

# PERFORMANCE AND EMISSION ANALYSIS IN CI ENGINE USING PONGAMIA OIL BLENDED WITH DIESEL

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**Abstract :** On the face of the upcoming energy problems, vegetable oils have come up as compromising source of fuel. They are being studied broadly because of their abundant availability, renewable nature and better performance when used in engines. Many vegetable oils have been tested in compression ignition engine by fuel modification or engine modification. The vegetable oils have very high density and viscosity, so they have used the methyl ester of the oil to solve those problems. Their use in form of methyl esters in unmodified engines has given encouraging results. Karanja oil (pongamia pinnata) is non edible in nature and is available abundantly in India. The main objective of the present work is to reduce higher viscosity of Karanja oil (pongamia pinnata) using esterification and then transesterification process. An experimental investigation was made to calculate the performance, emission and combustion characteristics of a diesel engine using different blends of methyl ester of karanja oil with mineral diesel. Karanja methyl ester was blended with diesel in proportions of 30% and 50% by mass and studied under various load conditions in a compression ignition (diesel) engine. The performance parameters were found to be very near to that of mineral diesel. The brake thermal efficiency and mechanical efficiency were better than mineral diesel for some specific blending ratios under certain loads. The emission characteristics were also studied and levels of carbon dioxide, carbon monoxide, nitrous oxide and hydrocarbons were found to be better than pure diesel.

Key words: vegetable oils, pongamia pinnata, transesterification process, combustion characteristics, Biomass fuel

## I. INTRODUCTION

Energy demand is increasing day by day due to transformation and industrialization of any country in world. Most of the developing countries like India import fossil fuels to achieve their energy demand. In the current condition, fast depletion of fossil fuels, increasing cost of petroleum fuels and strict emission norms forced by the government have urged the researchers to search for an alternative fuel for compression ignition (CI) engines like bio fuel and biomass [1]. Vegetable oils and biomass fuels have been found to be probable fuel for Diesel engines [2]. These fuels are readily available, biodegradable, environment friendly, and renewable in nature. The use of raw vegetable oils used as fuel for Diesel engines without modification causes some damage to parts of the engine and also the performance is significantly affected. However, the long term process of the engine problems of injector coking, dilution of engine oil, deposits in various parts of the engine due to its higher viscosity [3].

Fossil fuels are one of the major sources of energy in the world in current times. Their popularity can be accounted to easy usability, easily available and cost effective. But the limited reserves of fossil fuels are a great concern owing to fast depletion of the reserves due to increase in worldwide demand. Fossil fuels are the major source of atmospheric pollution in today's world. So efforts are on to find alternative sources for this depleting energy source[4]. Even though new technologies have come up which have made solar, wind or tidal energy sources easily usable but still they are not so popular due to problems in integration with present technology and processes. So, efforts are being focused towards finding energy sources which are similar to the present day fuels so that they can be used as direct substitutes. Diesel fuel functions as a major source of energy, mainly in the transport sector.

During the World Exhibition in Paris in 1900, Rudolf Diesel was running his engine on 100% peanut oil. In 1911 he stated "The diesel engine can be fed with vegetable oils and would help considerably in the growth of agriculture of the countries, which use it". Studies have shown that vegetable oils can be used in diesel engines as they are found to have properties nearly same to diesel fuel. It is being considered a breakthrough because of availability of various types of oil seeds in vast quantities. Vegetable oils are renewable in nature and may create opportunities for rural employment when used on large scale. Vegetable oils from crops such as soya bean, peanut, sunflower, rape, coconut, karanja, neem, cotton, mustard, jatropha, linseed and castor have been evaluated in many parts of the world. Non edible oils have been favored because they don't compete with food reserves. Karanja (pongamia) is an oil seed-bearing tree, which is non edible and does not find any other appropriate application due to its dark colour and odour [5]. The oils have high viscosity and other problems make their use difficult, so it was used after conversion to its methyl ester which modified all characteristics to suit our demand .In this work, different proportions of karanja methyl ester 30% and 50% respectively are mixed with 70% and 50% respectively with diesel fuel on mass basis.

## II. Materials and methods

As mentioned above biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste oils. There are three important routes for the production biodiesel from oils and fats:

1. Base catalyzed transesterification of the oil.
2. Direct acid catalyzed transesterification of the oil.

### 3. Finally fatty acid is converted into biodiesel.

Mostly all biodiesel is produced using base catalyzed transesterification as it is the most economical process demanding only low temperatures and pressures and producing a 98% conversion yield. For this reason only this process will be described in this report.

The Transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerin molecule as its base with three long chain fatty acids attached. The characteristics of the fats are determined by the nature of the fatty acids attached to the glycerin. The nature of the fatty acids can in turn affect the characteristics of the biodiesel. During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide or potassium hydroxide. [6]

The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel and crude glycerol. In most production methanol or ethanol is the alcohol used (methanol produces methyl esters while ethanol produces ethyl esters) and is base catalyzed by either potassium or sodium hydroxide. Potassium hydroxide has been found to be more suitable for the ethyl ester biodiesel production, while either base can be used for the methyl ester. A common product of the transesterification process is the Oil Methyl Ester (OME) produced from raw oil reacted with methanol.

The action between the fat or oil and the alcohol is a reversible reaction and so the alcohol must be added in addition to drive the reaction towards the right and confirm complete conversion. The products of the reaction are the biodiesel itself and glycerol.

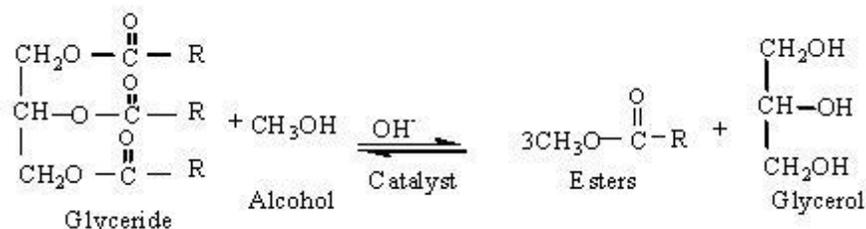


Figure 2.1. Glycerol formation from Glyceride

A successful transesterification reaction is denoted by the separation of the ester and glycerol layers after the reaction time. The heavier, co-product, glycerol settles out and may be sold as it is or it may be refined for use in other industries, e.g. the pharmaceutical, cosmetics etc. The engine combustion benefits of the transesterification of the oil are:

- Lowered viscosity
- Complete removal of the glycerides
- Lowered boiling point
- Lowered flash point
- Lowered pour point

### III. Trans-esterification process

Trans-esterification is the common term used to define the important class of organic reactions where an ester is converted into another through interchange of the alkoxy methane. When the original ester is reacted with an alcohol, the trans-esterification process is called alcoholysis. In this review, the word trans-esterification will be used as synonymous for alcoholysis of carboxylic esters, in agreement with most publications in this field. The trans-esterification is an equilibrium reaction and the transformation occurs essentially by mixing the reactants [7]. Accelerates considerably the adjustment of the equilibrium. In order to achieve a high yield of the ester, the alcohol has to be used in excess.

The applicability of trans-esterification is not restricted to laboratory scale. Several relevant industrial processes use this reaction to produce different types of compound. An example is the production of PET (polyethylene terephthalate), which involves a step where di methyl terephthalate is transesterified with methanol in the presence of sulphuric acid as catalyst.

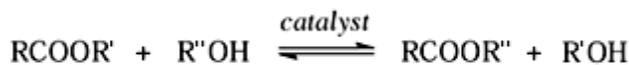


Figure 3.1. General equation of transesterification reaction

Furthermore, a large number of acrylic acid derivatives are produced by transesterification of methyl acrylate with different alcohols, in the presence of acid catalysts. If the alcohol and the ester groups are there in the same molecule simple lactones or macro cycles are formed by an intermolecular trans-esterification.

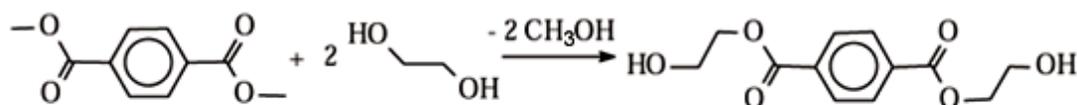
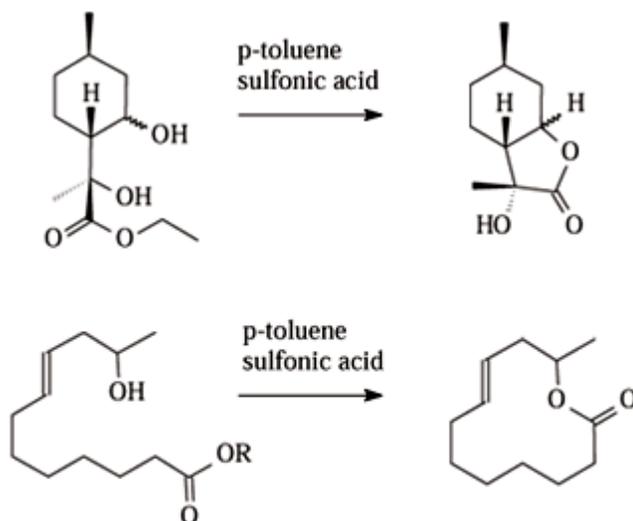


