Performance and Exhaust Emissions of A Low Heat Rejection Diesel Engine using Jatropha Oil As Fuel

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Abstract— **Many fuels are being investigated as potential substitutes for the current highly pollutant diesel fuel derived from diminishing commercial sources. Vegetable oils are one such alternative and they can be directly used in diesel engines as they have a high cetane number and calorific value close to that of diesel. However, the brake thermal efficiency of vegetable oil is inferior to diesel. The usage of vegetable oil may lead to problems of high smoke, HC and CO emissions. This is because the high viscosity and low volatility of vegetable oils cause difficulty in atomizing the fuel and in mixing it with air. The problem of high viscosity of vegetable oil has been approached in several ways, such as preheating the oils, blending or dilution with other fuel, transesterification and thermal cracking / Pyrolysis. The objective of the project is to carryout experimental investigation on low heat rejection engine with raw jatropha oil, methyl ester of jatropha oil, methyl ester of jatropha oil–kerosene blend in the proportion of 70:30 and diesel. The results obtained indicate better performance and emission characteristics of the engine with methyl ester of jatropha oil.**

Keywords*— *Diesel engine, Performance, Emission, Jatropha oil methyl esters blend.

1. INTRODUCTION

The increase in number of automobiles in recent years has resulted in great demand for petroleum products. Vegetable oils might provide a viable alternative to diesel since they are renewable in nature and environmentally friendly. The use of vegetable oil in engines without any modifications results in poor performance and emissions. Transesterification method is used to reduce the viscosity of the vegetable oil and solves the most of the problems of raw vegetable oil. Transesterification is the reaction wherein the vegetable oil is transesterified with alcohol and the process of removal of glycerol from fatty acids. This esterified vegetable oil is called biodiesel. In the present investigation biodiesel was prepared from jatropha oil and the blend with diesel in various volumetric proportions the prepared blends were fueled in the engine test rig. The performance, combustion and emission characteristics were analysed on a four stroke single cylinder direct injection diesel engine. The properties of Jatropha methyl ester and raw oil are compared with diesel as shown in Table.1.

Many investigators have used jatropha oil and pungam oil methyl esters with various proportions as a CI engine fuel and the following conclusions have been made: Jatropha oil, diesel and their blends exhibited similar performance and emission characteristics under comparable operating conditions. Pungam oil methyl ester and their blends exhibited lower unburned hydrocarbon, carbon monoxide and soot emissions with a penalty of higher nitric oxide emission Jatropha methyl ester and its blends are a potential substitute for diesel. JTME produces lesser emissions than petroleum diesel, except NOx, and have satisfactory combustion and performance characteristics, Improvement in performance characteristics and reduction in emissions were observed by preheating jatropha oil. A significant improvement in the performance and emissions was observed by optimizing the injector opening pressure, injection timing, injection rate and enhancing the swirl level when a diesel engine is to be operated with neat jatropha oil[8.]Performance and emission characteristics of JTME are superior when compared to other methyl esters produced from other feedstock. Peak pressure is higher for jatropha methyl ester compared to diesel[9].Most of the above research works are concentrated on performance and emission characteristics of JME and very limited work has been done to analyze the combustion characteristics. The present study investigates the combustion characteristics by highlighting their effect on performance and emission characteristics. This paper provides complete understanding and comprehensive analysis of the combustion, performance and emission characteristics of JME-diesel blends.

