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EXPERIMENTAL INVESTIGATION ON BIODIESEL FUELED COMPRESSION IGNITION ENGINE

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ABSTRACT

A single-cylinder four-stroke water-cooled constant speed diesel engine that could develop a power output of 5.6 kW at 1500 rpm was selected for this experiment. Biodiesel blend was prepared from the mixture of Neem oil and Jatropha curcas oil. Neem oil cost is higher than Jatropha curcas oil. If Neem oil alone used as biodiesel the cost is more. But the jatropha curcas oil price is less compared with Neem oil. If the mixture of both oils can increase bio-fuel quantity and can reduce the cost of fuel as effectively. Before going to conduct the testing process in the engine using Neem and jatropha oil mixture, the properties of biodiesel of the mixture must be calculated. There is no modification required in the engine because the design is similar to the working condition of mineral diesel. Various blend properties were analyzed using Neem and jatropha ester blend in different ratios. That different ratio blends were produced by adding pure biofuel (B100) with mineral diesel in various ratios. **D80B20, D70B30** and **D60B40.** These type of blends was made by mixing with base diesel and experiment will be conducted using these blends and best blend will be found out among these blends.

Key Words: Neem Oil, Jatropha Oil, Bio Diesel, Fossil Fuel, Esterification

1. INTRODUCTION

In this world, renewable energy and non-renewable energy are there. Fossil fuel and coal are non-renewable energy. But the availability of fossil fuel is reducing demand around the world is increasing rapidly as a result of ongoing trends in modernization and industrialization. Most of the developing countries import fossil fuels for meeting their energy demand. The environment also is affected due to the combustion of fossil fuels. In the current situation, the main considerations are the decrease in fossil fuels and environmental pollution. By these considerations, IC engines are affected. So hereafter a few years some demand will generate for fossil fuel. Therefore it is necessary to develop low-emission alternative fuels for diesel engines. So there is a need to move to the renewable energy source. Biodiesel is one of the renewable energy sources. But it cannot use biodiesel directly in the 4 stroke diesel engine. Biodiesel can be derived from vegetable oils and fats. Biodiesel has a higher flash point temperature, higher cetane number, and lower sulphur content and lower aromatics than petroleum diesel fuel. It could also be expected to reduce exhaust emissions due to fuel containing oxygen. The low flash point and high sulphur content of diesel can be improved by blending it with biodiesel. This paper is about to make a biofuel blend from two oil mixtures. This report contains what are the reasons behind that choosing Neem and Jatropha curcas oil and the purpose of mixing these two oils. This report also gives detailed about how the biodiesel blend prepared and how to check its properties.

2. EXPERIMENTAL SETUP

2.1. ENGINE SELECTION

The main objective of this report is to measure the engine performance by conducting the testing process in IC engine using biodiesel blends instead of mineral diesel and reducing the emissions. So the engine plays a pivotal role in this project, Based on the literature survey the engine selected for the testing was a single-cylinder four-stroke variable compression ratio water-cooled constant speed diesel engine that could develop a power output of 5.6 kW at 1500 rpm.

2.2. ENGINE INSTRUMENTATION

2.2.1. Load and Speed Measurement

The test engine was directly coupled with an eddy current dynamometer with suitable switching and control facility for loading the engine. The length torque arm of the dynamometer was 0.11m. The output measurements were made from a microprocessor-based load cell. The engine was set to run at a constant speed of 1500rpm. The load of the engine was obtained from load cell reading. The speed of the engine was monitored using a photosensor along with a digital speed indicator.

2.2.2. Fuel Flow Measurement

The fuel flow rate was measured on a volume basis using a burette and stopwatch. The fuel from the tank is sent to the engine through a graduated burette using a two-way valve. When the valve is set at position 1 the fuel is sent to the engine directly and in position 2 the fuel contained in the burette is sent to the engine. For the measurement of the fuel flow rate of the engine, the valve is set at position 2 and the time for a definite quantity of the fuel flow is noted. This gives the fuel flow rate for the engine. Commercially available high-speed diesel, ethanol and vegetable oil and its methyl ester were used as fuel.

2.2.3.Air Flow Rate Measurement

The inlet manifold of the engine is connected to the surge tank to avoid pressure fluctuation at the inlet. A calibrated orifice meter is attached to the tank which is directed to the atmosphere. This is done with due care that there is no air leakage. During the engine operation, the air to the engine from the atmosphere is through the orifice meter. The orifice meter is connected with a manometer, which measures pressure depression in the manometer. From the calculation, the velocity of the air and the intake of a definite quantity of air supplied to the engine are measured.

