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PERFORMANCE ANALYSIS OF DIESEL ENGINE FUELED USING JATROPHA BIO DIESEL BLENDED FUELED

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ABSTRACT

Biodiesels have recently been recognized as a potential substitute to Diesel oil. It is produced from oils or fats using a process called transesterification, in which oils are reacted with alcohols in order to form the esters, which are called biodiesels. Feedstock for biodiesel include animal fats, vegetable oils Jatropha, Mahua, Sunflower, Palm, Pongamia Pinnata (Karanja), Cotton seed, Neem, Rubber seed, Corn, Sesame, Cotton seed. Biodiesel is a liquid closely similar in properties to fossil/mineral diesel. Chemically, it consists mostly of Fatty Acid Methyl (or Ethyl) Esters (FAME). Most of the biodiesels meet the American Society for Testing and Materials (ASTM) biodiesel standards. Several developed countries have introduced policies encouraging the use of bio diesels made from vegetable oils, bio mass etc. in transport, agriculture and other sectors with the idea of achieving the following goals. It this experiment shows that B25 (25% Biodiesel & 75% Diesel) have closer performance to 100% Diesel and 100% Bio Diesel had lower brake thermal efficiency mainly due to its high viscosity compared to diesel. The brake thermal efficiency for Bio diesel and its blends was found to be slightly higher than that of diesel fuel at tested load conditions and there are no difference between the biodiesel and its blended fuels efficiencies. For Jatropha biodiesel and its blended fuels, the exhaust gas temperature increased with increase in power and amount of biodiesel. However, its diesel blends showed reasonable efficiencies, lower smoke, CO and CO_2. Methyl ester of Jatropha offers fuel conservation as well as reduces pollution. The emission constituents are carbon monoxide (CO), unburnt hydrocarbons (HC), Oxides of nitrogen (NO_X), Carbon Dioxide (CO_2).

KEYWORDS: Jatropha, blended fuels, performance, emissions, and efficiency.

INTRODUCTION

Biodiesels are greener to the environment, biodegradable, renewable, indigenous and have properties closer to that of conventional Diesel oils. Hence it can act as a potential diesel fuel supplement in the near future. They help a country to attain energy self sufficiency in transport, power, agriculture & other related sectors and also boosts rural economy by generating employment. The employment is generated, as more labour is required to maintain and cultivate trees whose seeds are feedstock for production of biodiesel. In a predominantly vast agricultural country like India, utilization of waste lands for growing non edible seed bearing trees gives a major thrust to agriculture, rural economy & agro based allied industries. Biodiesel does not need exclusively a separate storage infrastructure. Safe storage time would be up to 6 months beyond which it undergoes oxidation forming a gel like substance. The most important advantage of biodiesels is that its mass scale production & implementation on a large scale requires less expenditure in terms of cost and time compared to all other possible alternative energy sources. It is mentioned in the literature that biodiesels are successfully used in the form of blends with diesel in the existing diesels engines with no modifications.

JATROPHA OIL

Jatropha curcas is commonly found in most of the tropical and subtropical regions of the world. The oil content of jatropha seed ranges from 30 to 35 % by weight. The fatty acid composition of jatropha oil consists of myristic, palmitic, stearic, arachidic, oleic and linoleic acids. After extraction of oil from seed the detoxification of the seed cake is necessary so that the seed cake can be used as cattle feed. Economic development in India has led to huge increases in energy demand, which in-turn has encouraged development of the Jatropha cultivation and Biodiesel production system.

BIODIESEL PROCESSING FROM VEGETABLE OIL

Biodiesel can be produced by esterification followed by transesterfication . The oils and fats are filtered and pre-processed to remove water and contaminants. If, free fatty acids are present, they can be removed or transformed into biodiesel using special pretreatment technologies. The pre-treated oils and fats are then mixed with an alcohol (usually methanol) and a catalyst (usually sodium methoxide). The oil molecules (triglycerides) are broken apart and reformed into esters and glycerol, which are then separated from each other and purified. The edible oils like soybean, sunflower, mustard, palm, cotton seeds, whose acid values are less than 3.0 are transesterified with methanol in the presence of sodium methoxide as catalyst. Nonedible oil like, Mahua, karanja and jatropha oils having acid values more than 3.0 are undergoes esterification followed by transesterification. The methyl esters produced by these methods are analyzed to ascertain their suitability as diesel fuels.

SELECTION OF CATALYST

Transesterification is a chemical reaction that aims at substituting the glycerol of the glycerides with three molecules of mono alcohols such as methanol thus leading to three molecules of methyl ester of vegetable oil**.** The viscosity of esterified oil is lower than the oil. However, higher ratio of alcohol to oil is generally employed to obtain biodiesel of low viscosity and high conversion**.** Alkali-catalyzed transesterification is very fast compared to acid catalyzed**.** Methanol and ethanol is widely used in the transesterification because of low cost. The alkali hydrolysis of the oil must have acid value less than 1 and moisture content less than 0.5%. The acid catalyst is the choice for transesterification when low-grade vegetable oil used as raw material because it contains high free fatty acid and moisture. Acid catalyst such as Sulphuric acid (H_2SO4) is used for esterification process.