Figure 3.2 Trans esterification of dimethylterephthalate with ethylene glycol

If the alcohol and the ester groups are present in the same molecule simple lactones<sup>7,8</sup> or macrocycles<sup>9-10</sup> are formed by an intramolecular trans-esterification, as shown in Figure 3. Further trans-esterification reactions can be found in the literature, in which

metal alkoxides 11-16, aluminum isopropoxide 17-19, tetra alkoxytitanium compounds 20-22 and organotin alkoxides 23,24 are used as catalysts.[8]



**Figure 3.3** Examples of intramolecular transesterification reactions forming lactones or macrocycles

In the trans-esterification of vegetable oils, a triglyceride reacts with an alcohol in the presence of a strong acid or base, producing a mixture of fatty acids alkyl esters and glycerol. The overall process is a order of three successive and reversible reactions, in which mono glycerides are formed as intermediates. The reaction requires 1 mol of a triglyceride with 3 mol of the alcohol. However, an excess of the alcohol is used to rise the yields of the alkyl esters and to allow its phase separation from the glycerol formed. Several aspects, including the type of catalyst (alkaline or acid), alcohol/vegetable oil molar ratio, temperature, purity of the reactants (mainly water content) and free fatty acid content have an influence on the course of the transesterification and will be discussed below, based on the type of catalyst used[9]. However, the presence of a catalyst Biodiesel is a biodegradable, non-toxic, sulphur free renewable fuel, it can be made from vegetable oils and animal fats. Higher viscosity, high molecular weight, and low volatility cause poor atomization resulting in incomplete combustion resulting various problems. The physical and chemical properties of straight vegetable oil can be developed by trans-esterification and reduction in viscosity may be achieved. In general, the vegetable oils are in the forms of triglycerides, as per the ASTM standards, biodiesel was defined as “The mono alkyl esters of long chain fatty oils or animal fats, for use in compression ignition (diesel) engines”.



The ethyl esters of refined *Jatropha* oil were prepared for the experiment in place of methyl esters because ethyl esters have higher heat content and cetane number due to extra carbon atom brought by ethyl alcohol during trans-esterification process (Romain et al., 1995).

The result of process parameters show was studied to standardize the transesterification process for estimating recovery of ester as well as recovering ester of lowest possible kinematic viscosity in the process. In all 27 samples of refined *Jatropha* oil-ethyl alcohol having 9:1 molar ratio and another 27 samples having 6:1 molar ratio was transesterified to study the effect of three levels of selected preheating time, three levels of selected reaction temperature and three levels of selected settling time on ester recovery and subsequent measure of their kinematic viscosity. Each sample was replicated three times thus making 81 experimental units under each selected molar ratio Romain et al., (1995).[10]

#### IV. Experimental investigation

Performance test is done by using Electrical DC generator dynamometer test rig. Various loads are applied and the corresponding readings are tabulated. Emissions are measured by using the CRYPTON gas analyzer. In cylinder pressure was measured using IC engine model transducer equipped with cooling adapter and high temperature cables.

AL mech electrical loading resistance bank rheostat test rig is used. The unit calculates total fuel consumption, Brake power, Indicated horse power, Brake thermal efficiency and mechanical efficiency. Here for various loading condition, the fuel consumption can be obtained. Load is given in terms of Ampere.

The Krypton 290 series analyzer is used in this. It is a fully microprocessor controlled exhaust gas analyzer employing Non-dispersive infra-Red (NDIR) Techniques. The unit measures carbon monoxide, carbon dioxide and hydrocarbons. A further channel is provided employing electrochemical measurement of oxygen. Zero may be charged at any time by the operator, and automatically implemented by the analyzer [11]. An automatic auto zero check is executed every thirty minutes when the analyzer is switched on.