2.2.4. Temperature Measurement

The temperature of the cooling inlet, outlet and exhaust gas was measured using Chromel Alummel (K-Type) thermocouples. A digital indicator with an automatic room temperature compensation facility was used and it was calibrated periodically.

2.3. Emission Measurement

exhaust emissions namely CO, CO_2, HC and NO_2 measured with the help of an AVL DIGAS 444 LIGHT exhaust gas analyzer. The oxides of nitrogen (NO_2) were measured using an electro chemical sensor. The carbon monoxide and carbon dioxide emission were measured using Non-Dispersive Infra-Red (NDIR) analyzer and unburned hydrocarbons (UBHC) was measured by Flame Ionization Detector which is a well established and accepted method for measuring unburned hydrocarbons.

2.4. MIXTURE OF OILS SELECTION

According to the literature survey, now a day's all authors produce biodiesel from oil and focused on only one type of oil if doing like this the availability of source gets down and the cost of oil will increase. It can be overcome this problem using two oils mixture while the production of biodiesel. So two oils were selected to make an oil mixture of **Neem and Jatropha curcas.** This oil mixture used to make a biodiesel blend and these two oils were choosing under some conditions, that conditions are taken from our literature survey.

The main reason for the selection of these two oils is both are having the same catalyst and the esterification process temperature is approximately equalled for Neem and Jatropha curcas. According to the literature survey, the jatropha curcas biodiesel and Neem biodiesel calorific value and flash point both are approximately equal. These are the reasons for the selection of Neem and Jatropha curcas oils mixture to make biodiesel blend.

2.5. TRANSESTERIFICATION PROCESS AND UNIT

The esterification process is a chemical process that transforms the branched large molecules of oils and fats into smaller straight-chain molecules. The photographic view of the transesterification unit with accessories and dismantled view of the unit used in the investigation.

Biodiesel production unit consisted of 2000 ml three-neck flasks equipped with a reflux condenser, temperature indicator, temperature-controlled heater and a variable speed D.C motor through the shaft. The speed of the stirrer was easily varied with the help of an electronic speed regulator. The stirrer consists of four stainless steel blades at an angle of 45° and oriented at 45° to the base. A heater having a capacity of 1.5 kW was used for heating the oil in the three-neck flask. A temperature control unit was used to vary the temperature of the oil from 30° to 250° C. The temperature of the oil was measured by using a thermometer. An electronically controlled knob was to control the motor speed. The inlet neck at the top of the flask was used to feed the vegetable oil, reactant and catalyst mixture. The neck located at the top of the flask was used to collect transesterified product after the process was over.

Figure 1 Transesterification Unit (Source: TN Agricultural University, Coimbatore)

2.6. Neem and Jatropha Ester Preparation Method

Transesterification unit was used for the production of biodiesel blend from that mixture of Neem and Jatropha oil mixture. The objective is to make a blend using a mixture that Neem oil and Jatropha curcas oil mixed and making biodiesel.

Primarily the Neem oil and jatropha oil both are mixed and taken in the three-neck flask. The raw mixture oil measuring 1litre having FFA of 5.86% is taken in a reaction flask and heated to 40ºC initially with a continuous stirring. Then oil is filtered using tissue paper. The filtered oil is again heated to 60º - 65ºC for 15 minutes in a reaction flask. After the heating of the oil is carried out, then the mixture containing 300ml methanol and 10ml concentrated sulphuric acid is poured into the reaction flask slowly. The reaction takes place at constant stirring with suitable speed and the process is carried out at 60ºC for about 1hour. After the completion of the process, the mixture is transferred into a separating flask and then allowed to settle down to separate into two phases. The upper layer is the dark acid layer and the lower layer is oil. Now the sample of the esterified oil mixture is taken and the new FFA is measured which is found to be 2.95%. The FFA content of esterified Neem oil is less than 4%, therefore the Transesterification process is carried out.

