An Investigation on the Performance of a Compression Engine when fuelled with Blends of Coconut Oil and Diesel

A Khoodaruth*
Faculty of Engineering
University of Mauritius
Réduit
E-mail: a.khoodaruth@uom.ac.mu

R Leelachand
Faculty of Engineering
University of Mauritius
Réduit
E-mail: ravi.leelachand1@umail.uom.ac.mu

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Abstract

This paper presents the results of an experimental work carried out to evaluate the performance of a diesel engine when fuelled with blends of coconut oil and diesel. This project is in line with the 'Maurice Ile Durable' strategy that was launched by the Mauritian Government with a view to decreasing the country dependency on fossil fuels and encouraging the use of renewable locally available energy sources. The coconut oil is blended in different proportion up to 25% to that of diesel oil. The fuel properties such as density and the gross calorific value of each blend are then determined. The blends are then used to run a two cylinder diesel engine coupled with a dynamometer. The engine performance parameters such as the brake specific fuel consumption, thermal and mechanical efficiencies were then assessed and compared to that of diesel. The exhaust emissions of each blend and of diesel were monitored and compared. It is found that at a 25% blend of coconut oil with diesel, the specific fuel consumption is almost the same compared to that of diesel but the mechanical and thermal efficiencies are slightly greater. Moreover, it is observed that there is a large decrease of greenhouse gas emissions up to 80% when the proportion of coconut oil in the blend is increased compared to that of running the engine only with diesel. It is concluded that up to 25% blend of coconut oil can be used in diesel propelled engines.

Keywords: Biofuel, Coconut oil, Transportation, Greenhouse Gas Emissions.

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1. INTRODUCTION

Today the electricity generation and fuel in many vehicles relies primary on the imported oil and the high importation cost of the diesel fuels is causing a diseconomies of scale for the country. In addition the harmful gases which are exhausted by the millions of vehicles contributed immensely in the global warming for instant the carbon dioxide emission. In many countries there is a potential of the use of renewable energy from sources like the solar, wind, wave, hydroelectric, geothermal or biomass. The substantial increase in the price of the fossil fuels in the past ten years did affect small countries like Seychelles, Agalega, Mauritius and also small under developing countries. So, policy makers opt for alternatives to sustain the economy of these small islands states. From an engineering perspective the optional for a biodiesel would be a valuable alternative.

One renewable energy source which can be tapped is coconut oil. The latter is a potential source of energy for use in compression ignition engines (How *et al.* 2012). Coconut oil can be easily blended with diesel for different uses varied range from fuel in vehicle engines to electricity generation. In fact, the physicochemical properties of coconut oil are comparable to that of diesel (Kalam *et al.* 2003). Moreover, coconut oil is blended with ethanol to form hybrid fuel for use in compression engine without any modifications (Singh *et al.* 2010). Obviously, the use of coconut oil will definitely cut a percentage in the importation cost of diesel and also causes a reduction in the greenhouses gas emissions. Coconut as biofuel can contribute to 80% to 109% in net carbon dioxide emissions relative to diesel (Tan *et al.* 2004). However, the technical considerations for running a compression ignition engine with blended coconut oil should be taken into account and for this reason there are a series of dependent factors that must be taken into account for the proper running of the engine such as the maximum proportion of coconut oil blended with diesel that could be used without affecting the engine performance. Coconut oil is in solid when the ambient temperature is below $20^{o}C$ but in liquid form when the ambient temperature is above $20^{o}C$ (Shaheed & Swain, 1999).

Coconut oil is produced in the island of Agalega which is situated at around 1000 km north of Mauritius. Agalega forms part of the Republic of Mauritius and has a total surface area of 2,600 hectares. Around 20,000 coconut trees are cultivated on 500 hectares of land. Coconuts are harvested. The coconut meat is removed, dried, and is cut into small chips by cutter for greater efficiency of oil extraction. The chips are then pressed mechanically in an expeller to produce coconut oil. The production of coconut oil currently stands at 20,000 L per annum, that is, a yield of 40L of coconut oil per hectare. However, further study should be done to investigate on the low yield of 40 L/ha as the world average yields ranging from 650 to 1400 L/ha. Moreover, the area under coconut oil plantation could be increased by two or three times. This would result in a production of about 200 000L of coconut oil which could be used as fuel for a cleaner transportation sector in Mauritius.

The aim of this paper is to present the results of an experimental work carried out to evaluate the performance of a diesel engine when fuelled with blends of coconut oil and diesel. This project is in line with the 'Maurice Ile Durable' strategy (Mauritius, a sustainable island) that was launched by the Mauritian Government with a view to decreasing the country dependency on fossil fuels and encouraging the use of renewable locally available energy sources.

2. ENERGY MIX IN MAURITIUS

The uses of energy users in Mauritius are characterized by five different sectors namely transport commercial, distributive trade, manufacturing and households. The transport sector is the largest consumer of energy as shown in Fig.1 and consumed of about 50% of the total energy demand in 2012 (SM, 2013). The other two leadings energy users are the manufacturing and the household which have a percentage share of 24% and 14% respectively in 2012. In the transport sector, around 128 thousand tons of gasoline and 314 thousand tons of diesel were imported for use as fuel of cars, heavy motor vehicles, buses, vans and other diesel machine and this represents 458 ktoe of energy in the transport sector.