The ignition delay, maximum heat release rate and combustion duration are lower for JTME and its blends compared to diesel. The ignition delays were consistently shorter for neat Jatropha biodiesel, varying between 5.9degree and 4.2degree crank angles lower than diesel with the difference increasing with the load. Similarly, ignition delays were shorter for neat Karanja and Polanga biodiesel when compared with diesel[1]. Performance of the castor oil is validated as results are well comparable with the results of cotton seed oil and rice bran oils. Hence from above conclusions it may be stated that blends up to 25% without preheating and up to 50% with preheating can be substituted as fuel for diesel engine without any modifications in the engine. The performance and emission with ethanol blended Mahua biodiesel fuel and ethanol–diesel blended Mahua biodiesel fuel have also been studied. A considerable reduction in emission was obtained. Ethanol blended biodiesel is totally a renewable, viable alternative fuel for improved cold flow behavior and better emission characteristics without affecting the engine performance. Performance and emissions of different blends (B10, B20, and B40) of PME, JME and NME in comparison to diesel. Results indicated that B20 have closer performance to diesel and B100 had lower brake thermal efficiency mainly due to its high viscosity compared to diesel. However, its diesel blends showed reasonable efficiencies, lower smoke, CO and HC. Pongamia methyl ester gives better performance compared to Jatropha and Neem methyl esters.

2. THERMAL BARRIER COATING

The major promises of thermal barrier coated (also known as Low Heat rejection, LHR) engines are increased thermal efficiency and elimination of cooling system. A simple first law of Thermodynamics analysis of the energy conversion process within a diesel engine would indicate that if heat rejection to the coolant is eliminated, the thermal efficiency of the engine could be increased. The effect on NO_X emission is not as clear, with some investigator report increase in NO_X emission and others showing no increase. Also fuel economy penalty can be expected with a thermal barrier coated diesel engine, But as a strategy to reduce particulate emissions, thermal barrier coatings have proven to be effective.

Table -1: Seed Composition

Moisture	6.20 %
Protein	18.00 %
Fat	38.00 %
Carbohydrates	17.00 %
Fiber	15.50 %
Ash	5.30 %

Table -2: Chemical composition of Jatropha curcas oil

Acid value	37.2
Saponification value	195.0
Iodine value	101.7
Palmitic acid %	4.2
Stearic acid %	6.9
Oleic acid %	43.1
Linoleic acid %	34.3
Other acids %	1.4

3. EXTRACTION OF JATROPHA OIL

A dry seed of jatropha curcas contains about 55 % of oil. However, the maximum amount oil that can be extracted from a given sample of the seed depends on the method of extraction and perhaps the quality of the feedstock .Two main methods of extracting the oil have been identified. They are the chemical extraction method using solvent extraction with n-hexane and the mechanical extraction method using either manual ram press or an engine driven expeller. The solvent extraction with n-hexane would produce about 41 % yield by weight of oil per kg of the seed.

4. TRANSTERIFICATION

The transesterification process creates ester from vegetable oil by using an alcohol in the presence of catalyst. This reduction takes a triglyceride molecule or complex fatty acid, neutralizes the fatty acids and removes the glycerin thereby creating an alcohol ester. The problem with the transesterification refining method is that it is relatively expensive and produces glycerin as a byproduct that has to be processed again before it has any value.

Biodiesel is a fuel made from natural renewable sources such as vegetable oil. It is called as mono alkyl esters. Since it has properties similar to petroleum diesel fuel, biodiesel can be blended in any ratio with petroleum diesel fuel. Pure biodiesel is biodegradable, nontoxic and essentially free from sulphur and aromatics. The engine wear and tear and emissions have also been found to decrease with the use of biodiesel when compared to vegetable oil. The properties of raw jatropha oil, methyl ester of jatropha oil compared with diesel are shown in Table 3.

Biodiesel is composed of long-chain fatty acids with an alcohol attached, often derived from vegetable oils. It is produced through the reaction of a vegetable oil with methyl alcohol or ethyl alcohol in the presence of a catalyst. Animal fats are another potential source. Commonly used catalysts are potassium hydroxide (KOH) or sodium hydroxide (NaOH). The chemical process is called transesterification which produces biodiesel and glycerin. Chemically, biodiesel is called as methyl ester if the alcohol used is methanol. If ethanol is used, it is called as ethyl ester.