The esterified Neem and jatropha oil mixture is taken in a reaction flask and heated to 60ºC for about 15 minutes with continuous stirring. Then the methoxide mixture containing 300ml Methanol and 1.5ml of Sodium Hydroxide is poured into a reaction flask with constant slow stirring at 60ºC. The reaction temperature is maintained at about 60-65˚C and the process is carried out for another 2 hours. Once the process is completed, the reaction mixture is transferred into a separating funnel and then allowed to settle down into three phases. The upper layer is biodiesel which consists of methyl esters, the middle layer is glycerol and the lower layer is NaOH catalyst. The biodiesel obtained is washed with warm water of 40°C and allowed to settle for 1 hour. A bottom layer of soap water will slowly start to form and the soapy water is drained down carefully. The above procedure is repeated 10 to 15 times, till the clean wash water is got back which indicates that the catalyst is not present in the biodiesel. Later washed biodiesel is heated to 110ºC to remove moisture from biodiesel. This pure biodiesel (B100) was mix with mineral diesel to get a different ratio of blend. The different ratio blends are,

- D80B20 (Diesel 80%+Biodiesel 20%)
- D70B30 (Diesel 70%+Biodiesel 30%)
- D60B40 (Diesel 60%+Biodiesel 40%)

These blends were used to conducting the testing of the IC engine and found engine performances and control the emissions.

2.7. MEASUREMENT OF RELATIVE DENSITY

A hydrometer is an instrument, which is used to measure the relative density of the blends as shown in figure 2.2 A hydrometer is usually made of glass and consists of a cylindrical stem and a bulb weighted with mercury or lead shot to make it float upright. The liquid to be tested is poured into a tall container and the hydrometer is gently lowered into the liquid until it floats freely. The point at which the surface of the liquid touched the stem of the hydrometer was noted. Hydrometers usually contain a scale inside the stem, so that the relative density can be read directly.

Figure 2 Photographic view of the hydrometer (Source: TN Agricultural University, Coimbatore)

Relative density is one of the most important properties of fuel because the injection system, pumps and injectors must deliver the correct amount of fuel precisely adjusted to provide proper combustion.

The percentages of catalyst and additives in the blends were increased, the relative densities also increased. The catalyst with less density was used, the higher density of additives added with an equal concentration in the catalyst will lower the density of the blends when mixed with diesel. The value of the relative density of the blend is comparable to base diesel fuel. The value of relative density also depends on the density of the additives used in the blends. The equal volume of catalyst and additives mixed in the blend slightly increased the relative density, which was comparable with diesel.

2.8. MEASUREMENT OF VISCOSITY

Redwood viscometer is shown in figure 2.3 And it is used to measure the viscosity of the blends. A 50ml small flask was used to receive the oil from the jet outlet. The levelled oil cup was cleaned and the ball and the ball valve were placed on the agate to close it, the test oil or blend was filled in the cup up to the pointer level.

Figure 3 Photographic view of redwood viscometer (Source: PSG Tech, Chemistry lab)

The empty flash was placed just below the jar. Water was filled in the bath. The heater was switched on to obtain the required temperature. When the blended fuel reached the desired temperature, the ball valve was lifted and suspended from the thermometer bracket .the time required for 50ml of the blended fuel to collect in the flask was noted and the valve was immediately closed to prevent any overflow of oil. The dynamic viscosity was calculated using formulas.

Initially, the experiment was conducted at 35°C for blended fuels. Similarly, the same procedure was repeated for all blends fuels at different temperatures such as 40°C,50°C,60°C and 70°C and the viscosity was found out.

This is observed that catalyst concentration in the blend decreases the viscosity of the fuel blends and also comparable with diesel fuel. It can be found that the viscosity of the blends slightly increased as the equal percentage of catalyst and vegetable oil and its ester used in the blends. In general, the addition of all the additives at the same concentration with a catalyst to diesel slightly increases the fuel viscosity and also compared with the viscosity of base diesel fuel. At the same time, the addition of catalyst reduces the viscosity of blends. This is due to the lower viscosity of the catalyst as compared to all additives.

2.9. MEASUREMENT OF CALORIFIC VALUE

The bomb calorimeter was used to measure the calorific value of the blends. the heating values of the different blends were measure in an “Advance (ARICO) bomb calorimeter as shown in figure2.4. According to ASTM D2015 standard method, an oxygen–bomb was pressurized to 25 kg/cm^2 with oxygen. The bomb was fired automatically after the jacket and bucket temperatures equilibrated within acceptable accuracy of each other. The calibration of the bomb calorimeter was carried out by using the using bio-fuel blend samples which were obtained from PSG Tech, Chemistry laboratory.