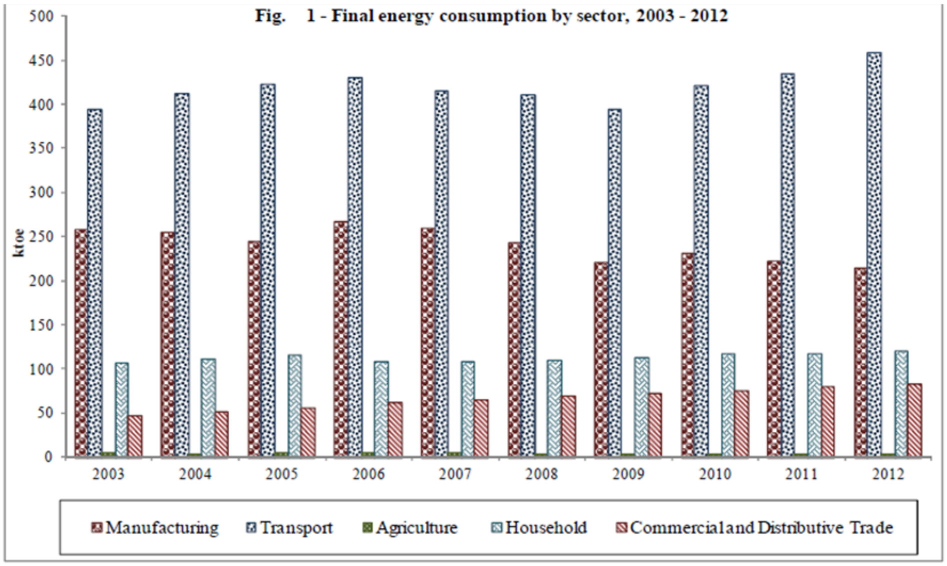

Figure 1: Energy consumption by different sectors in 2012 (SM, 2013)

Statistic show that the transport sector contributes about 25% of carbon dioxide emissions in Mauritius. This figure is comparable to the world average (IEA, 2013). Table 1 shows the trend of percentage carbon emissions for the period 2002 to 2011.

Table1: Percentage of carbon dioxide emissions for the period 2002 to 2013 (SM, 2012)

Sector	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Energy industries (electricity)	50.1	51.0	51.2	53.9	57.1	60.0	58.3	59.4	60.7	60.6
Manufacturing industries	14.6	13.9	13.0	11.6	12.1	11.6	13.1	10.4	9.6	9.2
Transport	28.7	28.5	28.9	27.8	25.2	23.2	23.3	25.1	24.9	25.3
Residential	5.4	5.2	5.5	5.3	4.1	3.8	3.8	3.6	3.7	3.7
Other	1.2	1.3	1.4	1.3	1.5	1.4	1.5	1.5	1.1	1.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

3. METHODOLOGY

Samples of different proportion of coconut oil with diesel were prepared. The blending of coconut oil and diesel (transesterification process) separates the glycerin present in the coconut (Hossain *et al.* 2012). In fact, due to the different densities of glycerin and the blend of coconut oil and diesel, the glycerin will be sinking in the bottom and the blend will be floating on the top which is then collected (Hossain *et al.* 2012a). The transesterification process also help to reduce the viscosity of the blends (Hossain *et al.* 2012b). Table 2 shows the proportion of the mixture.

Table 2: The Proportion of coconut oil

% Composition	Samples(cm^3)
Diesel	0 COCO + 2000 Diesel
5% COCO	100 COCO + 1900 Diesel
10% COCO	200 COCO + 1800 Diesel
15% COCO	300 COCO + 1700 Diesel
20% COCO	400 COCO + 1600 Diesel
25% COCO	500 COCO + 1500 Diesel
100% COCO	2000 COCO + 0 Diesel

The density of the blend of coconut oil with diesel was determined. A 200cm^3 of the fuel blend according to the proportion mentioned in Table 2 is weighed. The mass of the fuel is obtained and the density is thus calculated.

The calorific value of a fuel is determined by using the oxygen bomb calorimeter. The bomb calorimeter is a device, which is used to determine the heat, which is liberated due to combustion by igniting a sample in a high pressurize oxygen sealed vessel and the temperature rise is used to calculate the calorific value.

The performance of the engine was conducted on the test bed consisted of a 2 cylinder 'Petter' diesel engine (Type AV2) coupled with a 'Trou de Type DPX' hydraulic dynamometer. The test was carried out at different load for each particular sample and different parameters are recorded, for instant the fuel consumption in volume, the time taken, the brake load, the engine speed, the temperature of water in and out and the exhaust gas temperature. In this context the engine performance could be evaluated in finding the fuel consumption rate, brake power, torque, brake specific fuel consumption, thermal efficiency, frictional power and the mechanical efficiency.

The technical data of the Petter Diesel Engine are given in the Table 3.

Table 3: Engine Technical Data

Description	**Specification**
Number of cylinders	2
Bore	80mm
Stroke	110mm
Cubic capacity (Swept volume)	1106cc
Compression Ratio	16.5:1
Rated power and speed	1000-1800 rpm
Compression pressure	37.6 kg/cm²
Maximum firing pressure	73.8kg/cm²
Fuel Injection Release	176kg/cm²

The Petter engine is coupled to the DPX hydraulic dynamometer of non reversible type and this Froude hydraulic dynamometer uses the principle of the oppositional force of water in the system to assess torque and power of the engine. The engine is coupled to the main shaft of the hydraulic dynamometer and was fixed by the bearing which is found in the casing. The water gets distributed through the rotor which is driven by the main shaft of the engine. The lever arm which is connected to the weighing balance should be adjusted in order to nullify the oppositional force subjected on the casing. The number of turns is achieved in using the hand wheel so that the oppositional force on the hydraulic dynamometer is varied.

When the engine is being run with diesel, air is introduced into the fuel distribution system and this must be bled out. The easiest way was to remove air manually to pump the fuel from the tank to the engine and air is vented out at all the available points along the fuel system. The process is started at the point where is air leaked in that is the filter and moved towards the inflow of the engine. The bleed screw is loosened and the fuel is allowed to flow until a continuous steady flow of the fuel is observed. Now while the fuel is still in flow the line is connected to the point and screwed. The inflow valve of the consumption cylinder is opened and the fuel is allowed to enter and bubble of air is observed to rise up till it disappeared. At this point the fuel is safe from air circulation in the system.

On the other hand the lubrication oil level was checked before running the engine at regular time interval. The oil level was monitored and make sure that it does not rise to make sure that no coconut oil is entering the sump due to incomplete combustion.

Before the fuel content is change in the fuel tank, the filter of grid 15 micron removed and cleaned to remove the remaining particles and dirt presence in the previous fuel used.

The coolant fluid that is water is allowed to enter the system each time through an external water pumping system to counteract the problem of overheating due to vibration of the mechanical parts of the system.

As coconut oil has up to 10 - 30 times higher viscosity than the normal diesel at the same temperature (room temperature), the engine is modified with a fuel heater (a pre – heating tank). It consisted of an electric heater of specification 240 volt and 400 watts, this fuel tank heats the blended fuel up to 70^0C before it entered the engine for injection so that the resulting viscosity can be approximated to that of diesel.