JATROPHA BIODIESEL

Jatropha curcas is nonedible oil being singled out for large scale for plantation on wastelands. J. curcas plant can thrive under adverse conditions. It is a drought resistant, perennial plant, living up to fifty years and has capability to grow on marginal soils. It requires very little irrigation and grows in all types of soils (from coastline to hill slopes). The production of Jatropha seeds is about 0.8kg per square meter per year. The oil content of Jatropha seed ranges from 30% to 40% by weight and the kernel itself ranges from 45% to 60%. Fresh Jatropha oil is slow drying, odorless and colorless oil, but it turns yellow after matured **(Sarin et al., 2007).** In Madagascar, Cape Verde and Benin, Jatropha oil was used as mineral diesel substitute during the Second World War. **Forson et al. (2004)** used Jatropha oil and diesel blends in CI engines and found its performance and emissions characteristics similar to that of mineral diesel at low concentration of Jatropha oil in blends. Additives are abundantly manufactured and mixed with IC engine fuels to meet the proper performance of fuel in engine. Additives act like catalyst so that they support combustion, control emission, control fuel quality during distribution and storage and reduce refiners operating cost. Now in India MFA's are sold in retail market for better mileage of the vehicles and keeping the engine components clean, for better performance and to decrease pollution. For a long time industry has been using various types of chemical additives that are corrosive, toxic and non-ecofriendly. Use of multi functional additives for diesel will lead better fuel conservation and emission control takes place. Awareness of multi functional additives marketing and there use to be given to the automobile owner's especially fleet owners and huge genset users **(Ramana & Raghunadham, 2004).** Tests were conducted with two commercially available bio additives and results confirmed that pollution can be controlled by reducing CO and HC emissions and conserving fuel by high thermal efficiency **(Raghunadham & Deshpande, 2004).** Ethylene glycol mono alkyl ethers as oxygenated fuel additives had taken and studied for performance parameters such as brake specific fuel consumption, brake thermal efficiency and emission levels. Significant reduction in particulate emission is observed with fuel additives **(Suresh Shetty et al., 2007).** The present research is aimed at exploring technical feasibility of Jatropha oil in direct injection compression ignition engine without any substantial hardware modifications. In this work the methyl ester of Jatropha oil was investigated for its performance as a diesel engine fuel. Fuel properties of mineral diesel, Jatropha biodiesel and Jatropha oil were evaluated. Three blends were obtained by mixing diesel and esterified Jatropha in the following proportions by volume: 75% diesel+25% esterified Jatropha, 50% diesel+50% esterified Jatropha and 25% diesel+ 75% esterified Jatropha. Also 0.4 mL per litre Multi-DM-32 additive is added to methyl ester of Jatropha to study the performance and exhaust emissions of diesel engine. Performance parameters like brake thermal efficiency, specific fuel consumption, brake power were determined. Exhaust emissions like CO_2, CO, NOx and smoke have been evaluated. For comparison purposes experiments were also carried out on 100% esterified Jatropha and diesel fuel.

Figure 1.1: Seeds of Jatropha

Figure 1.2: Jatropha oil

Table 1.1 Properties of Diesel, Biodiesel Blend (B20) and Biodiesel [6]

Properties	**Diesel**	**B20**	**B100**
Cetane number	43.3	46	47.5
Flash Point (0C)	62	90	146
Sulphur wt (%)	0.0476	0.037	0.00

EXPERIMENTAL SETUP

The engine used for this experimental investigation was a single cylinder 4-Stroke naturally aspirated water cooled diesel engine having 5 BHP as rated power at 1500 r/min. The engine was coupled to a brake drum dynamometer to measure the output. Fuel flow rates were timed with calibrated burette. Exhaust gas analysis was performed using a multi gas exhaust analyzer. The pressure crank angle diagram was obtained with help of a piezo electric pressure transducer. A Bosch smoke pump attached to the exhaust pipe was used for measuring smoke levels. The experimental set up is shown in Figure 2.1

1. Engine
2. Hydraulic Dynamometer
3. Fuel Tank (Biodiesel)
4. Diesel Tank
5. Burettes
6. Air Box
7. Manometer
8. Exhaust

Table 2.1 specifications of diesel engine are given below

Manufacturer	Kirloskar engines Ltd
No of cylinders	One
No. of strokes	Four
Bore & Stroke	80 & 110 mm
Capacity	3.68 kW
BHP of engine	5
Speed	1500 r/min
Mode of injection	DI
Cooling system	Water

