II-MATERIALS AND METHODS

A) Materials

This section explains the experiments and the specifications of the devices and materials used in the experiments: diesel, jatropha biodiesel, ethanol (which are explained in the introduction above) and single cylinder four stroke diesel engines.

B) Engine specification

Experiments were conduct on a direct injection compression ignition (DI-CI) engine with a single cylinder, four stroke diesel engine (compression ignition) mounted on spread moving frame is provided with test bed . The specifications of the engine are shown in table (1) and figure (1) shows a schematic layout of the test system.

Table 1 Specifications of the Engine

Engine type	**One cylinder four stroke diesel engine**
Cylinder bore, mm	85
Piston stroke, mm	87.8
Compression ratio	12:1
Maximum torque, N-m	28
Engine Speed, rpm	1200-2000
Maximum Brake Power, kW	7.2
Displacement, cm^3	499
Orifice diameter, m	0.022
Generator efficiency, %	85
Density of jatropha biodiesel, g/cm	0.8841

C) Experiments

Experiments are conducted on four stroke single cylinder water cooled diesel engine at different speeds ranging from 1200 to 2000 rpm with interval of 200 rpm. Eddy current dynamometer is used to load the engine. Schematic representation of the experimental set up is as shown in figure1. The tests are conducted using four test fuel blends namely B20D80, B25E5D70, B30E5D65 and B40E5D55 as well as pure diesel fuel at zero and 80% load of the engine. Emission parameters like carbon dioxide (CO_2) and NO_x are measured using exhaust gas analyzer. The data pertaining to performance and emissions are recorded for these loads. Performance parameters like brake power, brake specific fuel consumption (BSFC), brake thermal efficiency (BTE) and emissions like NO_x and CO_2 are analyzed and discussed.

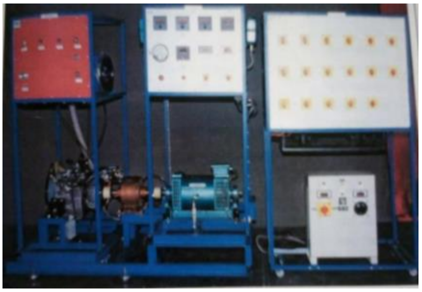


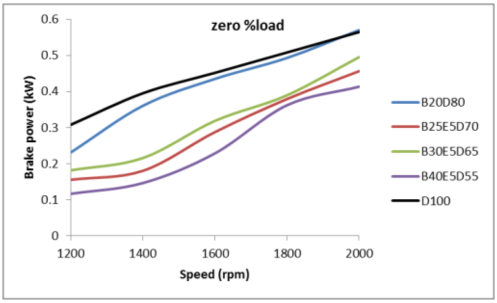
Figure 1. The Equipment of the Experiment

III- RESULTS AND DISCUSSION

The engine is run on four different test fuel blends as mentioned above. The performance and engine exhaust emission characteristics are analyzed and discussed.

1. Brake Power (BP)

Figure 2 shows the effect of engine speed variation on engine power. It is found that the engine power increases as the engine speed increases for all blends of biodiesel. The fuel D100 at zero loads at high speed (2000 rpm) gave high brake power of 0.57kW, when it compared to other fuel blends tested (B20D80, B25E5D70, B30E5D65 and B40E5D55) the engine power was shown to reduce by increasing the percentage of biodiesel in the blends. The main reason for power loss is due to the reduction in heating value and energy content of biodiesel compared to diesel[1]. Figure 2 showed that the D100 fuel at 2000 rpm at 80% load the break power of the engine was increased with the increase of the speed, the obtained brake power value reached 1.71 kW, after that B20D80 the BP was 1.23 kW and the other two blends gave the same value of 0.77 kW. In conclusion by increase the percentage of biodiesel (jatropha and ethanol) as well as the load and speed the break power increased.