The engine performance such as brake load, speed, brake power and torque are monitored and benchmarked with different proportion of blend of coconut oil to that of diesel. During the test, the load was varied by turning the hand wheel which is coupled to the hydraulic dynamometer and the brake load is recorded at the weighing balance. The speed of the engine was recorded via the infrared tachometer which is placed at the running disc at the end of the shaft. The following parameters could be determined with the help of the dynamometer:

- The fuel consumption. A fuel tank of the engine was connected to aTE13 Type plint fuel consumption gauge which consisted of a graduated cylinder glass tube with graduated mark through which the spacer represents the corresponding volume of fuel present. The cylinder glass is filled by the action of gravity from the fuel tank and these are monitored through the regulator valves, which are found at the fuel tank, the inflow of the cylinder glass, the outflow of the fuel. When doing the experiment a stopwatch is used to time the exact amount of 50 cm^3 of fuel being consumed within a span of time. The volumetric flow rate and the mass flow rate can be used to demonstrate the rate at which fuel is being consumed.
- The brake specific fuel consumption.
- Thermal efficiency. It is a measure of the completeness of combustion of fuel. The thermal efficiency is dependent on the brake power, the calorific value and fuel consumption rate of the fuel.
- The mechanical efficiency. The latter is the measured performance to the ideal performance of the engine. In this case the measured performance is the brake power while the ideal performance is the output power that is the summation of the frictional power and the brake power.
- The mean linear assessment of the fuel consumption rate and the brake power is known as the William's line. A graph is plotted. The frictional losses can be deduced from such graphical representation that is an extrapolation of the William's line to the negative brake power axis and at the point of intersection the value obtained on the brake power axis is the frictional power.
- The exhaust gases of the dynamometer were measured with the help of an electronic gas analyser. The gas emitted through the exhaust is tested in percentage of composition of the gas mainly carbon monoxide and

carbon dioxide. The Kane electronic gas analyzer was used in order to record the percentage composition of the gas. The probe was connected to the outside exhaust and after sometimes the Kane apparatus analyses the percentage composition of the exhaust gases and the results was printed by a laser infrared printer. The reading was taken initially when there were no load and at sixth number of turns of the hand wheel. Now the relative exhaust emission was calculated in order to reference the blending with that of diesel. The gases which were recorded with the Kane gas analyzer were the percentage carbon dioxide and the percentage carbon monoxide.

The relative exhaust emission percentage was calculated using Eq.1 [2].

$$R\alpha = \left(\frac{AE\beta}{AEd} - 1\right) X\ 100\% \quad (1)$$

Rα : Relative gas emission in %

AEβ: Mean gas emission from the blended fuel in %

AEd: Mean gas emission from diesel in %

The response surface methodology is also used to assess the performance of the engine with different blends of coconut oil. I is a statistical technique to generate an experimental design to find an approximate model between the input and output parameters and for the optimisation of process responses. It is a collection of statistical and mathematical methods that are useful for the modelling and analysing engineering problems. In this technique, the main objective is to optimise the response surface, which is influenced by various process parameters. The response surface Y can be expressed by a second order polynomial (regression) equation as shown in Eq 2.

$$Y = b_o + \sum b_i x_i + \sum b_{ii} x_i^2 + \sum b_{ij} x_i\, x_j. \quad (2)$$

The design procedure of response surface methodology is as follows:

- Selection of the process parameters.
- Selection of the upper and lower limit of the process parameters.
- Selection of the output response.
- Developing the experimental design matrix.
- Conducting the experiments as per the design matrix.
- Recording the output response.

- Developing a mathematical model to relate the process parameters with the output response.

Furthermore, the brake power and fuel type have been identified in previous work as being key parameters with regards to the mechanical and thermal efficiency as well as the Bsfc. For each parameter five levels were selected, evenly distributed in the design space. Break power has been treated as analytical parameter with five levels between 1-4 kW. This means the optimum break power could be any value between 1 to 4 kW. The fuel type has been treated as categorical parameters with fixed four levels which are Diesel, 5% Coco, 15 % Coco and 25% Coco. This means the optimum fuel has to be one of these four types. The process parameters and their levels are provided in Table 4. A user-defined central composite rotatable response surface design was used to design the experimental matrix. The output responses in this investigation were mechanical efficiency, thermal efficiency and brake specific fuel consumption(Bsfc).

Table 4: SLM process parameters and their levels

Parameter	Units	Levels			
		1	2	3	4
Break Power	(kW)	0	1	2	3
Fuel Type	-	Diesel	5% Coco	15% Coco	25% Coco

4. RESULTS

The density of fuel is an important factor which characterized the proper running of the engine and also assesses its performance. It is found that an increase in the percentage volume of coconut oil, there is an increase in the net density of the blended coconut oil and diesel as shown in Table 5. For instant the density of the diesel and coconut oil was found to be 820 kg/m³ and 919 kg/m³ respectively. The density for that of the blended 25% of coconut oil is 845 kg/m³ and is around 3 % greater than that of diesel. In fact, it can be deduced that for every percent increase of coconut oil in the blend. The percentage increase in the coconut oil content, which normally favor this increase in density.

Table 5: Density of the sample

% composition of fuel Coco-Diesel	Volume of fuel (10^{-6} m³)	Mass of fuel (kg)	Density of fuel, ρ_f (kg/m³)	Ratio of density of blend/diesel
100% Diesel	200	0.1640	820	1
5% coco	200	0.1650	825	1.006
10% coco	200	0.1660	830	1.012
15% coco	200	0.1670	835	1.018
20% coco	200	0.1680	840	1.024
25% coco	200	0.1690	845	1.030
100% coco	200	0.1838	919	1.121

The calorific values of the blends were measured by using the bomb calorimeter. The results are tabulated in Table 6. The calorific value of diesel and coconut oil was found to be 45.44 MJ/kg and 37.54 MJ/kg respectively. The calorific value for the blended 25% coconut oil is compressed to 43.44 MJ/kg due to the increasing percentage of the coconut oil that inhibits the property. This is because the combustion of diesel is more exothermic than coconut oil that is more energy is liberated during the combustion compared to that of coconut oil. An increase in the percentage of coconut oil caused a slight decrease in the calorific value of the blends fuel. For each 1% increase of coconut oil, there is a 0.078 MJ/kg decrease in the calorific value of the fuel.