Figure 4 Photographic view of bomb calorimeter (Source: PSG Tech, Chemistry lab)

The standard measure of the energy content of a fuel is its heating value (H.V) also called calorific value or heat of combustion. the calorific values of the blends proportionally decrease with the increase in catalyst percentage in the blends which is due to the lower calorific value of catalyst and oils.

2.10. MEASUREMENT OF FLASHPOINT

Figure 5 Photographic view of pensky apparatus (Source: PSG Tech, Chemistry lab)

The required level of blended fuel was filled in the removable test cup. The temperature of the cup was raised with the help of the heater arrangement. In this case, the blends were filled in the cup as required and the cup was placed in the collection of ice cubes for measurement of flashpoint. The temperature of the blend started to decrease and at the same time, the ignition source was introduced. The temperature at which the blend ignited was measured by the thermometer attached with the arrangement.

Flashpoint is the minimum temperature at which the vapour given off by a fuel will flash with a test flame held above the surface without continuous burning. The Flashpoint value of the blends mainly depends upon the percentage of ethanol in the blends.

2.11. BLEND PROPERTIES

Fuel property	B100	B20	B30	B40
Relative density (kg/m³)	892	833	836.3	842
Viscosity (mm²/s)	6.1	3.72	3.97	4.34
Flash point (°C)	152	58	62	65
Calorific value(MJ/kg)	35.33	39.66	38.2	37.12

Table 1 Blend properties

3. EXPERIMENTAL RESULTS

3.1. Performance and EXHAUST EMISSIONS ANALYSIS

3.1.1 Brake Thermal Efficiency

The variation of brake thermal efficiency with different percentage of load and blends are shown in figure 3.1. The brake thermal efficiency indicates the ability of the combustion system to accept experimental fuel and provides comparable means of assessing how efficiently energy in the fuel is converted into mechanical output.

From the results, it is observed that initially, the BTE of the engine improved with increasing concentration of the blends. The improvement in BTE can be to higher content of Neem and Jatropha curcas esters which could increase the lubricity and oxygen content of the blends, which will reduce the friction loss and improve the combustion and increase the BTE.

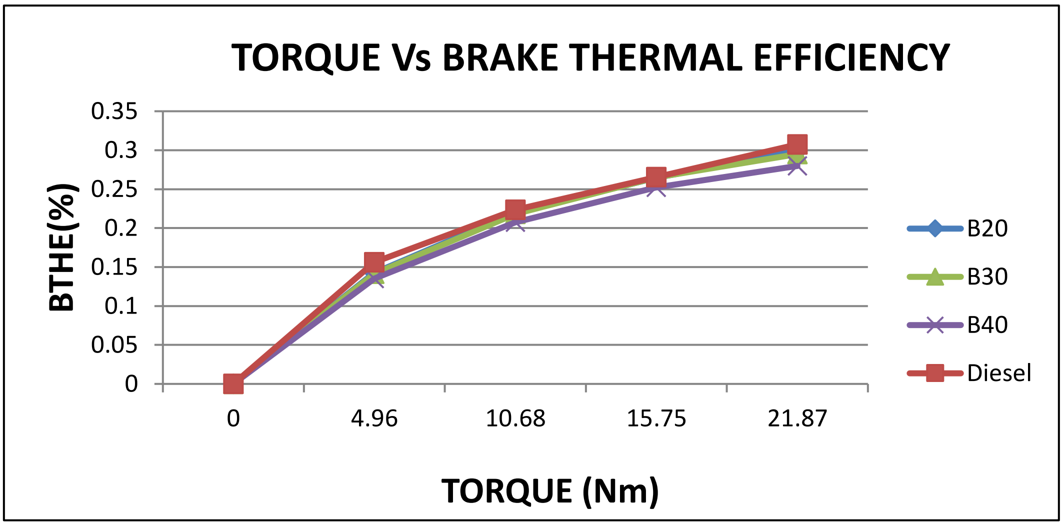

Figure 6 Torque Vs Brake thermal efficiency

The brake thermal efficiency is highest with B20 in all loads which are nearer to the diesel. B40 shows the minimum efficiency. The low efficiency due to low volatility, slightly higher viscosity and higher density of the ethyl ester of Jatropha oil and Neem oil, which affects the mixture formation of the fuel and thus leads to slow combustion. A slight lower efficiency with diesel was reported for the esters due to the lower heating value of the esters than with diesel.