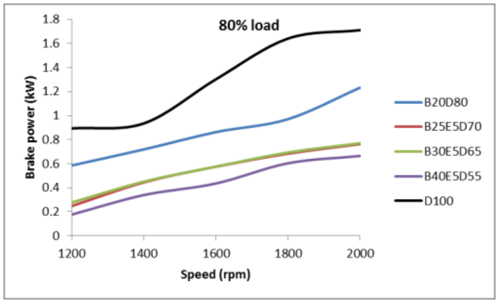


Figure 2. Brake Power VS Engine Speed at 0% and 80% loads

2. Brake specific fuel consumption (BSFC)

Figure (3) shows the effects of biodiesel percentage at zero and 80% load on the brake specific fuel consumption. The Figure shows that at zero-load and 2000 rpm the blends B25E5 and B30E5 gave approximately the maximum brake specific fuel consumption value, which is about $4.04e^{-5}$ (kg/kWh). The values for the brake specific fuel consumption increased rapidly with the increasing amount of biodiesel in the fuel blends B25E5, B30E5 and B40E5, while it increased slightly for the diesel and B20. The Figure shows that at 80% load the blends B25E5,B30E5 and B40E5 gave the same value at 2000 rpm which is the maximum brake specific fuel consumption value, about 6.72e-5 (kg/kWh), but at lower speeds the blend B40E5 gave the higher BSFC then B30E5 followed by B25E5. The diesel fuel and B 20 gave lower values in comparison to the above mentioned blends. The BSFC for the biodiesel blends is higher than that of diesel in the entire range of engine speeds examined. This is expected, and could be attributed to the lower heating value of the biodiesel and its blends, which leads to more fuel consumption in the engine for any particular power output when using biodiesel blends. The brake specific fuel consumption of the engine fuelled by the blends was higher compared with pure diesel.

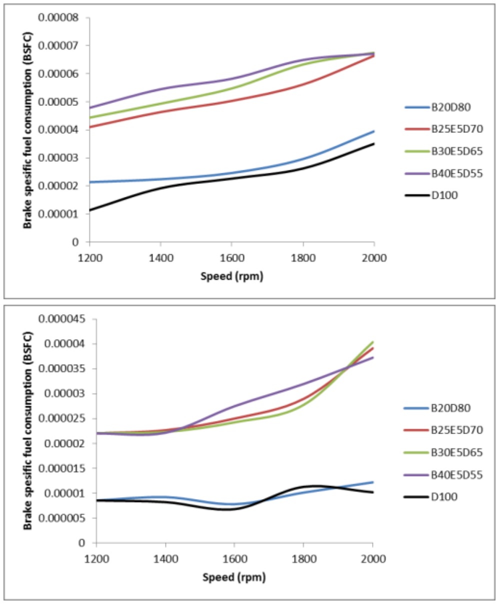


Figure 3. Influence of speed on BSFC at 0% and 80% Load

3. Brake thermal efficiency (η_{th})

The brake thermal efficiency (BTE) of the engine fuelled with biodiesel and ethanol fuels are shown in Figure. 4. B40E5D55 gives the best brake thermal efficiency of engine with the value 35.7% at full engine load. The minimum brake thermal efficiency of 19.7% was obtained by diesel fuel at 0% engine load. For 80 % load the B40E5D55 gives the best brake thermal efficiency of engine with the value 42.7% at 1600 rpm.The minimum brake thermal efficiency of 15.5% obtained by the diesel fuel at 1600 rpm. At 2000 rpm the maximum value 0f BTE was 39.9% and obtained by both of B30E5 and B40E5, the minimum value at 2000rpm was also obtained by diesel fuel. That means for the both loads the efficiency was improved with more effective combustion of these blends as compared to diesel fuel. The thermal efficiency has inverse relationship with the BSFC and lower heating value. In all cases, brake thermal efficiency has the tendency to increase with increase in applied load. This is due to the reduction in heat loss and increase in power developed with increase in load.

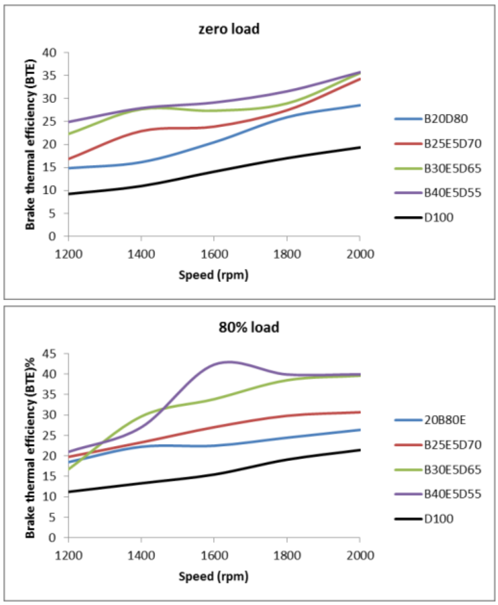


Figure 4. Influence of speed on BTE At 0% and 80% Load

4. Carbon dioxide (CO_2)

The variation of CO_2 emission with engine speed for diesel fuel and Jatropha biodiesel blends and ethanol is presented in Figure 5. It is found that the CO_2 emission decreases with the increase of biodiesel percentage in the blend for the entire range of engine speed for the zero and 80% loads. The same findings were obtained by other researchers. Significant drop in CO_2 emission profile when using B20D80, B25E5D70, B30E5D65 and B40E5D55 compare to the pure diesel was observed.