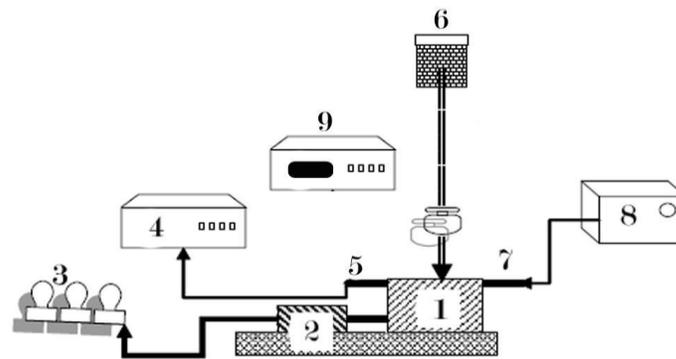


Figure 4.1. Experimental setup

Table 4.1 Components of experimental setup

SL NO	NAME
1	Single cylinder 4S diesel engine
2	Dynamometer
3	Resistance load
4	Gas analyzer
5	Exhaust manifold
6	Fuel tank
7	Inlet manifold
8	Air drum
9	Control system (computer)

The engine was coupled to a dynamometer to deliver load to the engine. A sensor is connected near the flywheel to measure the speed. Air intake was measured by air flow sensor that is fitted in an air box. A burette was used to measure fuel flow to the engine through fuel pump. A thermocouple with a temperature pointer measures the exhaust gas temperature. Emissions such as unburnt hydrocarbon (HC), carbon monoxide (CO) and nitric oxide (NO) were measured by an AVL 444 exhaust gas analyzer. Combustion diagnosis was passed out by means of a Kistler make quartz piezoelectric pressure transducer (Model Type 5395A) mounted on the cylinder head in the standard position. Kistler pressure transducer has the advantage of good frequency response and linear operating range.[13]



Figure 4.2. Experimental setup

A continuous circulation of air was maintained for cooling the transducer by using fins to maintain the required temperature. Combustion parameters such as mechanical efficiency, brake thermal efficiency, brake specific fuel consumption, ignition delay, and maximum rate of heat release and emission parameters like exhaust gas concentrations and Figure 4.2: Photography of experimental setup 31 temperature were evaluated. The experiments were carried out by using various blends of karanja methyl ester (KME 30,50) with diesel at different load conditions on the engine keeping all the independent variables same[14]. The engine performance test was done twice for all blends and average was taken and emission readings were taken thrice and average was taken. TableA continuous circulation of air was maintained for cooling the transducer by using fins to maintain the required temperature. Combustion parameters such as mechanical efficiency, brake thermal efficiency, brake specific fuel consumption, ignition delay, and maximum rate of heat release and emission parameters like exhaust gas concentrations and Figure 4.2: Photography of experimental setup 31 temperature were evaluated[15]. The experiments were carried out by using various blends of karanja methyl ester (KME

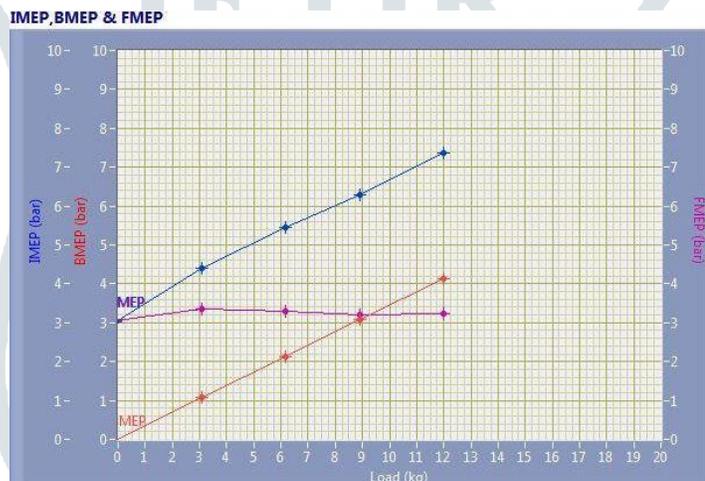
30,50) with diesel at different load conditions on the engine keeping all the independent variables same. The engine performance test was done twice for all blends and average was taken and emission readings were taken thrice and average was taken. TableA continuous circulation of air was maintained for cooling the transducer by using fins to maintain the required temperature [16]. Combustion parameters such as mechanical efficiency, brake thermal efficiency, brake specific fuel consumption, ignition delay, and maximum rate of heat release and emission parameters like exhaust gas concentrations and Figure 4.2: Photography of experimental setup 31 temperature were evaluated. The experiments were carried out by using various blends of karanja methyl ester (KME 30,50) with diesel at different load conditions on the engine keeping all the independent variables same.[17] The engine performance test was done twice for all blends and average was taken and emission readings were taken thrice and average was taken.