Table 6: Calorific Value of the blends

Composition	Calorific Value (MJ/Kg)
100% Diesel	45.44
5% COCO	44.98
10% COCO	44.58
15% COCO	44.19
20% COCO	43.82
25% COCO	43.44
100% COCO	37.54

Initially the experiment was conducted with diesel and then with the blends of coconut oil. However, for the blends of coconut oil, a heater was used to preheat the blends before entering the engine. The following were found:

(i) Diesel

It was observed that an increase in the brake load caused a gradual decrease in the engine speed. But on the other hand an increase in the brake power and torque of the engine respectively was noted. At the maximum load of 11.2 kg and minimum engine speed of 1138 rpm, the maximum brake power of 4.2259 kW and the maximum torque of 35.461 Nm were found. For each 1 kg increase in the load, there is a decrease of 30.82 rpm in the speed and these are clearly deduced from Fig 2a.

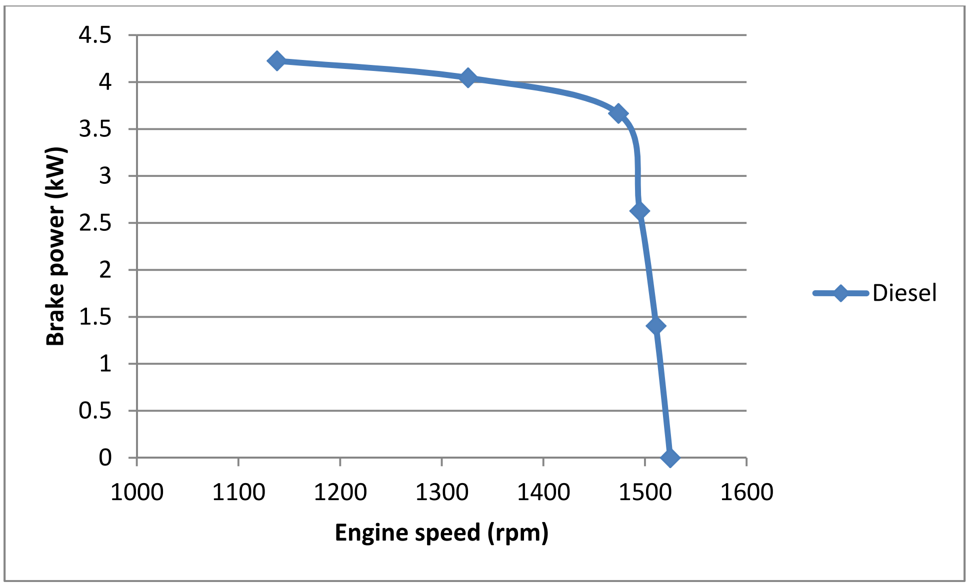

Figure 2a: Brake power against engine speed with diesel

(ii) 5% COCO

The heater was used and the blended fuel was heated to 70^{0}C before starting the engine. Here also an increase in the brake load caused a slight decrease in the engine speed. The torque and brake power however increased. At the minimum speed of 1504 rpm and maximum brake load of 8 kg, a maximum brake power of 3.9893 kW and a maximum torque of 25.329 Nm were recovered (Fig. 2b). These are lower compared to the experiment conducted with diesel only. For each increase in 1 kg of the brake load, there is a decrease 0f 2.168 rpm of the engine speed.

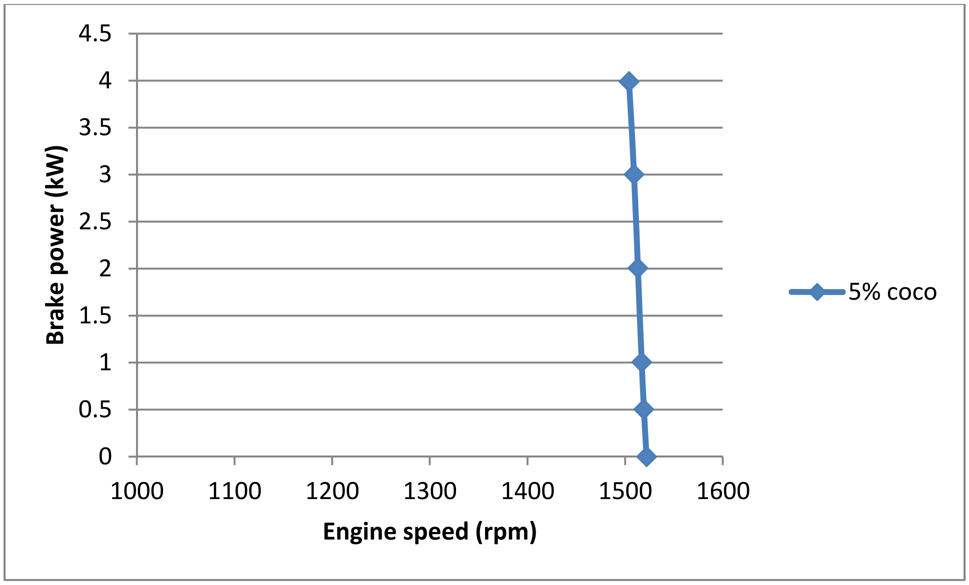

Figure 2b: Brake power against engine speed with 5% coco

(iii) 15% COCO

As the brake load was increased; a corresponding decrease in the speed of the engine was noted. The brake power and torque of the engine also increased with the increase in brake load. When the engine speed was at a minimum of 1508 rpm and maximum brake load of 7.5 kg, the brake power and torque was increased to a maximum of 3.7499 kW and 23.746 Nm respectively (Fig 2c). These are slightly lower compared to that of 5% COCO. For each increase in 1kg of the brake load, there was a decrease 1.586 rpm of the engine speed.

