Cottonseed Biodiesel and LPG Dual-Fuel Mode: An Experimental Approach

Daniel Ngugi*[1], Samuel Kimani[2], Grace Wanjiru[3], John Mwangi[4], Lucy Njeri[5]

[1]Assistant Professor, Department of Electrical Engineering, Kenyatta University, Nairobi, Kenya
[2],[3],[4],[5]UG Student, Department of Electrical Engineering, Kenyatta University, Nairobi, Kenya

ABSTRACT
Usage of biodiesel blends in traditional compression ignition engine has been well sought after. But reducing the emission from vehicles has become a daunting task for researchers. In this experimental investigation, biodiesel is extracted from crude cotton seed oil by single stage tranesterification process and this extracted biodiesel is blended with diesel via B20 and B30. The blended fuel is injected along with LPG in a dual fuel mode. 7.0 mg/cycle of cotton seed oil ethyl ester was injected with liquefied petroleum gas as pilot fuel. Its performance and emission characteristics were studied in a four stroke single cylinder vertical air cooled diesel engine. It was observed that in terms of performance there was a drop when compared to conventional fuel but there was a slight reduction in emission when LPG biodiesel blends were used as fuel.

KEYWORDS: Cottonseed oil, Liquefied Petroleum Gas, Bio-Diesel, Dual fuel, Emissions

I. INTRODUCTION
Utilization of biofuels is steadily increasing around the globe, which in turn making it imperative to fully understand the impacts of biofuels in diesel engine combustion, performance process and pollutant formation. Biodiesel is known as the mono-alkyl-esters of long chain fatty acids derived from renewable feedstock such as, vegetable oils or animal fats, to use in compression ignition engines. Compression ignition engines generally use diesel as the fuel for combustion, which expels more power and better efficiency, but it ultimately leads to environmental hazards like HC, CO and NO_X emissions [1]. In this current era, major findings in the field of IC engines is the use of alternate fuels which can partially replace conventional fuels. Gaseous fuels like LPG, CNG and Hydrogen are some the promising fuels which can slightly match diesel fuel properties. They have slightly higher octane number and calorific value and less exhaust emissions. Due this nature, CNG and LPG are popularly used in diesel and petrol engines respectively and good results in terms of performance and lesser emission is obtained. Alternative fuels are very useful in reducing the pollution from conventional engines. Besides this, alternative renewable fuels can play a major role in the economy of country and health of the humans [3]. Nowadays quite a lot of experimental investigations are carried out using LPG in conventional engines and these works are proven facts and the results are quite acceptable. Some results are as follows: SYED et el [4], The results obtained shows that engine running on LPG fuel system delivered a substantial improvement in power and torque in a high load condition and reduction of CO and HC exhaust gas emission when compared with original fuel. Allen Jeffrey et el [2], Lesser HC and CO emission in terms of emission and higher fuel consumption and lesser brake thermal efficiency when LPG biodiesel blends was used as fuel.

II. BIO-DIESEL PREPARATION
Transesterification of Crude Cottonseed Oil
Tranesterification is the process of breaking down of heavier molecules into lighter ones. Another name given to biodiesel is fatty acid methyl ester (FAME), which is extracted from the tranesterification of vegetable oils in addition with sodium hydroxide and ethanol. The procedure involved in this method is as follows: 500ml of Cottonseed oil was taken in a beaker and was heated using an electric hot plate for an hour. The temperature was maintained between 55-60˚C. 5 grams of sodium hydroxide (NaOH) and 100 ml of ethanol (CH_3CH_2OH or C_2H_5OH) are taken in a separate beaker. The sodium hydroxide (NaOH) and ethanol are thoroughly mixed until it was properly dissolved. The Sodium Ethoxide solution obtained was mixed with Cottonseed oil and stirred properly. The ethoxide solution with Cottonseed oil was heated to 60˚C and it was continuously stirred at constant rate for 1 hour by stirrer.

Figure 1: Heating of Crude Cottonseed Oil

The solution was then poured down to a separating flask and allowed to settle for 24 hours. The glycerol settled at the bottom and the ethyl ester floated at the top. Ethyl ester was separated from glycerin in a beaker. This ethyl ester obtained is pure biodiesel i.e. B100, which was later blended with diesel of blending ratios B20 and B30 respectively.

Figure 2: Heated oil with Sodium Ethoxide in the separating flask

III. EXPERIMENTAL SETUP AND PROCEDURE

A Kirloskar TAF1, naturally aspirated, single cylinder constant speed engine was used for the experimental investigation. Kirloskar engine was selected as it is one of the oldest model engines and is very sturdy in construction. Researchers prefer this model as the engine modifications such as injection timing variation, injection pressure variation etc. could be easily performed. AVL DI GAS 444 series, gas analyzer was used for measuring hydrocarbon (HC), Carbon monoxide (CO) and Oxides of nitrogen (NOx) emission. An analog to digital convertor (ADC) was used to convert the signals from crank angle encoder and pressure pick up sensor and feed the same to data acquisition system. AVL 415 smoke meter was used to measure smoke opacity in terms of Hatridge Smoke Units (HSU). The load was applied by eddy current dynamometer and readings were taken from zero loading to full load condition. The experimental investigation was conducted on a single cylinder four stroke compression ignition engine with the following specifications shown below.