**Table 4.2. Engine specification**

Make	Kirloskar
Type of Engine	Four stroke
Speed	single cylinder, DI diesel engine
Bore	1500 rpm
Stroke	87.5 mm
Compression ratio	110 mm
Method of cooling	17.5
	Air cooled with radial fan

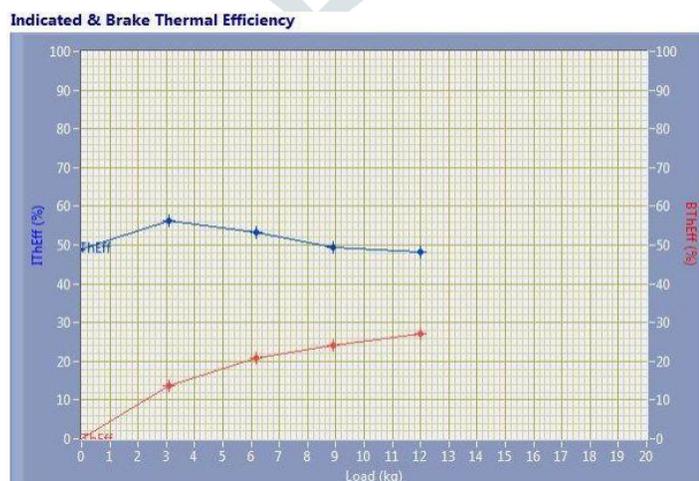
**V. RESULTS AND DISCUSSION**

**5.1. PERFORMANCE CHARACTERISTICS**



**Figure 5.1. IMEP, BMEP & FMEP (30% Blend)**

In the Figure5.1 , 1500rpm speed is constant when the low load condition -0.07kg, the Brake Mean Effective Pressure is - 0.02bar. In the medium load condition 6.18kg, the Brake Mean Effective Pressure is 2.13bar. High load condition 12.01kg, the Brake Mean Effective Pressure is 4.14bar. In this graph when the load gets increased Brake mean Effective Pressure also gets increased.



**Figure5.2 BThEff & IThEff (30% Blend)**

In the Figure 5.2, 1500rpm speed is constant when the low load condition -0.07kg, the Brake Thermal Efficiency is -0.39%. In the medium load condition 6.18kg, the Brake Thermal Efficiency is 20.82%. In the High load condition 12.01kg, the Brake Thermal Efficiency is 27%. In this graph when the load gets increased Brake Thermal Efficiency also gets increased.

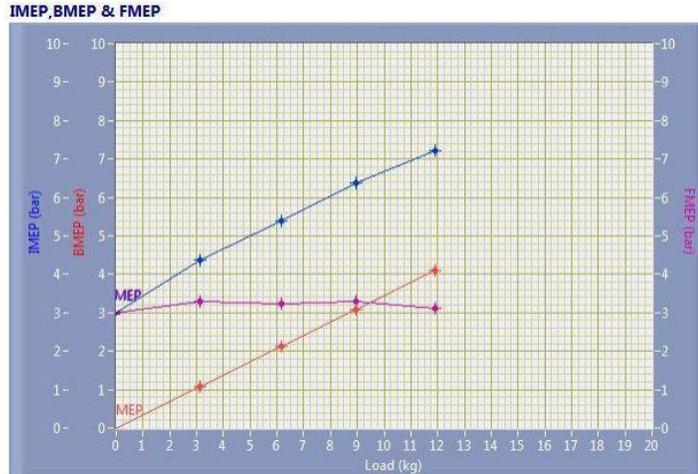


Figure 5.3 . IMEP, BMEP & FMEP (50% Blend)

In the Figure 5.3, 1500rpm speed is constant when the low load condition -0.10kg, the Brake Mean Effective Pressure is -0.03bar. In the medium load condition 6.17kg, the Brake Mean Effective Pressure is 2.13bar. High load condition 11.92kg, the Brake Mean Effective Pressure is 4.11 bar. In this graph when the load gets increased Brake mean Effective Pressure also gets increased.