Figure 2.1: Experimental Test Rig

Table 2.2: Description of temperature measurement

T1	Engine cooling water inlet temperature
T2	Engine cooling water outlet temperature
T3	Calorimeter water inlet temperature
T4	Calorimeter water outlet temperature
T5	Exhaust gas calorimeter inlet temperature
T6	Exhaust gas calorimeter inlet temperature
T7	Room temperature

Figure 2.2: Temperature, Load and Speed indicator

Figure 2.3 Rear View of the Engine

Fuel Injection Pump

Figure 2.4: Fuel tank

The fuel injection pump manufactured by MICO BOSCH is used for injecting Diesel oil or biodiesel in to the engine. The fuel injection pump is operated by the cam shaft and the fuel injection timing can be varied by adding/removing.

WATER BRAKE DYNAMOMETER

3.3.1 Construction: The Water Brake Dynamometer is designed to absorb and measure the power developed by prime movers at various speed. The mechanical construction of Dynamometer is very robust. The rotor and stator blade rings are cast from phosphor bronze. The power absorption unit is mounted on a C.I. base plate by trunion bearings with bearing housing. The load indication can be by means of a spring balance or by digital display. If required a dashpot is provided to minimize the vibration of load indicator. A calibration kit is provided for periodic re-calibration of dynamometer in order to ensure accuracy of the dynamometer.

Figure 3.1: Water Brake Dynamometer

Principle of Operation

Water acts as a cooling and loading medium. The running rotor causes the water to whirl in the chamber. The braking energy thus absorbed converts to heat, which is dissipated with circulating water. At a given constant speed of the dynamometer its reaction torque is a function of the water value in the whirl chamber, which in turn is controlled by sluice gates.

Generation of Power

The power absorbed by the dynamometer is dependent upon the mass and the velocity of the water circulating in the rotor and stator pockets. From the above it will be seen that the forces resisting rotation of the dynamometer shaft may be divided into three main clauses.

1) The hydraulic resistance created by rotor.
2) The friction of the main shaft, which is usually of ball bearing type.
3) The friction of glands ropes.

Every one of the above forces reacts upon the main body of dynamometer (casing).

The main body being free to swivel is mounted on antifriction trunion bearings. The swinging body transmits the all forces to the load cell or spring balance and displayed accordingly.

General Arrangement

Following are the sub assemblies of dynamometer.

1) Rotor
2) Stator
3) Load/ Unload
4) Display of load

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5) Foundation

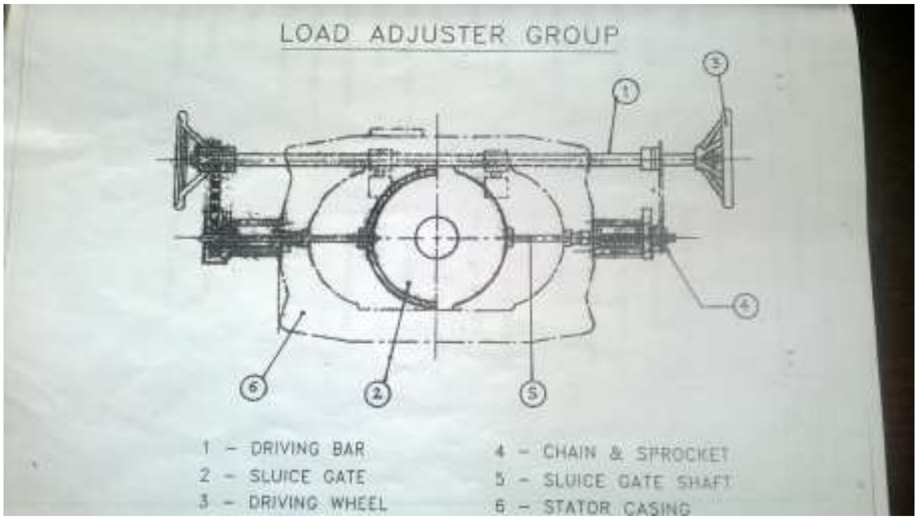

Figure 3.2: Schematic Layout of Load Adjuster Group

1) Rotor: It is with main shaft, impeller, sleeves, ball bearings and flange couplings.

- **Shaft:** Total grinding finish to close accuracy.
- **Impeller:** Machined to close accuracy and fitted over main shaft.
- **Sleeves:** Machined to close accuracy and press fitted on main shaft.
- **Ball Bearings:** SKF make no. 6308 – 2 nos.
- **Flange coupling:** Material to close accuracy and mounted at the end of driving side of main shaft.

2) Stator: It consists of main casings, blade rings, extended shaft for trunion bearings, water inlet and outlet connections and glands.

- **Stator casings:** Machined to close accuracy for bearing fitment and rotor alignment.
- **Extended shafts:** It is bolted with main casing and the whole casing body is mounted on trunion bearing with the help of extension shaft.