Table 1: Engine specifications

Engine type	Four stroke single cylinder vertical air cooled diesel engine
Make and Model	Kirloskar TAF 1
Bore and stroke	87.5 and 110 mm
No of cylinders	Single cylinder
Compression ratio	17.5:1
Rated power	4.4 kw
Injection timing	23^0
Injection pressure	200 bar
Rated speed	1500 rpm

The layout of the experimental setup is shown below.

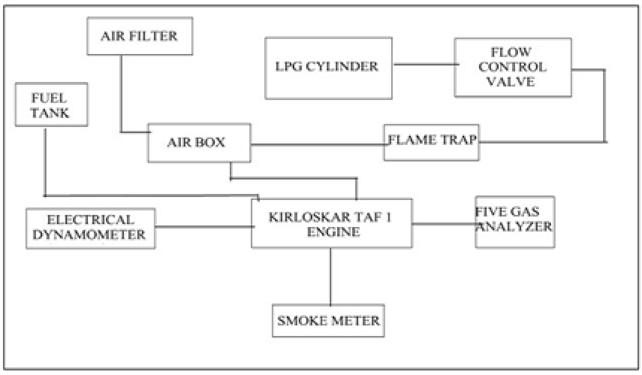

Figure 3: Experimental layout

Figure 4: Experimental setup

Experimental Procedure

The engine was allowed to warm up for few minutes. The engine was started with diesel until it is in warmed up condition and then the performance and emission characteristics of the engine under various loading conditions were noted. Five readings were taken for each loading condition of the engine and the average values obtained from the tests were considered for analysis. Then the fuel was switched to Cottonseed biodiesel B20 blend along with the supply of LPG and the characteristics of the engine were noted for various loading conditions of the engine and the results were obtained. Various readings for parameters such as current, voltage, engine speed, time taken for 10 g fuel consumption, manometer reading and exhaust gas temperature were noted down. Various readings of the emissions were noted down from the smokemeter. The combustion and performance characteristics were obtained from the Data Acquisition System separately. The same procedure was repeated for the second blend i.e. B30. Before stopping the engine, the fuel was again switched to pure diesel so as to avoid future startup problems.

IV. RESULTS AND DISCUSSION

The readings are plotted in separate graphs for various parameters. Both emission and performance characteristics are plotted in the following graphs.

Emission characteristics

1. Load vs. Carbon Monoxide

It is observed that, Cottonseed oil biodiesel blends with LPG produce lower carbon monoxide emission compared to diesel fuel. The CO emissions further decreases with an increase in biodiesel content in the blend. It is due to the higher oxygen content in the oil that promotes better combustion. As the load increases the carbon monoxide also increases. The load vs carbon monoxide graph shows the variation of emission under various loading conditions.

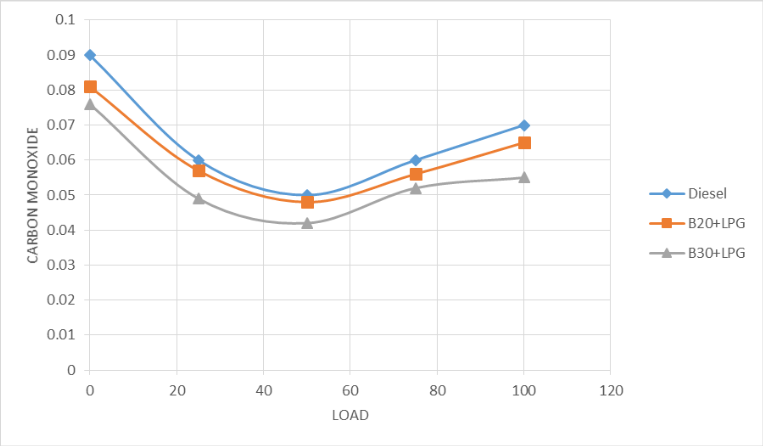

Figure 5: Load Vs Carbon monoxide

2. Load vs. Oxides of Nitrogen

Compared to neat diesel fuel Cottonseed oil biodiesel blends with LPG produce higher NO_x emission. It is due to the high temperature combustion of biodiesel blends compared to diesel. As the load increases the carbon monoxide also increases for the biodiesel blends. The load vs NO_x graph shows the variation of emission under various loading conditions.