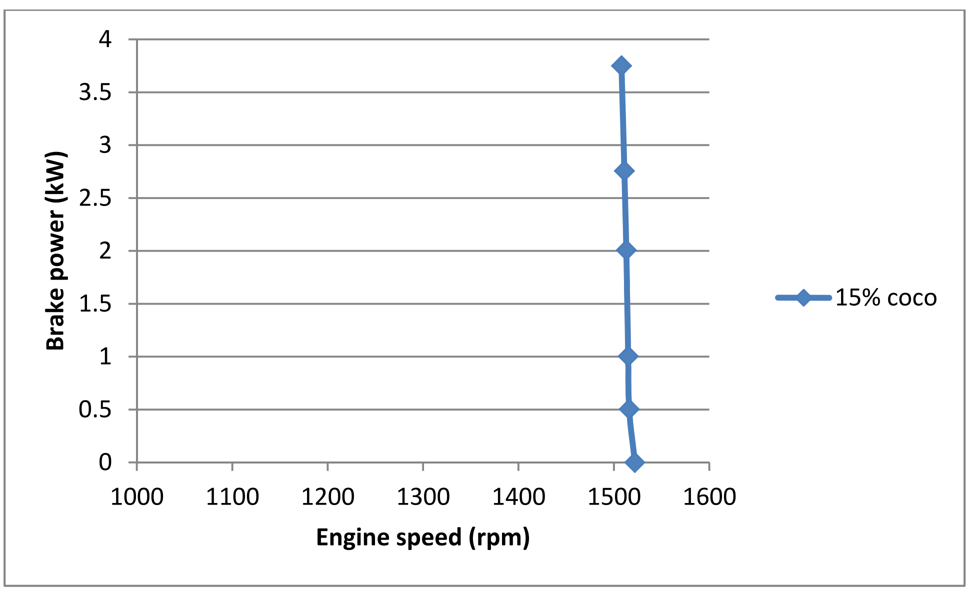

Figure 2c: Brake power against engine speed with 15% coco

(iv) 25% COCO

At the minimum engine speed of 1365 rpm and maximum brake load of 10 kg, the maximum brake power of 4.5257 kW and maximum torque of 31.661 Nm was obtained (Fig 2d). Comparing the two previous blends, this show clearly that the 25% COCO blends operate at the maximum brake power and maximum torque at the maximum brake load and minimum speed of the engine respectively. But the brake load and torque of the operating diesel fuel is 1.12 times greater than that of the blended 25% COCO. For each 1 kg increase in the brake load there was a gradual decrease of 14.708 rpm in the engine speed.

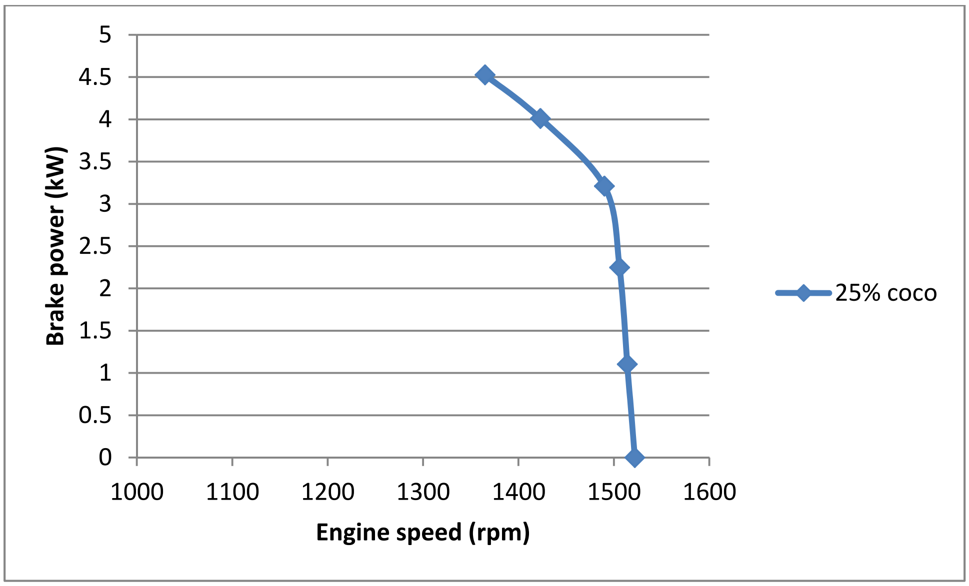

Figure 2d: Brake power against engine speed with 25% coco

It can therefore be deduced that a decrease in the engine speed and increase in the brake load, causes an increase in the brake power. But the brake power and engine speed does not vary linearly.

As the engine speed tends to the maximum engine speed rated, the brake power was found to decrease to zero. The brake power of diesel fuel varied almost constant throughout a large range of variable engine speed. For the 25 % COCO, at the minimum engine speed of 1365 rpm, the maximum brake power of 4.5257 kW was noted as compared to the other blended fuels and also diesel. The diesel and 25 % COCO fuel is exhibiting the same pattern in this context that is for a greater increase or decrease in the engine speed, the brake power fluctuates over a small range at a certain range of engine speed. In the blended 5% COCO and 15% COCO, there is a higher increase in the brake power for a small negative variation in the engine speed. It can be clearly noted from the graph that all fuel blends curve is concentrated about the maximum engine speed when the brake power is zero.

Moreover, the Bsfc remained in the range of 0 to 0.590 kg/kWh when the engine speed operates at a limit of maximum 1500 rpm and when it increased beyond 1500 rpm, the Bsfc increases to a maximum of 1.647 kg/kWh for the 15% COCO at an engine speed of 1516 rpm. At that point a small change in the engine speed causes a sudden increase in the Bsfc. The Bsfc of diesel is much lower compared to the fuel blends and this is because in the blended fuel there contained a percentage of coconut oil which has to be more injected in the combustion chamber for a greater amount of energy to be liberated. In addition this proved due to the lower calorific value of coconut oil which is 37.54 MJ/kg. Fig. 3 shows the fluctuation of the Bsfc with the engine speed.

The minimum brake power of diesel was 1.4027 kW and the corresponding Bsfc was 27.4 MJ/kWh and Bsfc which was 0.603 kg/kWh is lower compared to that of the minimum brake power of the blended fuels. For the blended 25% COCO the minimum brake power of 1.1043 kW contributes to a Bsfc of 33.1 MJ/kWh and Bsfc of 0.763 kg/kWh which is lowered compare to the blended 5% COCO and 15% COCO but greater than diesel. So, at the minimum brake power of the fuels, the corresponding Bsfc is greater. Fig. 3 shows the relationship of the Bsfc with brake power.