3) Load/ unloads Mechanism: It consists of following components, like C.I. brackets, sluice gates, driving bar, chain and sprocket.

4) Display of Load: It is with Load Cell and digital display unit.

5) Foundation: The group consists of following components
Base plate, bearing housing, water inlet connection.
Base Plate- C.I. casting, machined to high surface finish.
Bearing Housing- C.I. casting, this holds the stator body by means of trunion bearing. The bearing housing is mounted on base plate. The base plate is having provision for mounting water in & out connections.

Installation Instructions

The foundation of the dynamometer can be done with 2 methods. These are as following
1) With cement concrete block isolated from engine foundation
2) With common base frame along with engine and cement concrete block by anti vibration pads.
3) Moveable with common base frame along with engine.

Water supply

The circulating water temperature at the dynamometer outlet should not exceed more than 60 Deg. C. If it is exceeded then inside part of dynamometer get affected by scaling. It adds rise in bearing temperature hence the bearing life reduces. To avoid this sufficient, clean and steady flow of water to be provided. By experience it is proved that minimum 20 litre per BHP per hour water is required to circulate to this dynamometer. By pressure gauge measurement 2 to 2.5 kg/cm^2 at ¾" BSP pipeline water will be sufficient.

Glands

It is made from gunmetal material. These are assembled with main shaft to the stator casing. Water leakages are prevented with gland rope by tightening the glands. Drop-by-Drop water leakages are allowed to maintain minimum friction on main shaft.

Before starting the engine:

1) Take the stopper bolts down so that main stator body will be free to swing along with shaft.
2) The bolts are provided on base plate, but below the stator casing.
3) Switch on the mains supply of the load indicator.
4) See the zero position of load indicator.
5) Check the calibration if required.
6) Open the dynamometer water inlet valve fully.
7) Open the dynamometer water outlet valve slightly.
8) Unload the load adjuster mechanism fully so that while starting the engine there will not be load on the engine.

After starting the Engine:

1) Check the leakage from main glands. Slite drop of water leakages should be allowed, for proper lubrication and longer life of rope.
2) Check all the rotating parts and sliding parts are properly lubricated.
3) Load the engine to desired load by adjusting engine RPM, loading/ unloading mechanism and water outlet control valve.
4) After testing while stopping the engine unload the dynamometer to close position.

Calibration Checking:

1) Decouple dynamometer from engine.
2) Stop water supply of dynamometer.
3) Check the zero position of load indicator.
4) Put the calibration arm to one side of stator casing by means of key way provided on extension shaft. Calibration arm must be fitted on the opposite direction of load cell.
5) Put counter weight on opposite side of the calibration arm, till the display shows zero. This is just to nullify the calibration arm effect.
6) Now put the supplied weight only on load arm. It is attached with calibration arm.

COMPARISON BETWEEN PROPERTIES OF DIESEL AND BIODIESEL (JATROPHA BIODIESEL)

Table 4.1: Fuel properties of mineral diesel, Jatropha biodiesel, Jatropha oil

Property	**Mineral Diesel**	**Jatropha bio diesel**	**Jatropha oil**
Density **(kg/m^3)**	840±1.732	879	917±1
Kinematic viscosity	2.44±0.27	4.84	35.98±1.3
Pour point (**^{o}C**)	6±1	3±1	4±1
Flash point (**^{o}C**)	71±3	191	229±4
Calorific Value **(MJ/kg)**	45.343	38.5	39.071
Cetane No.	48-56	51-52	23-41
Carbon **(%, w/w)**	86.83	77.1	76.11
Oxygen **(%, w/w)**	1.19	10.97	11.06
Hydrogen **(%, w/w)**	12.72	11.81	10.52
Ash Content **(%, w/w)**	0.01±0.0	0.013	0.03±0.0

THERMAL PERFORMANCE

Thermal Performance Evaluation is carried out in three different experimental programs:
1. With Diesel oil as fuel at different Loads.
2. With Jatropha biodiesel as fuel following similar condition as in 1.
3. With blends of Jatropha biodiesel and diesel as fuel following similar condition as in 1.

The blend proportions used to conduct the experiments are B25, B50 and B75. B25 corresponds to a blend with 25% of Jatropha biodiesel and 75% Diesel oil by volume. The blends are prepared by direct mixing of both the fuels in required proportions. The experimental procedure undertaken for conducting the, thermal performance evaluation using Jatropha biodiesel and blends of Jatropha biodiesel with diesel are explained in detail in table 4.2, 4.3, 4.4,4.5 and 4.6 respectively. The Diesel oil and Jatropha biodiesel used during the study are obtained from the same lot acquired for the purpose and from the same source to ensure consistency in their properties.