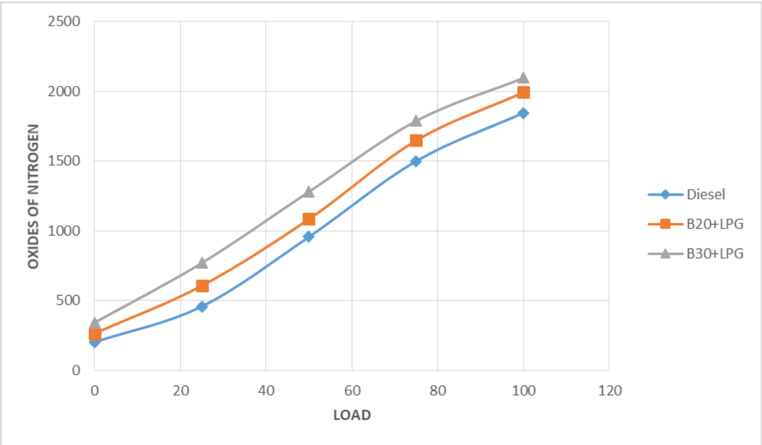

Figure 6: Load Vs Oxides of nitrogen

3. Load vs. Hydrocarbons

Compared to neat diesel fuel Cottonseed oil biodiesel blends with LPG produce lower HC emission. It is due to the high temperature combustion of biodiesel blends which promotes complete combustion when compared to diesel. This in turn reduces unburnt hydrocarbon emissions. The load vs HC graph shows the variation of emission under various loading conditions.

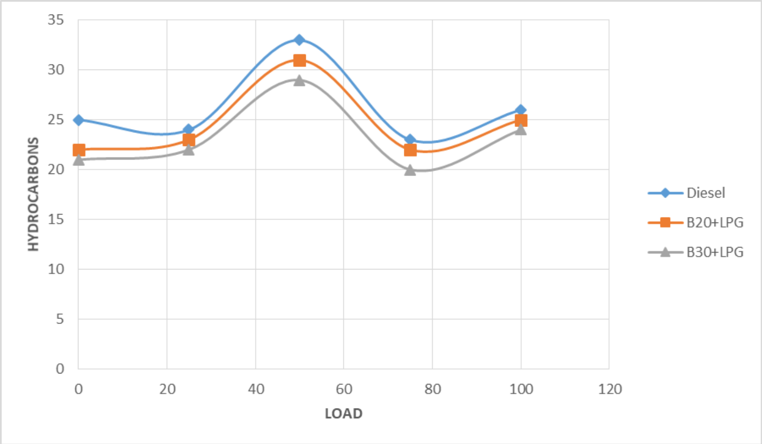

Figure 7: Load Vs Hydrocarbon

Performance characteristics

1. **Brake power vs Brake thermal efficiency**
   Brake thermal efficiency and load are directly proportional to each other. The Brake Thermal Efficiency (BTE) of an engine represents how efficiently the input fuel energy is converted into thermal energy. The BTE is inversely proportional to the specific fuel consumption (SFC) of the fuel. The relationship between BTE and brake power for diesel, B20 blend and B30 fuel blend is shown in figure 8. The overall characteristics of BTE follow a general trend for both diesel and biodiesel blends. It can be seen that, for all the cases, the BTE increases with an increase in the load on the engine. As expected, the BTE of diesel fuel is found to be higher than biodiesel blends at almost all loads. The reason for the decrease in BTE for biodiesel blends when compared to diesel may be the lower calorific value, higher viscosity and higher density of the biodiesels when compared to diesel.

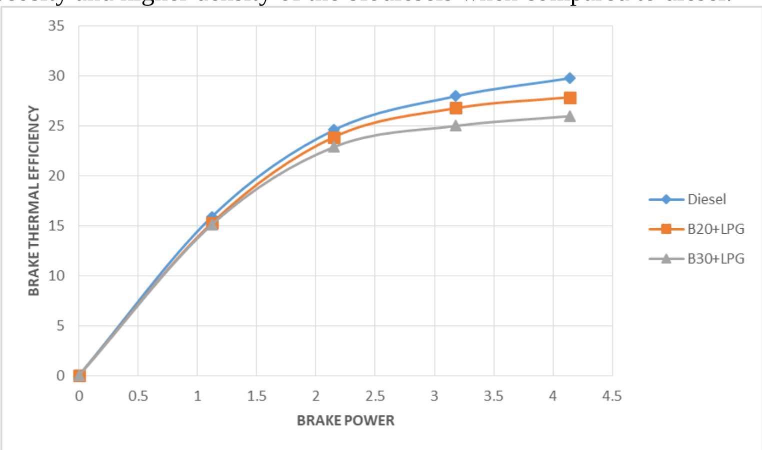

Figure 8: Brake power vs. Brake thermal efficiency

2. **Brake power vs. Specific fuel consumption**
   The SFC of an engine is defined as the ratio of the total fuel consumption to the brake power output of the engine. The various factors like the fuel specific gravity, viscosity, calorific value etc. influences the SFC of a diesel engine. When the biodiesel content present in the fuel blend increases, the calorific value of the blend decreases and so as to maintain the same speed and power output of the engine, the flow rate of the fuel blends increases. Therefore, with increase in biodiesel quantity in the fuel blend, the SFC of the engine increases. However, when the power output of the engine increases, the SFC decreases for all the tested fuel blends.