Thus, when the brake power increases, the Bsfc tends to the range of 0.4 – 0.6 kg/kWh. As noted in the graph some points of the diesel and blended 15% COCO are common or more or less the same and this show clearly that the Bsfc at some point of the brake power is the same. The amount of fuel consumed at same points of specific brake power would be more or less the same amount. For instant at a brake power of 4.0447 kW for diesel favored an Bsfc of 0.454 kg/kWh and that for the 25% COCO are 4.0103 kW and 0.468 kg/kWh which is approximately in the same range. At the maximum brake power of each fuels, the Bsfc was calculated to be 0.512 kg/kWh for the diesel, 0.538 kg/kWh for the blended 5% COCO, 0.590 kg/kWh for the blended 15% COCO and 0.505

kg/kWh for the blended 25% COCO. The increased in the brake power causes the Bsfc to vary within a small range that is for each 1 kWh a specific amount of fuel is consumed within the range of 0.505 – 0.590 kg at the maximum brake power of each fuel.

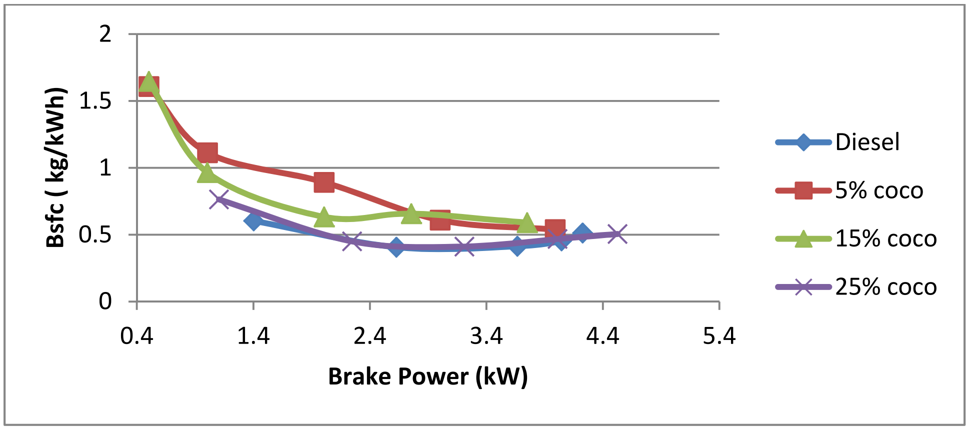

Figure 3: Bsfc against brake power for different percentage of coconut oil

The greatest thermal efficiency of 20.1% was obtained at the brake power 3.2111 kW and fuel consumption rate of 0.367×10^{-3} kg/s with the blended 25% COCO. Fig. 4 shows the variation of the thermal efficiency with the brake power of the different fuels. Brake power and fuel type both have significant influence upon the mechanical efficiency, Bsfc and thermal efficiency.

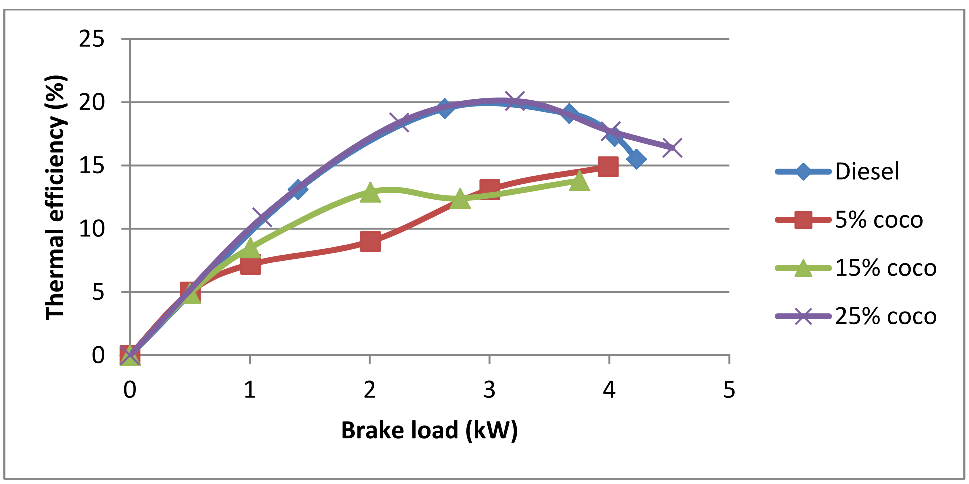

Figure 4: Thermal efficiency against brake power at different percentage of fuels

It shows that diesel and blended 25 % COCO exhibits a similar pattern and the maximum thermal efficiency for the diesel was 19.5% at 2.6271 kW of the brake power. The thermal efficiency is dependent on the calorific value of the fuel and it also characterized the injection of fuel in the combustion chamber. Beyond 2.621 kW the thermal efficiency of Diesel and the blended 25% COCO is found to decrease to 15.5% and 16.4% respectively at a maximum brake power of 4.2259 kW and 4.5257 kW respectively. For the blended 5% and 15% COCO, the maximum thermal efficiency of 14.9% and 13.8% were obtained at the maximum brake power of 3.9893 kW and 3.7499 kW respectively.

Concerning the frictional power, a graph generated as shown in Fig.5 was quoted as line of best fit and the at the maximum brake power the graph should be normally turned up slightly as it can be clearly seen from the graph. But to obtain the frictional power a line of best fit was opted. The frictional power for the diesel fuel was 1.68 kW, blended 5% COCO was 1.94 kW, and blended 15% COCO was 1.56kW and that for the blended 25% COCO was 1.6 kW. The minimum fuel consumption that is required to counteract frictional power is within the range of 0.1 – 0.3 10^{-6} m^3/s when the brake power is zero.

The gradient of the William's line indicates the fuel consumption of the fuels per kW of the brake power. For instant to produce 1 kW of brake power there is a need of 0.106 x 10^{-6} m^3/s of fuel rate for diesel, and for the blended 5% , 15% and 25% there are a need of 0.127, 0.134, and 0.107 x 10^{-6} m^3/s of fuel rate to produce the 1kW of brake power. It can be clearly deduced that for the blended 25% COCO the fuel consumption for the production of 1 kW is less compared to that of the two other blended fuels but is slightly greater by 0.001 x 10^{-6} m^3/s compared to diesel. The increasing percentage of coconut oil have an effect on the fuel consumption as explained above and these are due to the losses that occur during the experiment for instant the frictional power. The graphs below show the William's line for the different blends of coconut oil.