EXPERIMENTAL PROCEDURE

An experimental test is conducted using Diesel oil as fuel. The following step-by-step procedure is adopted for the test:
1. Check the lubrication, cooling and fuel systems of the engine for their adequacy.
2. Switch ON the electric supply and ensure that all digital and electric instruments are ON.
3. Start the engine and run under idling condition (no load) for 5 minutes to ensure warm and steady operating conditions.
4. Set the compression ratio at a selected value (say 14) using the tilting block arrangement for the engine.
5. Set the injection pressure at a selected value (say 150 bar) using the nut provided on the cylinder head near fuel injection line.
6. Record all the thermal performance parameters for no load condition through a data acquisition system.
7. Adjust the load for 1kg using the loading unit dimmer stat and wait for 3 minutes for engine to get stabilized. Repeat step 6 to ensure correctness & reliability/ repeatability of the data recorded.
8. Repeat step 6 for different loads viz. 2kg, 4kg, 6kg and 8 kg.
9. After all readings are recorded, bring down the loading condition to no load before stopping the engine. The water is allowed to circulate for about 5 minutes for engine cooling and then the pump is stopped.

Observation Tables

Table 4.2: 100% Diesel combustion parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 20cc of F.C. (s)	Exhaust Gas temp (°C)
0	2.6	135	190
2	2.6	98	260
2	2.6	85	270
6	2.6	75	290
8	2.6	68	320

Table 4.3: Esterified Jatropha oil combustion parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 25cc of F.C. (s)	Exhaust Gas temp (°C)
0	2.6	128	185
2	2.6	126	190
4	2.6	109	200
6	2.6	104	210

8	2.6	95	225

Table 4.4: 75%Diesel+25% esterified Jatropha oil combustion parameters

Load (kgf)	**Manometer Reading (cm)**	**Time taken for 25cc of F.C. (s)**	**Exhaust Gas temp (°C)**
0	2.6	160	180
2	2.6	142	190
4	2.6	127	200
6	2.6	117	210
8	2.6	110	219

Table 4.5 : 50%Diesel+50% esterified Jatropha oil combustion parameters

Load (kgf)	**Manometer Reading (cm)**	**Time taken for 25cc of F.C. (s)**	**Exhaust Gas temp (°C)**
0	2.6	153	175
2	2.6	134	190
4	2.6	122	200
6	2.6	114	205
8	2.6	106	220

Table 4.6 25%Diesel+75% esterified Jatropha oil combustion parameters

Load (kgf)	**Manometer Reading (cm)**	**Time taken for 25cc of F.C. (s)**	**Exhaust Gas temp (°C)**
0	2.6	151	174
2	2.6	128	185
4	2.6	117	195
6	2.6	110	205
8	2.6	102	220

FORMULAS USED FOR CALCULATIONS

Brake Horsepower (BHP)

It is the measure of an engine's horsepower before the loss in power caused by the gearbox, alternator, water pump, and other auxiliary components like power steering pump, muffled exhaust system, etc. Brake refers to a device used to load an engine and hold it at a desired RPM. During testing, the output torque and rotational speed can be measured to determine the brake horsepower which is the actual shaft horsepower and is measured by the dynamometer by:

$$\mathbf{BHP = IHP\text{-}FP}$$

Where, BHP = Brake horse power
IHP = Indicated horse power
FP = Frictional power

The indicated power is produced from the fuel inside the engine while some power is lost due to friction the remaining power available at the shaft of the engine is brake horse power. The engine load is measured in the hydraulic dynamometer on the load indicator in terms of kg.

Generally the value of torque 'T' is the total weight applied, multiplied by the arm length.

T= W X L Kg.m

The power or the rate of doing work is measured in kilowatts and is defined as the torque multiplied by the angular velocity.

P(BHP) = $\frac{2\pi NT}{4500}$

5.1.2 Fuel Consumption

For a volume of 20cc, fuel consumption per second is given by

$\frac{20}{t}$ **where t = Time in sec.**

This may be converted to grams/ second by multiplying by the specific gravity which is 0.84 for diesel.

Weight of fuel per second

$= \frac{20 \ X \ 0.84}{\text{Time in sec X 1000}}$ kg/sec

$= \frac{20 \ X \ 0.84}{68 \ X \ 1000}$

= 0.000247 kg/sec = 0.88 kg/h

Specific Fuel Consumption

An important characteristics of internal combustion engine with the specific fuel consumption, which relates the thermal efficiency of the engine. This is defined as the weight of fuel required generating each BHP hours of energy.