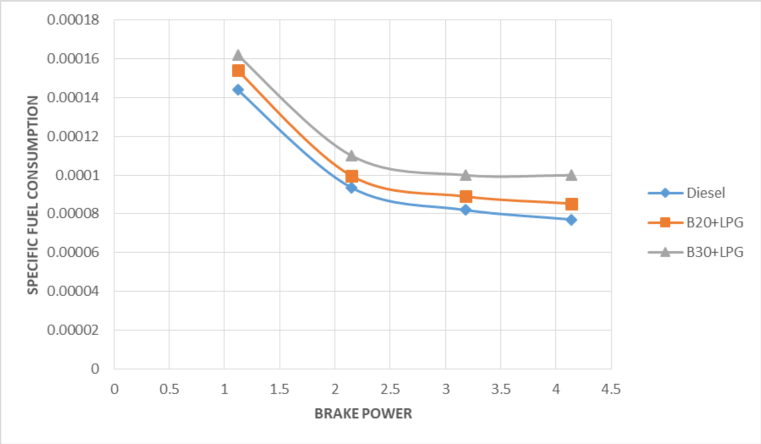

Figure 9: Brakepower vs Specific fuel consumption

3. Brake power vs Mechanical efficiency

Mechanical efficiency measures the effectiveness of a machine in transforming the energy and power that is input to the device into an output force and movement. From the graph below it is clear that the mechanical efficiency of LPG biodiesel blends are comparatively lesser than that of pure diesel. It is due to the fact that less calorific value of biodiesel blends.

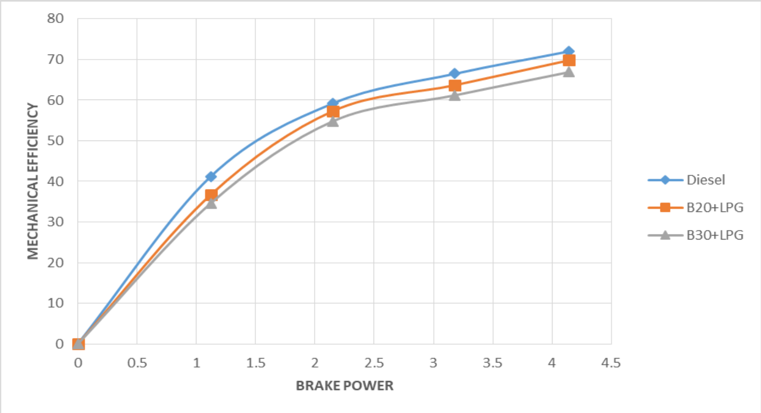

Figure 10: Brakepower vs Mechanical efficiency

V. CONCLUSION

In this work, the effects of blending Cottonseed biodiesel with LPG on the performance and emission characteristics of a direct injection diesel engine were tested. In order to overcome the problems created by the high viscosity and lower heating value of the pure oils, transesterification process was employed. The biodiesels thus obtained were then blended with petro-diesel in the ratio 20% and 30% by volume. The similarities of various properties of Cottonseed biodiesel with diesel show its suitability for use as an alternative fuel. Following are the main conclusions drawn from this work.

- Cottonseed oil biodiesel blends with LPG produced significantly lower carbon monoxide emission compared to diesel fuel and this trend continues with increasing biodiesel composition.
- Oxides of Nitrogen emission increases noticeably in biodiesel blends compared to pure diesel. It is mostly unavoidable due to its properties. NO_x increases with load and with higher blends of biodiesel.
- Unburnt Hydrocarbon emission has a significant reduction with biodiesel blends with LPG as high temperature combustion promotes complete combustion.
- It can be seen that, for all the cases, the BTE increases with an increase in the load on the engine. As expected, the BTE of diesel fuel is found to be higher than biodiesel blends at almost all loads.
- Specific fuel consumption increased with an increase in biodiesel quantity in the fuel blend, which is caused by low calorific value of biodiesel blends
- Mechanical efficiency also follows the same trend which decreases with an increase in load for biodiesel blends when compared to diesel fuel.

In general, Cottonseed biodiesel is found to be a very good alternative to be used in direct injection diesel engines as it has reduced emissions and appreciable performance. It could be blended with diesel, up to 30% by volume, and used in engines, without any major modifications to the existing engine.

VI. REFERENCES

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