3.1.2 EXHAUST GAS TEMPERATURE

The variation of exhaust gas temperature with load for different diesel–biofuel blends & neat diesel at a compression ratio of 18:1 and injection pressure of 200 bar is shown in figure 3.2. Exhaust gas temperature of all blends B20, B30 and B40 increase with increasing load of the engine. It is obvious from the simple fact that more amount of fuel is required in the engine to generate more power than needed to take up the additional load. The results show that the exhaust gas temperature increases with an increase in load for all blends & diesel.

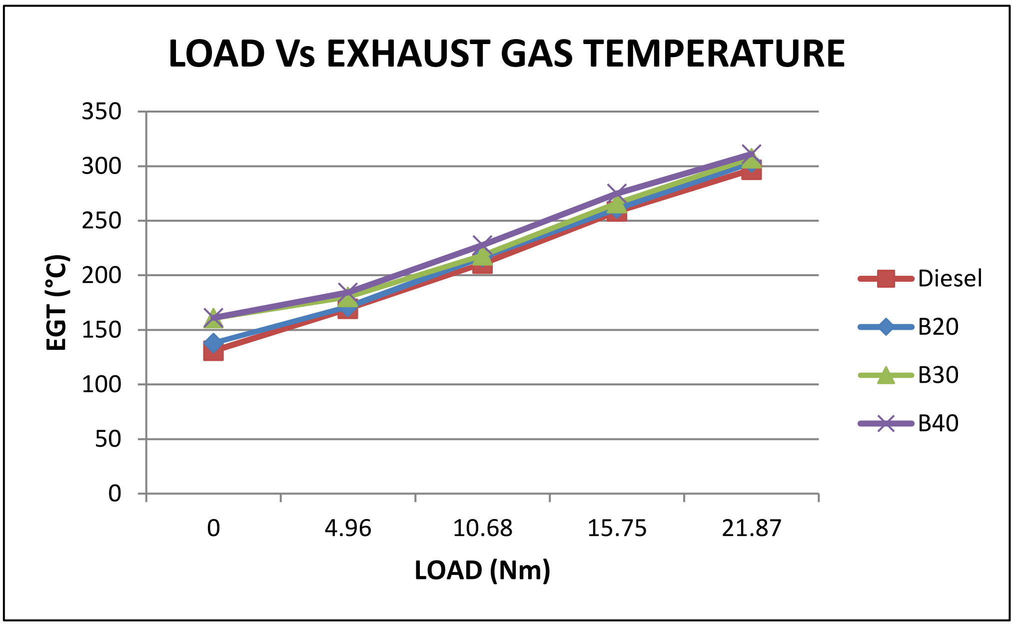

Figure 7 Torque Vs Exhaust gas temperature

At all loads, diesel was found to have the lowest temperature and the temperatures for various blends show an upward trend with increasing concentration of Jatropha and Neem biodiesel in the blends. The biodiesel contains oxygen which enables the combustion process and hence the exhaust gas temperatures are higher.

3.2. EMISSIONS ANALYSIS

3.2.1. Hydrocarbon Emissions

The variation of HC emissions with different percentage of load for diesel biofuel blends with B20, B30 and B40 is shown in figure 3.3.