Therefore $= \frac{\text{Consumption in kg/hr}}{BP}$

$= \frac{0.88}{1.984}$

= 0.44 kg/BHP/Hour

= 443.5 Gram/BHP/Hour

Brake Thermal Efficiency (BTE)

It is the ratio of the thermal energy in the fuel to the energy delivered by the engine at the crankshaft. It greatly depends on the manner in which the energy is converted as the efficiency is normalized respect to the fuel heating value. It can be expressed by:

BTE (η_{bth}) = BP/(m_f x NCV)

Where, BP = Brake power (kW)
m_f = fuel consumption (kg/sec)
NCV = net calorific value (kJ/kg)

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TEST RESULTS

To compare the performance of the biodiesel to that of regular diesel, power curves were performed with the engine running on the respective fuel samples.The slight power increase for the blends in the mid engine speed range region might be due to the improved lubricity of the biodiesel, improving the fuel pump and injector performance, but the subject need further investigation. The graph shows that the engine is most affected at high power conditions where more fuel is used.

Result Tables

Table 5.1: 100%Diesel combustion parameters

Load (kgf)	**Manometer Reading (cm)**	**Time taken for 20cc of F.C (s)**	**F.C. (kg/h)**	**S.F.C. (kg/kWh)**	**B.P (kW)**	**Bth (%)**	**Exhaust Gas temp (°C)**
0	2.6	135	0.416	-	0	0	190
2	2.6	98	0.573	1.154	0.496	7.45	260
4	2.6	85	0.661	0.670	0.992	12.83	270
6	2.6	75	0.750	0.503	1.488	17.1	290
8	2.6	68	0.826	0.416	1.984	20.65	320

Table 5.2: Esterified Jatropha oil combustion parameters

Load (kgf)	**Manometer Reading (cm)**	**Time taken for 20cc of F.C (s)**	**F.C. (kg/h)**	**S.F.C. (kg/kWh)**	**B.P (kW)**	**Bth (%)**	**Exhaust Gas temp (°C)**
0	2.6	128	0.523	-	0	0	185
2	2.6	126	0.531	1.071	0.496	8.0	190
4	2.6	109	0.614	0.619	0.992	13.84	200
6	2.6	104	0.644	0.432	0.488	19.84	210
8	2.6	95	0.705	0.355	0.984	24.84	225

Table 5.3: 75%Diesel+25% esterified Jatropha oil combustion parameters

Load (kgf)	**Manometer Reading (cm)**	**Time taken for 20cc of F.C (s)**	**F.C. (kg/h)**	**S.F.C. (kg/kWh)**	**B.P (kW)**	**Bth (%)**	**Exhaust Gas temp (°C)**
0	2.6	160	0.368	-	0	0	57
2	2.6	142	0.414	0.835	0.496	10.3	58
4	2.6	127	0.464	0.467	0.992	18.4	59
6	2.6	117	0.503	0.338	1.488	25.44	64
8	2.6	110	0.535	0.270	1.984	31.86	68

Table 5.4: 50%Diesel+50% esterified Jatropha oil combustion parameters

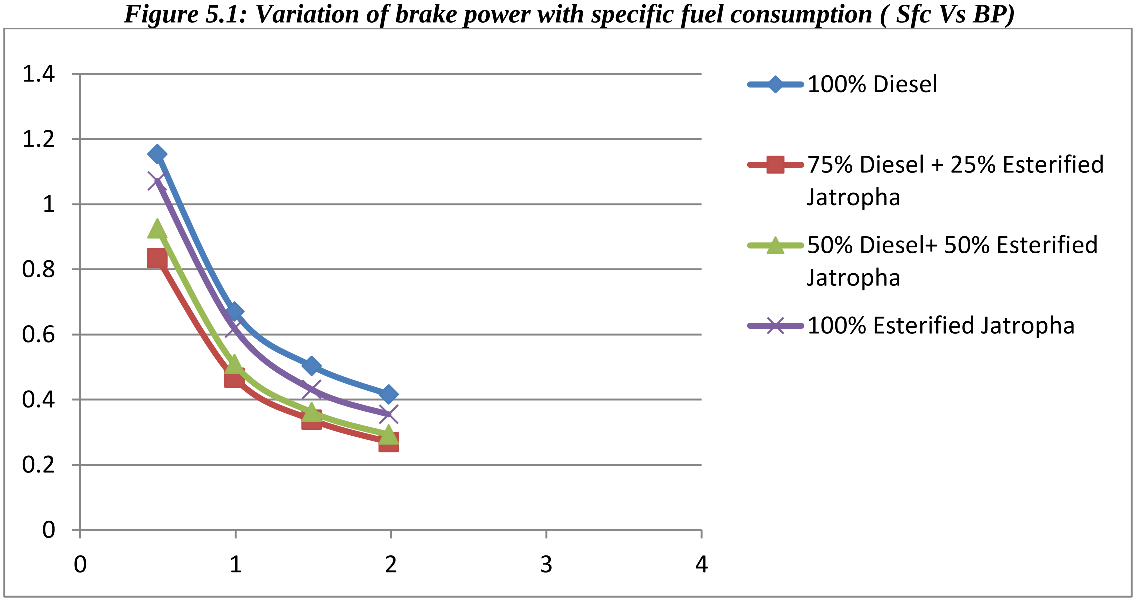
Load (kgf)	Manometer Reading (cm)	Time taken for 20cc of F.C (s)	F.C. (kg/h)	S.F.C. (kg/kWh)	B.P (kW)	Bth (%)	Exhaust Gas temp (°C)
0	2.6	153	0.402	-	0	0	175
2	2.6	134	0.459	0.926	0.496	9.3	190
4	2.6	122	0.505	0.509	0.992	16.9	200
6	2.6	114	0.540	0.362	1.488	23.7	205
8	2.6	106	0.580	0.293	1.984	29.32	220