5. PREPARATION OF JATROPHA AND KEROSENE OIL BLEND

It is evident from (4) and (5) that dilution or blending of vegetable oil with other fuels like alcohol or diesel fuel
would bring the viscosity close to a specification range. Therefore, jatropha oil was blended with kerosene in varying proportions with the intention of reducing its viscosity close to that of the diesel fuel. The important properties of blend.
Thus prepared on given below

Table 3: Comparison of Raw and Methyl ester of Jatropha with Diesel

PROPERTIES	DIESEL	JATROPHA OIL	METHYL ESTER OF JATROPHA OIL
Specific	0.834	0.9186	0.88
Kinematic	6.2	81.80	8.722
Flash point	50	240	170
Net-heat	43600	39774	38450
Cetane number	45-55	38	50

Net heat Content (kJ/kg) :38803

Kinematic Viscosity at 40°C in cst : 4.14

Specific Gravity : 0.864

6. EXPERIMENTAL SETUP

The experiments were conducted on a single cylinder, naturally aspirated, air cooled, kirloskar DI Diesel engine Coupled to an electrical generator. The specifications of the engine are shown in Table 4. Cylinder wall and cylinder head of the engine were coated with Zirconium Oxide (Zr_2O_3) for a thickness of 100 microns. The engine was run at constant speed of 1500 rpm. The performance of the engine was evaluated in terms of brake thermal efficiency, peak firing pressure and emission characteristics like HC, CO, NO_X and smoke were recorded using diesel fuel, raw jatropha oil, methyl ester of jatropha oil-kerosene blend (70:30) and methyl ester of jatropha oil. In order to determine the cylinder pressure, the combustion analysis was performed in the engine. The experimental set-up employed in the investigation is shown in Figure 2.

Figure 1: Pictorial view of Experimental Setup

Table 4: Specifications of Engine

Make	Kirloskar
Model	TAF 1
Type	Direct injection, air cooled
Bore × Stroke (mm)	87.5 × 110
Compression ratio	17.5:1
Cubic capacity	0.661 lit
Rated power	4.4 KW
Rated speed	1500 rpm
Start of injection	24° bTDC
Connecting rod length	220 mm
Injector operating Pressure	220 bar

7. RESULT AND DISCUSSION

The results obtained after carrying out experiments using raw Jatropha oil, methyl ester of Jatropha oil and methyl ester of Jatropha oil-kerosene blend are presented and discussed in this section.

A. BREAK THERMAL EFFICIENCY

The variation of brake thermal efficiency with brake power output is shown in Fig. 2. Owing to poor mixture formation, as a result of the low volatility and higher viscosity the brake thermal efficiency is lower with raw Jatropha oil as compared to diesel. The maximum brake thermal efficiency with raw Jatropha oil is about 22.54 % where as it is 24.43 % with diesel at 75 % load condition. The brake thermal efficiency is higher with methyl ester of Jatropha oil and 30 % kerosene blend compared to raw Jatropha oil. The values are 23.89 % and 23.40 % respectively. The methyl ester of Jatropha oil and the blend have lower viscosity and density than the raw Jatropha oil. The reduction in viscosity leads to improved atomization, fuel vaporization and combustion. In addition the ignition delay time is expected to be closer to diesel with ester as the cetane rating is higher.