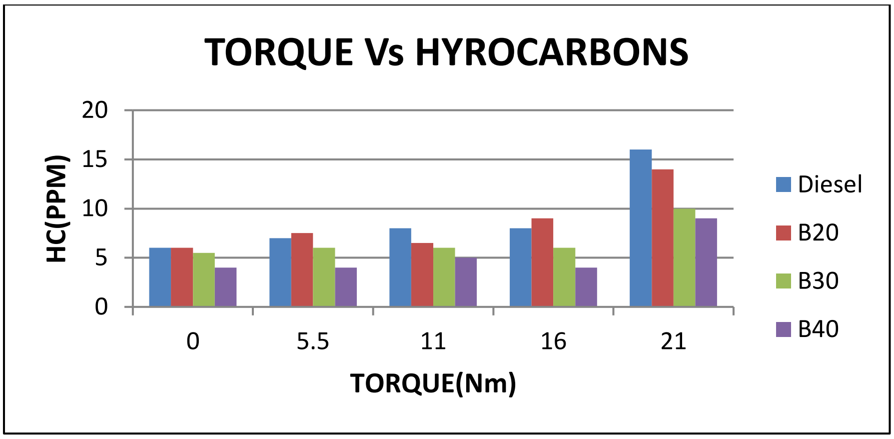

Figure 8 Torque Vs hydrocarbons

The amount of hydrocarbon emissions increased by increasing the load for diesel and all fuel blends. At the same time, the blend that contained a higher percentage of ethanol, vegetable oil and its ester emitted more amount of hydrocarbon emission. Higher content of Blends modifies the effects of fuel viscosity, fuel spray quality. It may delay the ignition of fuel and the accumulation of the fuel in the combustion chamber produces higher hydrocarbon emission. The increasing concentration of ethanol increases the HC emission because the high latent heat of vaporization of ethanol slowed both air-fuel mixing and fuel evaporation.

3.2.2. CARBON MONOXIDE EMISSIONS

The variation of CO emissions with different percentages of load for diesel-biofuel blends with B20, B30 and B40 is shown in figure3.4. The CO emission gets slightly increased by an increase in the engine load.

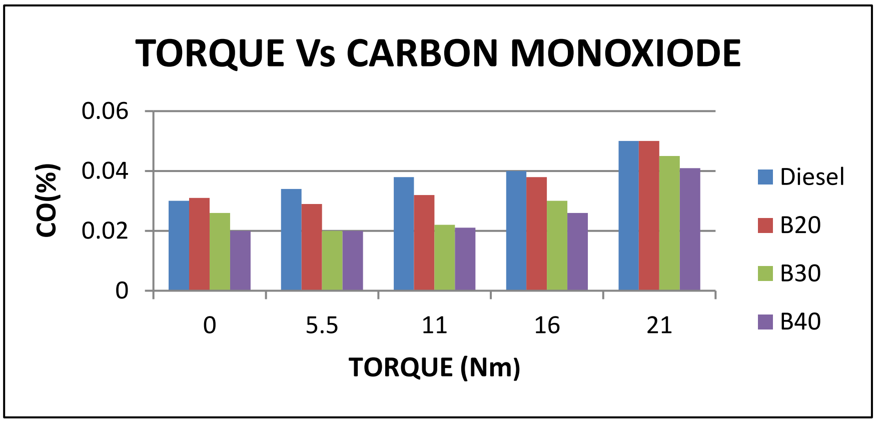

Figure 9 Torque Vs Carbon monoxide

When the engine is operated from low to high load, the temperature in the cylinder is high, which leads to the chemical reaction of fuel with oxygen and hence complete combustion occurred at higher load conditions. The rising temperature in the combustion chamber, physical and chemical properties of the blend, air-fuel ratio shortage of oxygen at the high-speed engine and lesser amount of time available for complete combustion will take incomplete combustion and thus produce higher CO.

The CO emission for all the blends and neat diesel goes on increases as load increases for injection pressure. B50 shows a lower CO emission compared to neat diesel at all loads. A reason for the reduction of CO emissions with biodiesel is the oxygen content in the fuel, which enhances the complete combustion of fuel, thus reducing CO emissions.

3.2.3. CARBON DIOXIDE EMISSIONS

Variation of CO_2 emissions with different percentage of load for diesel- biofuel blends with B20, B30 and B40 at a compression ratio of 18:1 and injection pressure of 200 bars is shown in figure 3.5.