Table 5.5: 25%Diesel+75% esterified Jatropha oil combustion parameters

Load (kgf)	Manometer Reading (cm)	Time taken for 20cc of F.C (s)	F.C. (kg/h)	S.F.C. (kg/kWh)	B.P (kW)	Bth (%)	Exhaust Gas temp (°C)
0	2.6	151	0.426	-	0	0	174
2	2.6	128	0.502	1.012	0.496	8.5	185
4	2.6	117	0.550	0.223	0.992	15.5	195
6	2.6	110	0.584	0.392	1.488	21.9	205
8	2.6	102	0.630	0.317	1.984	27.0	220

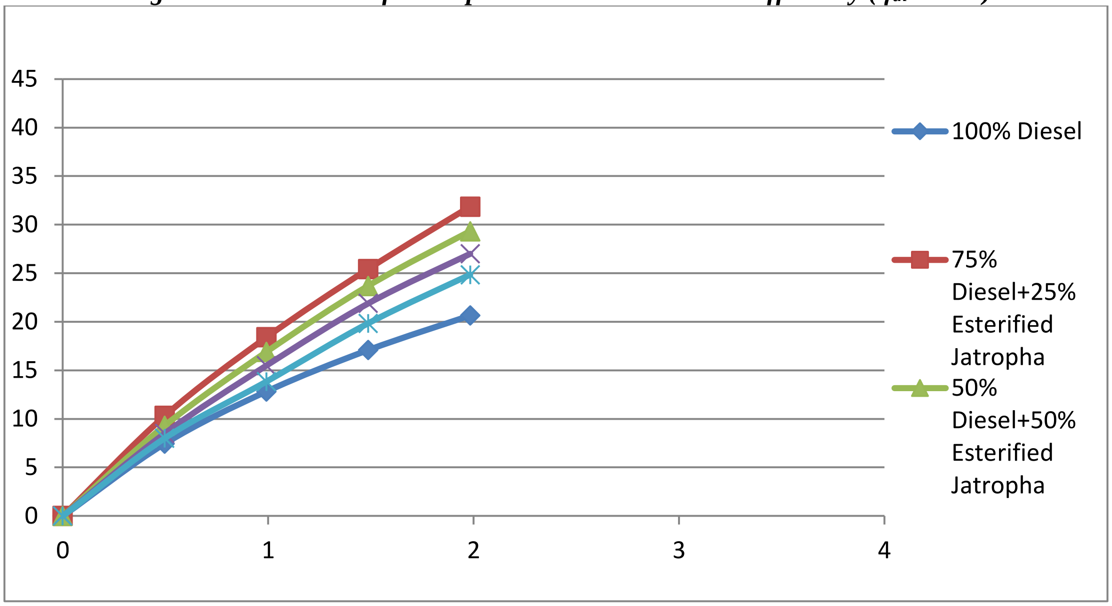
Graph

Figure 5.1: Variation of brake power with specific fuel consumption (Sfc Vs BP)