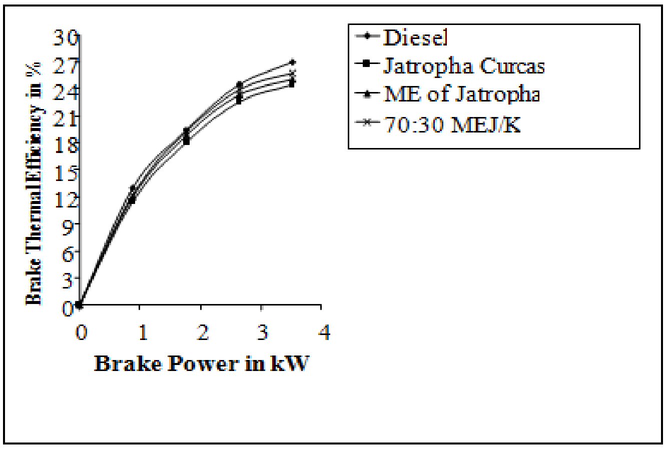

FIGURE 2: VARIATION OF BREAKE THERMAL EFFICIENCY WITH BREAK POWER

B. EXHAUST GAS TEMPERATURE

Exhaust gas temperature as plotted in Fig. 3 is high with raw jatropha oil than diesel. This is due to slow combustion of jatropha oil. The maximum temperature of exhaust gas at peak brake power output is 352°C with raw jatropha oil and 331°C with methyl ester of jatropha oil. The maximum exhaust temperature of methyl ester of jatropha oil- kerosene blend is 320°C. The exhaust gas temperature of raw jatropha oil, methyl ester of jatropha oil and methyl ester of jatropha oil-kerosene blend was higher than that of diesel. The reason for this is poor spray characteristics and higher self-ignition temperature of the raw jatropha oil, methyl ester of jatropha oil and methyl ester of jatropha oil-kerosene blend to that of diesel, which may cause longer ignition delay. As a result, energy release at the expansion stroke increases the exhaust temperature.

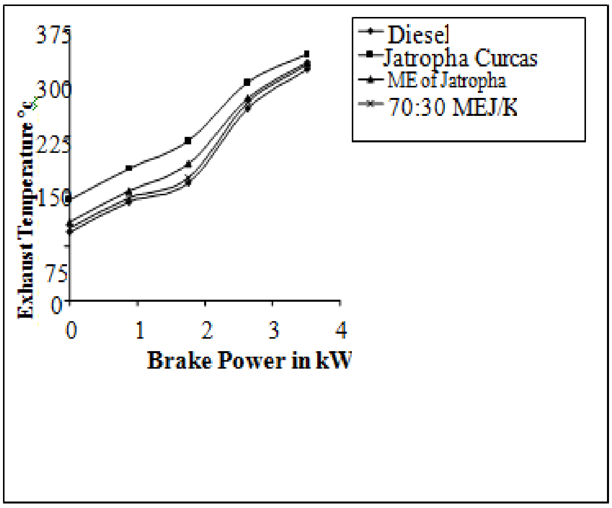

Fig 3: Variation of Exhaust Temperature with Break Power

C. HYDROCARBON EMISSION

Fig. 4 shows the variation of HC emission with power output for raw jatropha oil, methyl ester of jatropha oil, methyl ester of jatropha oil-kerosene blend and diesel. It can be noticed from the figure that HC emission of raw jatropha oil, methyl ester of jatropha oil and methyl ester of jatropha oil-kerosene is lower than that of diesel. The reason behind this phenomenon may be due to combustion extending into the exhaust stroke. At full load condition HC emission is 92 ppm for raw jatropha oil, 83 ppm for methyl ester of jatropha oil, 128 ppm for methyl ester of jatropha oil-kerosene blend and 132 ppm for diesel.

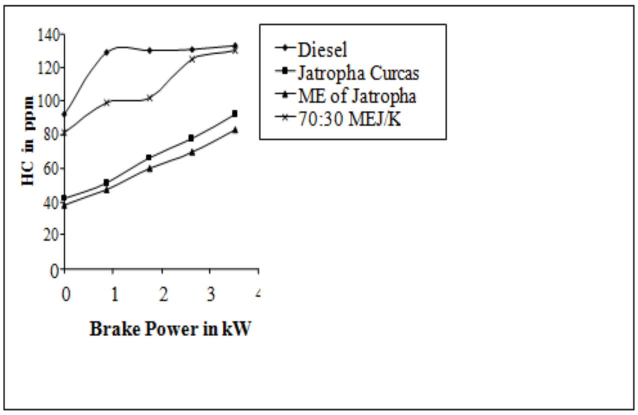

Fig 4: Variation of HC with Break Power

D. CARBON MONXIDE EMISSION

The variation of CO emission with respect to brake power is shown in Fig. 5. CO emission levels are lower with raw jatropha oil, methyl ester of jatropha oil and methyl ester of jatropha oil-kerosene blend when compared to diesel. The CO of the raw jatropha oil is 0.34 % at full load, 0.32 % for methyl ester of jatropha oil-kerosene blend, 0.35 % for methyl ester of jatropha oil and 0.37 % for diesel. This may probably due to the use of lean mixture with ester.