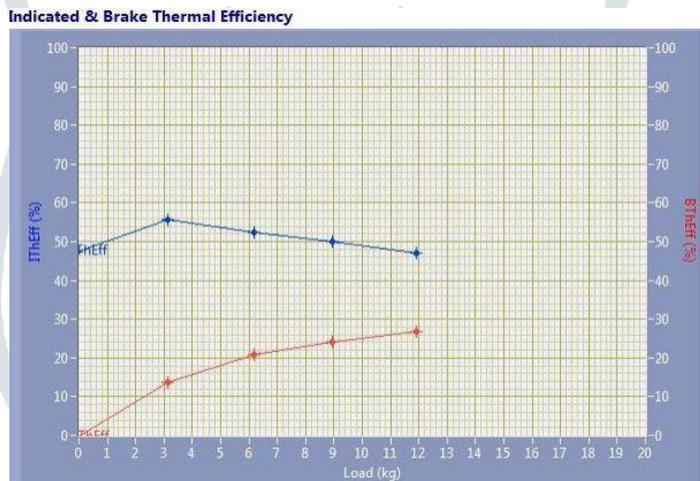


Figure 5.4 .BThEff&IThEff (50% Blend)

In the Figure 5.4 , 1500rpm speed is constant when the low load condition -0.10kg, the Brake Thermal Efficiency is -0.53%. In the medium load condition 6.17kg, the Brake Thermal Efficiency is 20.72%. In the High load condition 11.92kg, the Brake Thermal Efficiency is 26.80%. In this graph when the load gets increased Brake Thermal Efficiency also gets increased.

## 5.2 . EMISSION CHARACTERISTICS

### 5.2.1 INFLUENCE OF HYDROCARBON EMISSION

In existing piston, the emission characteristics is low in no load condition and gradually increasing by increasing the load after reaching the particular point is maintain constant with using diesel and biodiesel blend ratios.

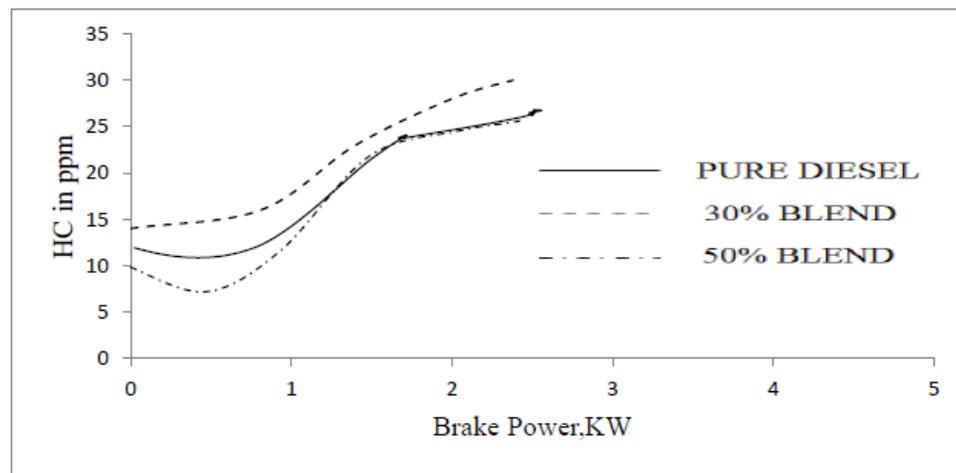


Figure 5.5. Comparison of HC emissions for Diesel Blended with 30%, and50% of Pongamia Oil

If the fuel supply is more in high load condition the HC emission will increase. An emission reduces as the load increases in all pistons.

### 5.2.2 INFLUENCE OF CO<sub>2</sub> EMISSION

In starting the emission characteristics is less in all the type with diesel and blend ratios. But it is increasing slightly when increasing the load.