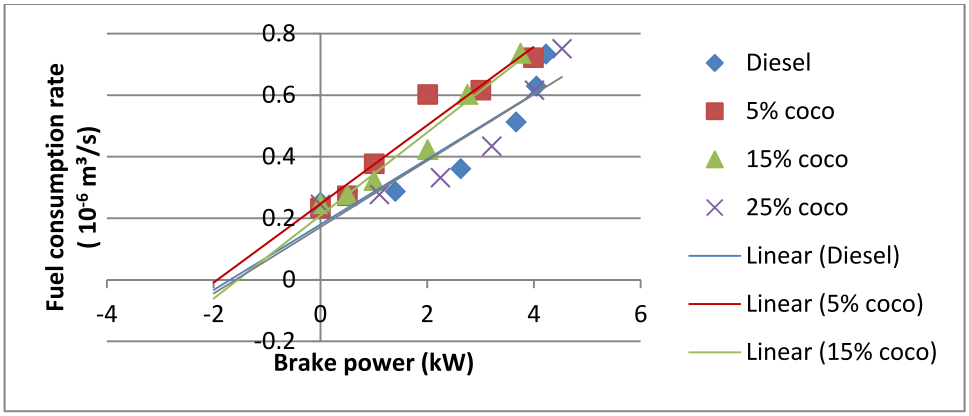

Figure 5: William's line

The mechanical efficiency is found to increase with an increasing brake power. For instant, the maximum mechanical efficiency was obtained at the maximum brake power. Fig. 6 shows the variation of mechanical efficiency with different fuels at different brake power.

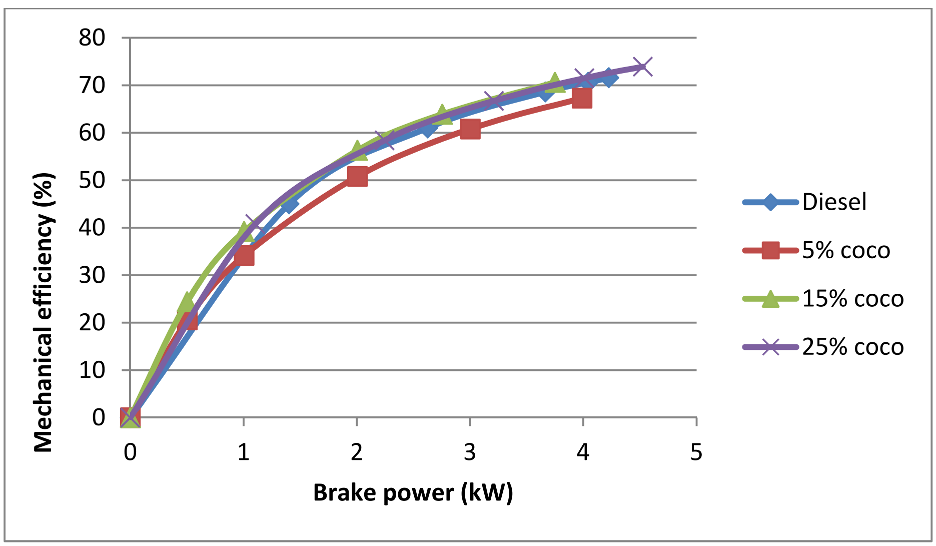

Figure 6: Mechanical efficiency against brake power of different percentage of fuels

For diesel the maximum mechanical efficiency of 71.6% was obtained at the maximum brake power of 4.2259 kW. Those of the blended 15% and 25% COCO were 70.6% and 74.0% at the maximum brake power of 3.7499 kW and 4.5257kW respectively. These were close to the maximum mechanical efficiency of the diesel fuel. These are characterized by the frictional power which adheres to the energy output of the system. The blended 5% COCO exhibit a maximum mechanical efficiency of 67.3% at the maximum brake power of 3.9893 kW and this is because the frictional power for this part is 1.94 kW which is greater compared to the other fuels. The maximum mechanical efficiency of the blended 25% COCO was greater by 2.3% because of the greater maximum brake power compared to diesel. There is a difference of 0.2998 kW in the brake power and this contributes to the higher mechanical efficiency of the blended 25% COCO. The increase in the percentage of coconut oil to the fuel is varying the brake power, total energy output and the mechanical efficiency of the system and it is observed that the curves of the different converges about the maximum mechanical efficiency of 74.0% with the increasing brake power of the system.

Finally, the exhaust gas emissions of the tail pipe of the compression engine under study were monitored. These were measured by its percentage volume and it can be deduced that a shift from no load to load of the engine, there is a fluctuations in the percentage volume of carbon monoxide and carbon dioxide as noted in Fig. 7. An increase in the percentage of coconut oil in the fuel causes a decrease in both % volume of carbon monoxide and carbon dioxide. The percentage decrease in volume of the gases is assessed in reference to the base fuel that is diesel. This is known as the relative exhaust emission in percentage. Fig. 6 shows the variation of the gases with the increase in the percentage of coconut oil to the fuel.