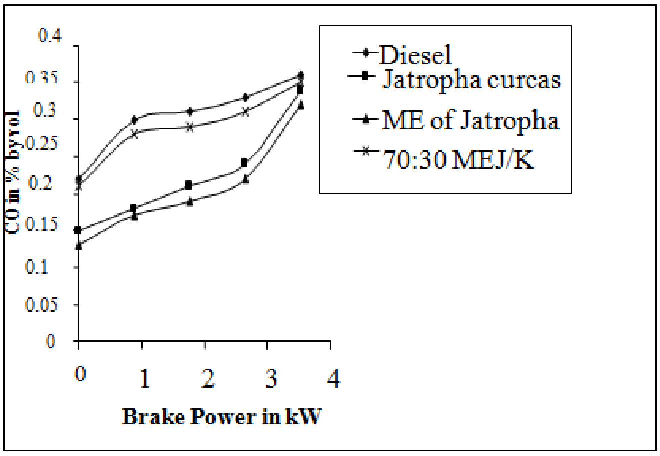

Fig 5: Variation of CO with Break Power

E. OXIDE OF NITROGEN EMISSION

Fig. 6 depicts the variation of NO_X with power output for raw jatropha oil, methyl ester of jatropha oil and methyl ester of jatropha oil-kerosene blend. Due to sluggish combustion of raw jatropha oil, jatropha ester and jatropha ester-kerosene blend compared to diesel, the combustion temperature was lower, hence reduced NO_X emissions. The NO_X concentration was 639 ppm for methyl ester of jatropha oil, 632 ppm for raw jatropha oil, 358 ppm for methyl ester of jatropha oil-kerosene blend and 649 ppm for diesel.

F. SMOKE INTENSITY

The variation of smoke emission with power output is shown in Fig. 8. Smoke level at the maximum power output is 4.25 BSU with raw jatropha oil. The smoke level with diesel is 2.25 BSU at maximum power. It can be observed that the smoke level increases with the use of jatropha oil. This may due to higher viscosity and density of raw jatropha oil that leads to poor vaporization and slow combustion of injected fuel. When highly viscous jatropha oil is injected, the atomization of fuel is poor leading to large droplets and less air entertainment resulting in inefficient combustion. This leads to higher smoke with raw jatropha oil. However with esterified oil the smoke is very low.