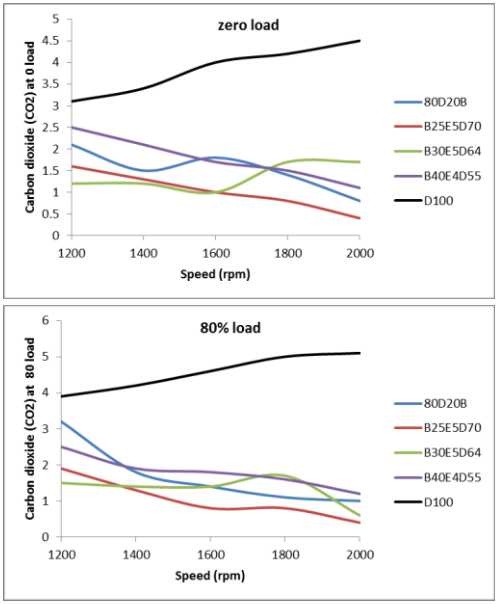


Figure 5 Influence of speed on CO_2 At 0% and 80% Load

6. Nitrogen Oxides (NO_X)

Nitric oxide (NO) and Nitrogen dioxide (NO_2) are usually expressed as combined NOx emissions. The NO is the dominate fraction of the oxides of nitrogen produced inside the engine cylinder. The oxidation of molecular nitrogen is the principal source of NO emission. The variation of NOx emissions with engine speed utilizing diesel and Jatropha biodiesel blends is presented in Figure 6. The NOx emission at zero load profile for all biodiesel blends tested increases with the increase in engine speed. It is obvious from Figure (6) at 80% load that increasing the biodiesel percentage in the blend leads to increase in the NOx emissions. Thus, all biodiesel blends tested produce higher NOx emissions than diesel for all engine speeds.

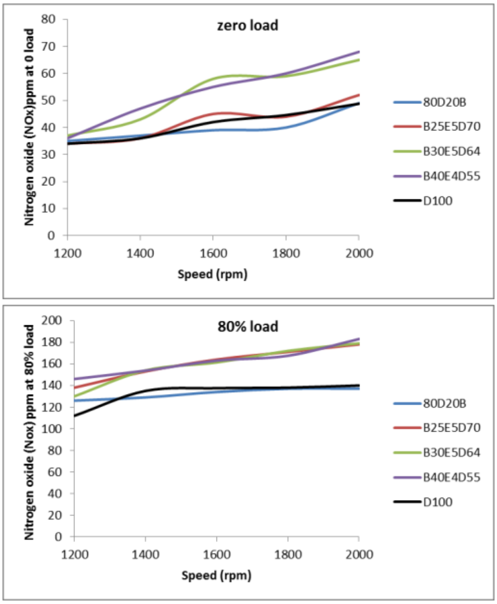


Figure 6 Influence of speed on NO_X at 0% and 80% load

IV. CONCLUSION

The objective of this study was to investigate the engine performance and emissions of a diesel engine operating on Biodiesel-ethanol blends and to compare them with pure diesel fuel.

Based on the experimental results, the following conclusions can be inferred:

- The break power increases with the increasing of speed and load and this due to increase in viscosity and reduction in heating value at the percentage of biodiesel and ethanol increases in the blends.
- The BSFC for the biodiesel blends is higher than that of diesel in the entire range of engine speeds examined. The brake specific fuel consumption of the engine fuelled by the blends was higher compared with pure diesel.
- The brake thermal efficiency has the tendency to increase with increase in applied load in all cases.

- The amount of CO_2 and NOx emissions with engine speed for diesel fuel and Jatropha biodiesel blends and ethanol were varied, it was found that the CO_2 emission decreases with the increase of biodiesel percentage in the blend. While The NOx emission for all biodiesel blends tested increases with the increase in engine speed.

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