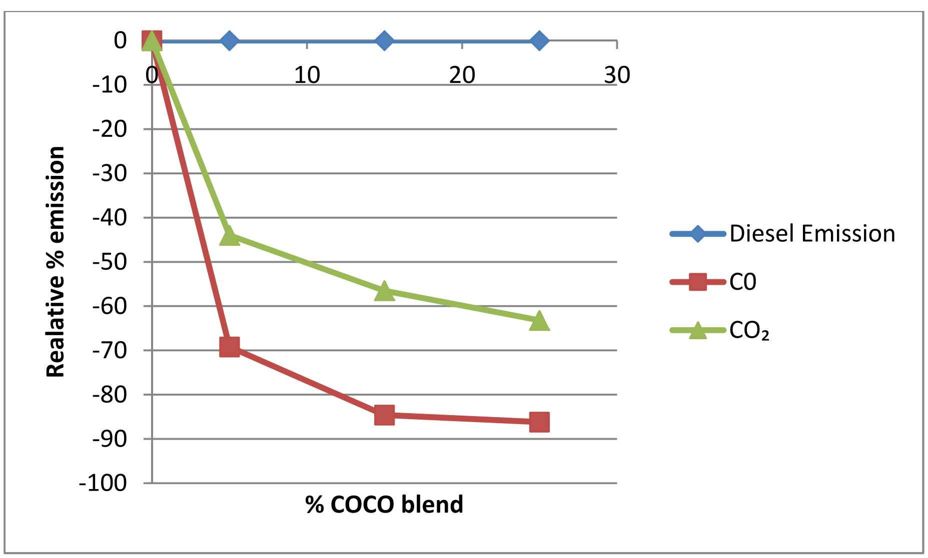

Figure 7: Relative gas Emission

In using the blended 5% COCO, there is a decrease of 69.2% in the emission of carbon monoxide as compared to diesel. The carbon dioxide also decreases by 44% when using the 5% blends. On the other hand the use of 15% carbon monoxide favored a decrease of 84.6% and 56% of carbon monoxide and carbon dioxide respectively referenced to the base fuel. A further decrease in the relative exhaust emission is observed with the blended 25% COCO with a percentage decrease of 86.2% and 63.2% of carbon monoxide and carbon dioxide respectively. The graph is observed to decrease in steepness and tends to stabilize for further increase in the percentage of coconut oil in the fuel. This normally shows the optimal composition of blended 25% COCO for a better exhaust emission. The reason why there is much decrease in carbon monoxide is that the oxygen which is available reacts to the unstable carbon monoxide to form carbon dioxide.

5. CONCLUSION

The project was an investigation of the performance of a compression engine with fuel blends of coconut oil and diesel. The Petter Engine found in thermodynamics lab was used to carry out the experiment. The different variables like the engine speed, torque, brake power, mechanical efficiency, fuel consumption rate, thermal efficiency and the relative exhaust emission were studied along with the properties of the fuels and these were represented on graphical model so that the different parameters can be analyzed.

A fuel tank was used to heat the blended fuels and then injected in the engine combustion chamber. The densities of the blended mixture were found to increase linearly from 100% diesel with density of 820 kg/m^3 to 100% coconut oil with density of 919 kg/m^3. On the other hand the calorific values were found to decrease with the increasing percentage of coconut oil to the fuel from 100% diesel with calorific value of 45.44 MJ/kg to the 100% coconut oil of calorific value of 37.54 MJ/kg. An increase in the brake load causes a decrease in the engine speed in all the cases but the steepness varied according to the type of blended fuels used and this was demonstrated by the gradient of the line of best fit drawn. At maximum brake power, the fuel consumption per second was found to be slightly greater in the blended fuels compared to diesel fuel. There was an exception for that of the blended 5% COCO due to a disturbance in the system, for instant turbulence of flow could have occurred in the fuel line, and this is slightly lesser than that of diesel. The Bsfc of the 25% COCO was 0.505 kg/kWh and that for diesel was 0.512 kg/kWh which was approximately the same at the maximum brake power. The mechanical efficiency of an individual fuels were found to increase with an increasing brake power. The mechanical efficiency of diesel at maximum brake power were found to be 71.6% and for the blended 25% COCO were found to be 74.0 % which is higher than that of diesel. The mechanical efficiency is dependent on the frictional power of the system and the presence of a greater percentage of coconut oil acts as a lubricant to the mechanical part for instant the piston ring, the camshaft and other inter connected part of the system which in turns decreased the frictional or power loss encountered with 100% diesel or small percentage of coconut oil. In this context the frictional power reduced to an amount which increases the mechanical efficiency along with the maximum brake power. The maximum thermal efficiency of 20.1% were noted at the brake power 3.2111 kW and calorific value of 43.44 MJ/kg of the blended 25% COCO. This value was close to the maximum thermal efficiency of 19.5% at the brake power of 2.6271 kW of the diesel fuel.

The emission of the percentage by volume of the carbon dioxide and carbon monoxide were found to decrease with an increasing percentage of coconut oil in the fuel. This was evaluated through the relative exhaust emission in referenced to the diesel base fuel. For instant, the decrease of 86.2% of carbon monoxide and 63.2% of carbon dioxide for the blended 25% fuel show clearly the evidence of the benefits of using coconut oil as blended fuels to the environment. A greater percentage of decrease was observed in the carbon monoxide exhausted due to the reaction with the oxygen generated after combustion which produced carbon dioxide in return.

At some points of the investigation some similarity were found with the blended 25% COCO and diesel for instant the mechanical efficiency, the thermal efficiency and the brake efficiency fuel consumption and the most important thing is that since most of the diesel imported are used in the transport sector and using the blended fuel would definitely decrease the importation cost and also decrease the percentage emission of carbon dioxide and carbon monoxide which will be highly beneficial to the environment.

6. FUTURE WORKS

The temperature of the pre-heated coconut oil should be maintained throughout the engine and this is achieved by using the coolant fluid which is the radiator water which normally operates at 70^0C to 80^0C once the engine attain the operating temperature and condition. In this context, a suitable heat exchanger is used so that the viscosity of the coconut oil is maintained to that of the diesel. The easiest way is to wound a length of copper pipe adjacent to the outlet pipe, somewhere along the manifold, where the hot water passes. The amount of heat transfer will then depends on the size and length of the two pipes. In this way the viscosity and the flow rate of the fluid could be well maintained for the proper running of the engine. In some cases of Cars and Lorries, a cabin heating unit can be used where the hot water passes in the cabin which consists of a metal coil tube preferably copper through which the fuel is passed and then carried away to the engine where combustion occurred.

The design of a switch which allows the diesel starts and stops of the engine and then shifted to the blended fuel after the engine reaches the operating temperature and condition. The use of different actuators is recommended in the implementation of the switch in order to actuate the opening and closing of valves when the switch button is pressed. When the car is started, the switch button should activate the diesel tank outlet through the valve and the after sometimes the switch is shifted to the blended fuel where the diesel tank outlet valve is closed and the blended fuel tank valve is opened. And for the stop of the car engine the switch should be reverted to the diesel fuel tank.

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