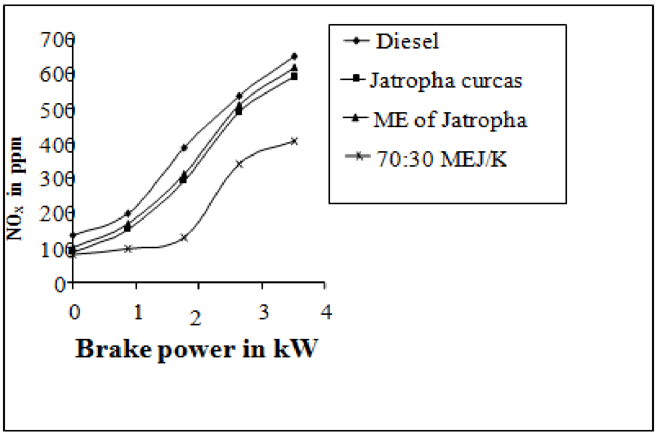

Fig 6: Variation of NOx with Break Power

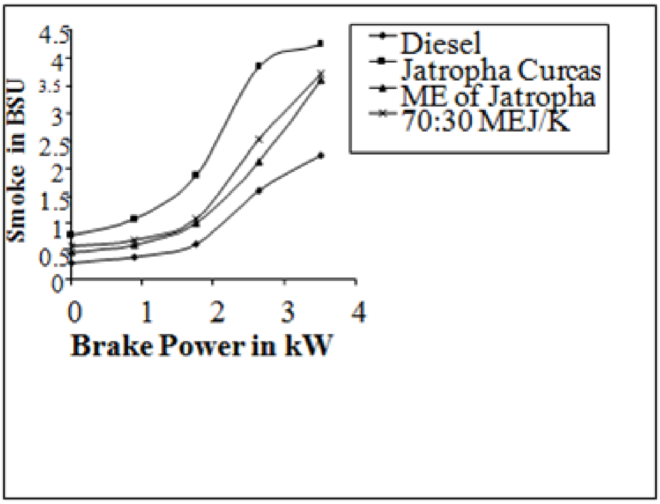

Fig 7: Variation of Smoke with Break Power

G. CYLINDER PRESSURE

Cylinder pressure mainly depends on the combustion rate in the initial stages, which is influenced by the fuel taking part in uncontrolled heat release phase. The high viscosity and low volatility of the raw jatropha oil lead to poor atomization and mixture preparation with air during the ignition delay period.

The variation of peak pressure with brake power output for raw jatropha oil, methyl ester of jatropha oil and diesel is shown in Fig. 8**.** The peak pressure with the methyl ester of jatropha oil is higher due to the improvement in preparation of air fuel mixture as a result of low fuel viscosity.

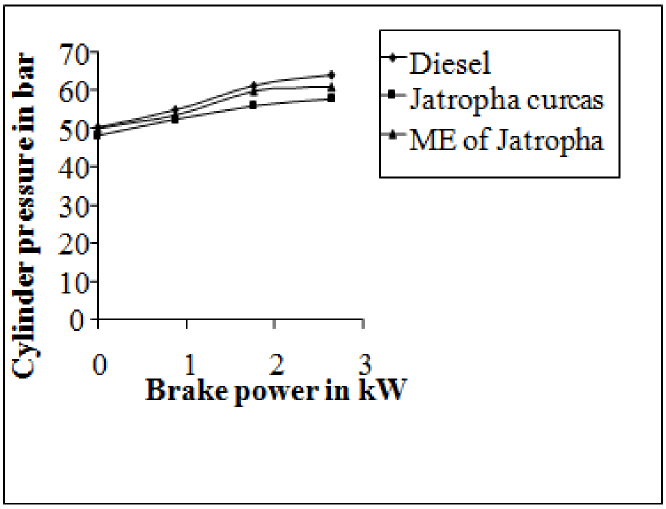

Fig 8: Variation of Cylinder Pressure with Break Power

8. CONCLUSION

Experiments were conducted on a single cylinder, water cooled, zirconium coated DI diesel engine using raw jatropha oil, methyl ester of jatropha oil, methyl ester of jatropha oil-kerosene blend and diesel. The following conclusions are drawn based on the experimental results:

Engine operation with raw jatropha oil and methyl ester of jatropha oil
Jatropha oil resulted in a slightly reduced thermal efficiency as compared to diesel. With the methyl ester of jatropha oil the brake thermal efficiency is comparable to diesel values. Maximum brake thermal efficiencies are
25.10 %, 25.31 % and 26.9 1% with raw jatropha oil, methyl ester of jatropha oil and diesel.

HC emission is higher with diesel as compared to raw jatropha oil. It is 92 ppm for raw jatropha oil and 132 ppm for diesel at the maximum output. However it is 83 ppm only with the methyl ester of jatropha oil.

CO emission is lower with jatropha oil as compared to diesel. It is 0.34 % for raw jatropha oil and 0.36 % for diesel at the maximum power output. However it is 0.32 % with the methyl ester of jatropha oil.

NO_X emission is lower with jatropha oil as compared to diesel. The NO_X concentration is 632 ppm for raw jatropha oil and 649 ppm for diesel.

The maximum smoke level with raw jatropha oil is 4.25 BSU and it is 3.605 BSU with methyl ester of jatropha oil. In the case of diesel it is 2.25 BSU.

Cylinder pressure is lower with raw jatropha oil as compared to diesel. It is 57.01 bar with raw jatropha oil and 64.38 bar with diesel. The peak pressure when methyl ester of jatropha oil is 60.81 bar.

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