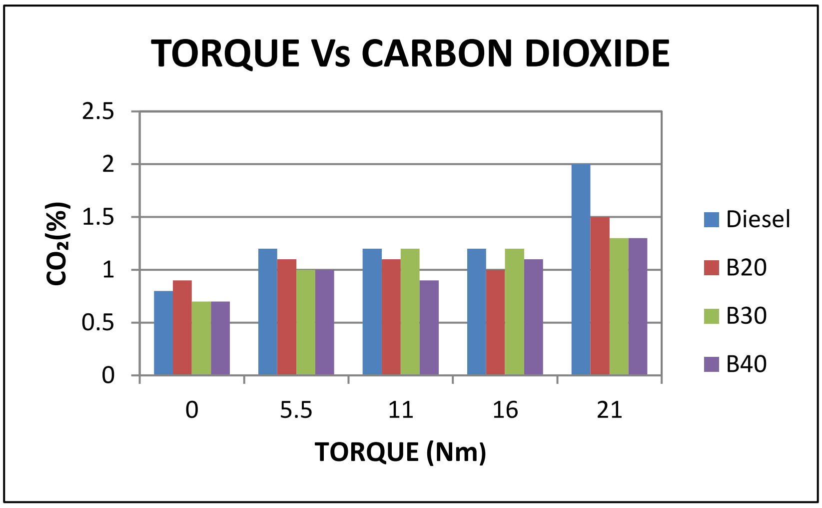

Figure 10 Torque Vs Carbon dioxide

The CO_2 emission increases with increasing load for all fuel blends with B20, B30 and B40. This is because increasing exhaust gas temperature with load resulting in incomplete combustion of the fuel in the combustion chamber. B50 shows a lower CO2 emission compared to neat diesel at all loads. A reason for the reduction of CO2 emissions with biodiesel is the oxygen content in the fuel, which enhances the complete combustion of fuel, thus reducing CO2 emissions. The CO2 emissions for all blends of biodiesel are less compared to neat diesel at 200 bars injection pressure.

3.2.4 Nitrogen dioxide (NO_2)

The variation of NO_2 emissions with different percentages of load for diesel- biofuel blends with B20, B30 and B40 at a compression ratio of 18:1 and injection pressure of 200 bars is shown in figure 3.6.

Biodiesel shows a higher NO_2 emission compared to diesel at all loads for injection pressure. From this curve, two observations can be made. First, NO_2 emissions are a direct function of engine loading. This is expected because, with increasing load, the temperature prevailing inside the combustion chamber increases and NO_2 formation is a strongly temperature-dependent phenomenon.

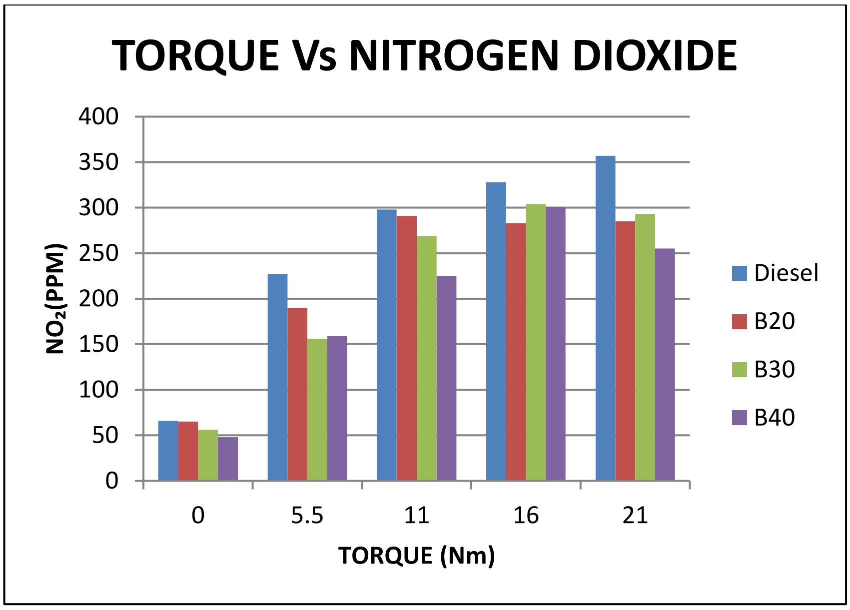

Figure 11 Torque Vs Nitrogen Dioxide

The second observation is that higher NO_2 is due to higher temperatures prevailing in the combustion chamber of the biodiesel-fuelled engine. This is also reflected by the higher exhaust gas temperature from the biodiesel-fuelled engines.

4. CONCLUSION

Bio-fuel blend was prepared through a transesterification process using Neem and Jatropha curcas oil mixture. Fuel properties were measured and the values are tabulated for various blends B20, B30, B40 and B100. The fuel properties results of all blends show that blends of up to 20% straight blend have a value of viscosity and density equivalent to the specified range for diesel engine fuel, therefore it can be concluded that up to 20% blend can be used to run the stationary diesel engine at short term basis. Engine performance with biodiesel does not differ greatly from that of diesel fuel. The B20 shows good brake thermal efficiency in comparison with diesel. A little increase in fuel consumption is often encountered due to the lower calorific value of the biodiesel. Most of the major exhaust pollutants such as CO, CO2 and HC are reduced with the use of neat biodiesel and the blend as compared to neat diesel. But NO2 emissions increase when fuelled with diesel– biodiesel fuel blends as compared to conventional diesel fuel. This is one of the major drawbacks of biodiesel. Among the blends, B20 shows better performance and emission characteristics.

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