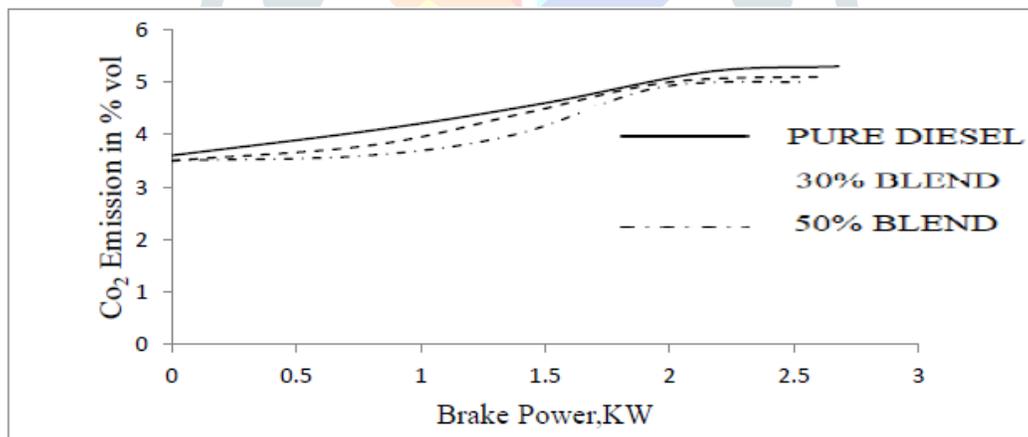


Figure 5.6. Comparison of CO<sub>2</sub>emissions for Diesel Blended with 30%, and50% of Pongamia Oil

### 5.2.3 INFLUENCE OF NO<sub>x</sub> EMISSION

The variation in NO<sub>x</sub> with loading condition, it can be seen from this figure that the maximum NO<sub>x</sub> values were obtained with the blends. In addition, NO<sub>x</sub> emission of the conventional diesel was lower than that of biodiesel blends. NO<sub>x</sub> emission slightly increases due to the higher combustion temperature and the presence of fuel oxygen with the blend at all load condition.

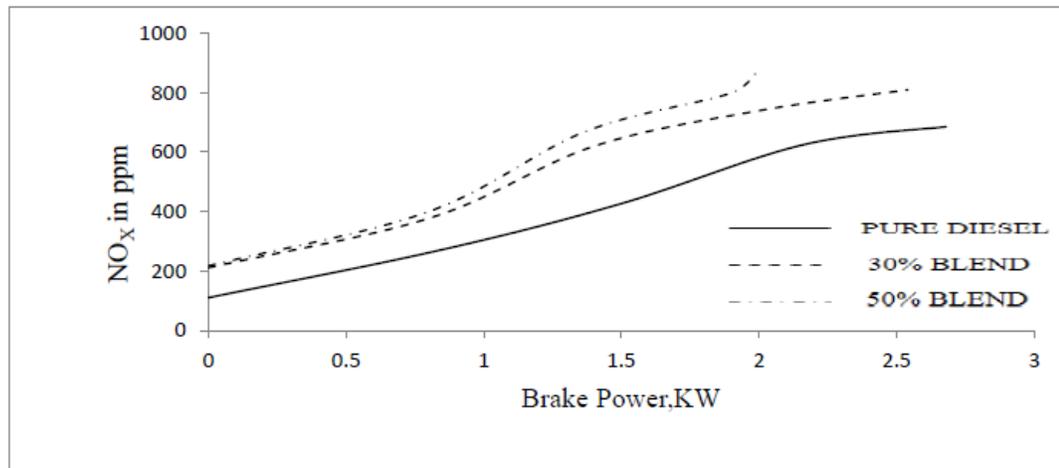


Figure 5.7 Comparison of NO<sub>x</sub> Emissions for Diesel Blended with 30%, and 50% of Pongamia Oil

## VI. CONCLUSION

Karanja methyl ester seems to have a potential to use as alternative fuel in diesel engines. Blending with diesel decreases the viscosity considerably. The following results are made from the experimental study.

- The brake thermal efficiency of the engine with karanja methyl ester-diesel blend was marginally better than with neat diesel fuel.
- Brake specific energy consumption is lower for karanja methyl ester-diesel blends than diesel at all loading.
- The exhaust gas temperature is found to increase with concentration of karanja methyl ester in the fuel blend due to coarse fuel spray formation and delayed combustion.
- The mechanical efficiency achieved with KME30 is higher than diesel at lower loading conditions. At higher loads, the mechanical efficiency of certain blends is almost equal to that of diesel.
- The emission characteristics are higher than pure diesel but the KME30 has relatively better performance with respect to other blends.
- KME30 can be accepted as a suitable fuel for use in standard diesel engines and further studies can be done with certain additives to improve the emission characteristic.

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