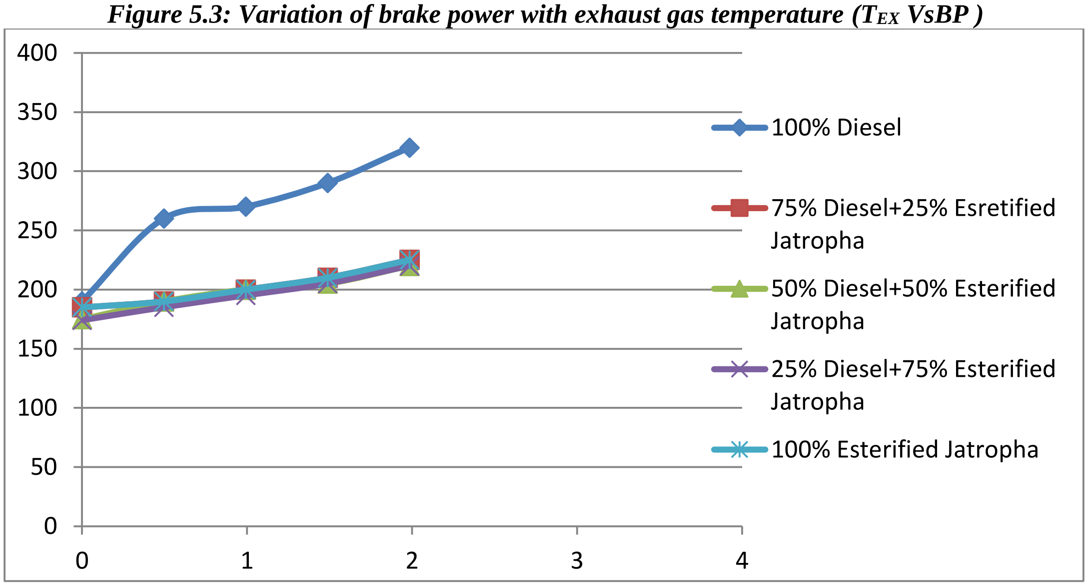
In Figure 5.1 it indicates that Specific Fuel Consumption is lower than the diesel for various proportions of Jatropha oil with diesel at constant operated conditions. This is due to complete combustion, as addition oxygen is available from fuel itself. The percent increase in Specific Fuel Consumption was increased with decreased amount of diesel fuel in the blended fuels. This may be due to higher specific gravity and lower calorific value of the biodiesel fuel as compared with diesel fuel **(Forson et al., 2004).** The calorific value of the Jatropha biodiesel was about 7 % lower than that of diesel fuel.

Figure 5.2: Variation of brake power with brake thermal efficiency (η_{th} Vs BP)



Brake thermal efficiency is defined as actual brake work per cycle divided by the amount of fuel chemical energy as indicated by lower heating value of fuel **(Senthil Kumar et al., 2003).** In Graph 5.2 the brake thermal efficiency with biodiesel and its blends was found to be slightly higher than that of diesel fuel at tested load conditions. There was no difference between the biodiesel and its blended fuels on efficiencies. The brake thermal efficiencies of engine, operating with biodiesel mode were 22.2, 30.6 and 37.5 per cent at 2, 2.5 and 3.5 kW load conditions respectively.

Figure 5.3: Variation of brake power with exhaust gas temperature (T_{EX} VsBP)



The exhaust gas temperature gives an indication about the amount of waste heat going with exhaust gases. The exhaust gas temperature of the different biodiesel blends is shown in Figure 5.3. The exhaust gas temperature increased with increase in load and amount of blended biodiesel in the fuel. The exhaust gas temperature reflects on the status of combustion inside the combustion chamber **(Takeda, 1982).** The reason for raise in the exhaust gas temperature may be due to ignition delay and increased quantity of fuel injected. Adjusting the injection timing/injection pressure in to the diesel engine can reduce the exhaust gas temperature.

CONCLUSION
A single cylinder compression ignition engine was operated successfully using methyl ester of Jatropha oil as the soul fuel with additives. The following conclusions are made based on the experimental results.

- Engine works smoothly on methyl ester of Jatropha oil with performance comparable to diesel operation.
- Methyl ester of Jatropha oil results in a slightly increased thermal efficiency as compared to that of diesel.
- The exhaust gas temperature is decreased with the methyl ester of Jatropha oil as compared to diesel.
- CO_2 emission is low with the methyl ester of Jatropha oil.
- CO emission is low at higher loads for methyl ester of Jatropha oil when compared with diesel.
- The vast majority of literatures agree that NO_X emissions will increase when using biodiesel. This increase is mainly due to higher oxygen content for biodiesel. Moreover, the cetane number and different injection characteristics also have an impact on NOx emissions for biodiesel.
- It is predominant viewpoint that HC emissions reduce when biodiesel is fueled instead of diesel. This reduction is mainly contributed to the higher oxygen content of biodiesel.
- It can be concluded from the limited literatures that the use of biodiesel favors to reduce carbon deposit and wear of the key engine parts, compared with diesel. It is attributed to the lower soot formation, which is consistent to the reduced PM emissions of biodiesel, and the inherent lubricity of biodiesel.
- There is significant difference in smoke emissions when the methyl ester of Jatropha oil is used.
- Multi-MD-32, Bio-additive possesses many attributes as Multi-Functional fuel additive. Its ability to reduce the surface tension between two or more interacting immiscible liquids helped the fuel to flow better.
- Through injector and better atomization of fuel, which improved the combustion and performance of the engine at all variable loads.
- With proper adjustments at fuel injection pump settings bio additives will improve performance of IC engine.
- Use of bio additives for diesel will lead to better fuel economy and reduced emissions and should be used by Indian refineries.
- Automotive industry and oil industry must work closely to find solutions for lower emissions and conserving fuel.

Overall, biodiesel, especially for the blends with a small portion of biodiesel, is technically feasible as an alternative fuel in CI engines with no or minor modifications to engine. For environmental and economic reasons, their popularity may soon grow.

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